Understanding Developer and Lending Risk Associated with Offsite Construction

by

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ABSTRACT

This thesis investigates the potential of offsite construction as an effective alternative to traditional onsite methods in the construction industry. Targeting real estate professionals, financers, developers, construction contractors, and architects, the research aims to foster confidence and awareness in offsite techniques, specifically among project lenders. Through a combination of a literature review, interviews, workshop attendance, and site visits, the study addresses three critical research questions. First, it quantifies the project finance risk profile of offsite construction compared to traditional methods. Second, it identifies the qualitative determinants that influence lending decisions for offsite projects. Finally, it explores the data and education required for the finance industry to gain confidence in offsite construction's risk profile. The findings highlight the importance of incorporating modular offsite methods into educational curricula to create a cultural shift among industry professionals. This cultural shift can dispel misconceptions about offsite construction's quality, durability, and visual appearance, ultimately encouraging wider adoption. Moreover, lenders must conduct thorough personal due diligence when financing offsite projects, as manufacturing requires significant capital early in the timeline. Understanding the financial wherewithal of offsite manufacturers and assessing their experience in completing similar projects is crucial for mitigating risks. To facilitate offsite construction financing, industry leaders should explore innovative contractual, legal, and financial instruments. Implementing recourse provisions and enabling working capital financing for offsite manufacturers can alleviate the financial burden on developers. The Uniform Commercial Code approach could also make offsite projects more appealing to traditional lenders, enhancing their security interests during fabrication. Integrating these solutions can support and facilitate financing for offsite projects, driving increased efficiency, sustainability, and effectiveness in building practices. Overall, this thesis provides valuable insights into offsite construction, offering a comprehensive understanding of its benefits and challenges. By disseminating these findings to the target audience, the research aims to promote the widespread adoption of offsite construction and pave the way for a more innovative and sustainable future in the construction industry.

Thesis supervisor: James Scott

Title: Lecturer

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1. Introduction

The construction industry has long grappled with inefficiencies, hindering progress, and contributing to increased costs (Galante et al., 2017; Razkenari et al., 2020). In recent years, there has been a growing interest in offsite construction strategies to improve efficiency and reduce expenses. Offsite construction involves the prefabrication of building components in a controlled factory environment, which are then transported and assembled at the project site (Razkenari et al., 2020). Far from being a new technique, countries like Finland, Japan, and Sweden have been generating a significant portion of their housing stock through offsite construction for decades (Galante et al., 2017). In the United States, offsite construction experienced notable growth after World War II, driven by a high demand and housing shortage (Galante et al., 2017). In the late 1960s, the federal government launched Operation Breakthrough to support the expansion of offsite construction, primarily focused on single-family suburban production (Galante et al., 2017). Today, offsite construction methods are gaining traction in the US due to their potential benefits, including enhanced productivity, quality, and sustainability. This thesis explores the financing aspect of offsite construction projects which has served as a significant impediment to greater adoption, presenting valuable insights for real estate professionals, developers, construction managers, architects, and lenders. By addressing the financial considerations of offsite construction, this research aims to contribute to the wider acceptance of this method of construction, revolutionizing the construction industry and meeting the demands of modern construction projects.

The popularity of offsite construction is steadily increasing despite encountering various obstacles (Assaad et al., 2022). According to a report by the Modular Building Institute (2019), the global market size of modular construction (a form of offsite construction, which I will detail in later chapters) in 2018 was valued at USD 112.3 billion and is expected to continue growing in the future. However, in the United States, offsite construction is still relatively uncommon (see figure 1). Although there is a growing interest in this construction method, the scale of adoption is limited, particularly when compared to international trends (Galante et al., 2017).

Overcoming the barriers and technical challenges, which include a lack of familiarity, misconceptions about the quality of the finished product, higher upfront costs, regulation, design challenges, and difficulty in securing financing, will be crucial to unlocking the full potential of offsite construction. These obstacles hinder the widespread adoption of offsite construction, with one of the most significant difficulties being financing. To explore this topic further I have posed three research questions based on my review of the literature:

- What is the quantified project finance risk profile of offsite construction versus traditional construction?
- What are the qualitative determinants that lending institutions use to assess the risk of offsite construction?
- What data and education are required for the finance industry to gain confidence and determine that offsite construction for housing has no added risk or lower risk than traditional construction?

Based on these questions, I conducted research using a qualitative approach in which I interviewed approximately ten industry experts, attended a working group session, conducted site visits, and reviewed the leading academic commentary on the topic. The literature review discusses what offsite construction is, what the benefits are, what barriers exist, explains the specific types, and details previously established industry best practices. The research questions and methods sections are designed to provide readers with an understanding of what questions guide this research and how I will go about addressing those questions. The discussion section synthesizes the information gathered during the literature review, interviews, and other research methods. Finally, the conclusion section highlights overarching themes and findings, discusses limitations, and identifies questions and directions for future research.

This thesis underscores the need for a cultural shift and increased awareness among real estate professionals, lenders, developers, construction contractors, and architects (Wilson, 2019). Additional research is required about the operational benefits of buildings constructed using offsite techniques. Positive operational data (lower operating expenses, rental premiums, higher occupancy, etc.) can help move the needle for lenders to get comfortable providing financing. Moreover, by integrating offsite construction methods into the curriculum of architecture and construction education programs, the industry can foster a deeper understanding and appreciation for the advantages of these innovative methods, thereby avoiding some common current pitfalls (Barrett, 2020).

In addition, this research emphasizes the importance of conducting thorough personal due diligence for lenders considering financing offsite construction projects. Visiting project sites and manufacturing facilities, in-depth assessments of the financial stability of a manufacturer, and evaluating the manufacturer's experience are vital steps to mitigate risks associated with offsite construction lending (Johnson et al., 2022). Furthermore, the thesis explores innovative solutions, such as treating modules as "goods" under the Uniform

Commercial Code (UCC) and enabling working capital financing instruments for offsite manufacturers (Smith, 2023). By embracing these advancements, the industry can better support and facilitate financing for offsite projects, thereby encouraging wider adoption. By presenting a comprehensive overview of offsite construction and its potential benefits, this research endeavors to engage and empower the audience to embrace these innovative methods and contribute to the transformation of the construction industry.

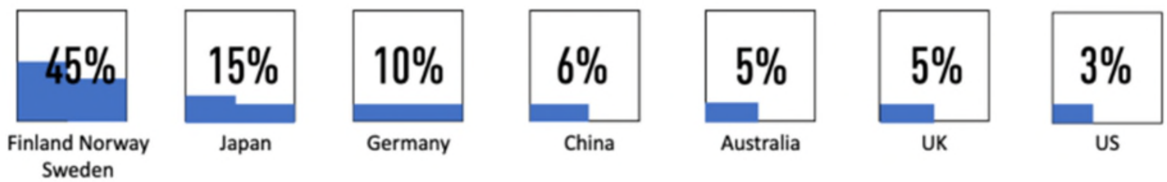

Figure 1. Comparison of Off-site construction penetration in the housing market by country.

2. Literature Review

2.1 What is Offsite Construction?

Offsite construction refers to a broad set of construction methods in which individual components of a project are manufactured offsite in a factory, then transported, and later assembled on-site (Galante et al., 2017). Although often used interchangeably, off-site, modular, and prefabricated construction techniques all retain slightly different definitions, so I will attempt to distill and clarify some of these terms through this review of the literature (Barbosa et al., 2017). According to the National Institute of Buildings Sciences (NIBS), off-site construction involves the planning, design, fabrication, and assembly of building elements at a location other than their final installed location (Barry et al., 2020). This approach supports rapid and efficient construction but requires rigorous integrated planning and supply chain optimization strategies (Barry et al., 2020).

The applicability and level of off-site production for development depends on the specific project requirements and market demands (Bertram et al., 2019). Factors such as asset type (housing, hotel, retail, etc.), site conditions, and the scale of production (i.e., one-off or mass production) influence the applicability and extent off-site construction techniques can be implemented (Barry et al., 2020). For example, a condo project that is physically constrained and located at grade may not be conducive to off-site construction techniques because the specialized cranes required to hoist building materials could have difficulty accessing the site. Offsite construction methods are often categorized by three different overarching types: 1. 2D panelized systems, 2. 3D modular or volumetric systems, and 3. hybrid systems (Hairstans, 2015). Off-site construction can also consist of building elements, such as stairs, doors, locks, and windows, called sub-assemblies and components that are manufactured offsite and then transported to the site for installation (Hairstans, 2015). However, these sub-assemblies and components are often much smaller and less structurally significant than more intensive forms of offsite construction techniques. Therefore, for the purposes of this thesis, I will only be examining 2D panelized systems, 3D modular systems, and hybrid systems in-depth.

2.2 Benefits of Offsite Construction

Off-site construction techniques have emerged as a promising alternative to traditional construction approaches (e.g., stick-built) because off-site is purported to offer numerous benefits in terms of efficiency, safety, cost-effectiveness, sustainability, and quality control (Feldmann et al., 2022; Galante et al., 2017; Hairstans, 2015). Stick-built construction refers to a method of constructing buildings entirely onsite, where materials are delivered to the site and then each component is built and assembled from scratch at the project location (Vukelich, 2022). This method can be prone to difficulties stemming from a relatively slower rate of construction, weather interruptions, highly labor intensive individualized tasks, large amounts of waste generation, and quality-related challenges (Gupta & Onkar, 2022). One of the most highly touted benefits of off-site construction techniques is that they can translate into overall bottom-line cost savings. However, according to Bertram et al., 2019, overall cost savings currently are not materializing in projects. Therefore, in this chapter I will focus on the cost-savings achieved by off-site construction projects at the individual line-item level without an assumption about overall project cost savings.

2.2.1 Time and Cost Savings

Off-site construction, by centralizing the production process in a controlled factory environment, can allow for the opportunity to generate labor, equipment, and production synergy and optimization (Galante et al., 2017). The use of assembly line and automation techniques in off-site construction increases production efficiency and reduces the need for skilled trade labor (Bertram et al., 2019; Galante et al., 2017; Garcia, 2019). This is crucial because labor, in particular specialized subcontractors that include a profit margin in their price quotes, is a considerably expensive line item in construction budgets, sometimes responsible for up to 60% of the total project cost for traditional builds. Moreover, unlike traditional construction processes that involve sequential tasks, off-site construction enables the simultaneous completion of multiple construction phases (Bertram et al., 2019). For example, module manufacturing can occur concurrently with site work and foundation preparation (Brown & Carranza, 2023; Feldmann et al., 2022; Galante et al., 2017) (See Figure 2). This parallel approach significantly decreases construction time, estimates range from a 20 to 50 percent reduction compared to traditional methods (Bertram et al., 2019; Razkenari et al., 2020). Furthermore, factories are climate controlled making them immune to weather-related delays that often hamper projects which are fully exposed to the elements (de Laubier et al., 2019; Wilson, 2019). The shorter project durations can lead to specific line-item cost savings by reducing variable expenses such as general contractor fees, site security, equipment rentals, and temporary facility costs (Galante et al., 2017). In addition, time savings achieved through faster project completion can contribute to earlier repayment of construction loans which can result in savings on interest expense, and potentially quicker returns on equity (i.e., increasing the Internal Rate of Return (IRR)) (Galante et al., 2017; Wilson, 2019). Highlighting the differences between financing associated with offsite construction in comparison to traditional construction is a crucial objective of this thesis and will be explored further in later chapters.

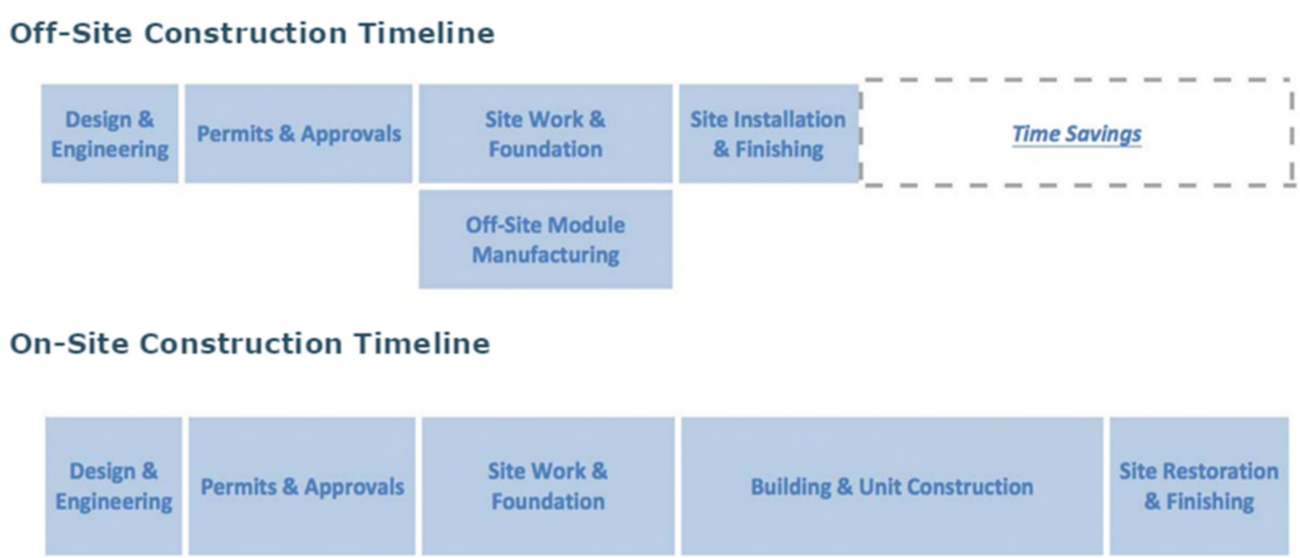

Figure 2. Comparison of Onsite vs. Offsite Construction Timelines

2.2.2 Working Environment

Another appealing benefit of off-site construction is that it offers a safer, healthier, and less disruptive working environment compared to traditional construction which has struggled with a poor track record for safety and reputation among project abutters (Brown & Carranza, 2023; Feldmann et al., 2022; Razkenari et al., 2020). According to the National Bureau of Labor Statistics, rates of fatal workplace injuries are substantially lower in the manufacturing sector, which more closely resembles off-site construction methods, than in traditional onsite construction (Wilson, 2019). The enhanced safety of off-site construction is the result of less workers required to be located physically at the site, thus reducing the likelihood of injuries stemming from the less structured, and therefore more unpredictable, environment on site (Brown & Carranza, 2023; Pervez et al., 2021). As mentioned above, factories benefit from climate control, thereby reducing workers exposure to weather-related hazards such as thunderstorms, heat waves, and blizzards (de Laubier et al., 2019; Wilson, 2019). Some proponents of off-site construction argue that the enhanced working conditions have the potential to improve the overall culture of construction work and bolster employee satisfaction (Galante et al., 2017; Wilson, 2019). In addition to making construction work safer, off-site construction is purported to minimize disruptions (e.g., less noise and dust) to the surrounding neighborhood because less heavy duty work is needed at project site (Brown & Carranza, 2023; Feldmann et al., 2022; Galante et al., 2017). In theory, this should foster a more harmonious working relationship with the community and reduce acrimony directed toward development projects among abutters (Galante et al., 2017).

2.2.3 Improved Quality and Sustainability

The ability to leverage manufacturing technology to increase precision is a major strength of off-site construction because they can improve quality, minimize waste, and optimize material usage (Hairstans, 2015). According to Berry et al., (2020), quality control and consistency are enhanced by off-site construction methods though the use of automation techniques and precision fabrication tools such as Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM). CAD is an umbrella term for software programs that allow engineers and draftsmen to create illustrations or 3D models (*What Is the Difference between CAD, CAE and CAM?*, 2021). CAM, on the other hand, is a broad term used to describe software that automates manufacturing processes and is able to translate CAD designs into instructions for machinery to increase efficiency of production and reduces the amount of materials required (*What Is the Difference between CAD, CAE and CAM?*, 2021). In addition, off-site construction is well adapted for the utilization of Building Information Modeling (BIM) software, which enables digital prototyping and coordination of designs, reducing errors and delays (Galante et al., 2017).

As mentioned above, off-site construction is believed to reduce the quantity of material used and waste produced. According to Brown & Carranza (2023), off-site construction can reduce the amount of material utilized by as much as 50% and can produce between 70% to 80% less waste onsite. Interestingly, this reduction in onsite waste translates into fewer overall carbon emissions associated with the project because there are fewer waste removal truck trips required (Ahn et al., 2022; Pervez et al., 2021; Razkenari et al., 2020). Furthermore, off-site construction techniques are conducive to the use of sustainable components (e.g., wood) because they are manufactured in a sheltered moisture-free environment (Ahn et al., 2022; Razkenari et al., 2020). For these reasons, supporters of off-site construction methods argue that they promote sustainability much more than traditional onsite construction (Hairstans, 2015; Pervez et al., 2021).

2.2.4 Conclusion

In conclusion, off-site construction techniques appear to offer significant advantages over traditional construction methods, including increased efficiency, cost savings, improved safety and working conditions, enhanced quality control, reduced material usage and waste, greater sustainability, and better community relations. These benefits make off-site construction an attractive and transformative approach to construction with the potential to reshape the industry. However, contemporary off-site construction projects are still relatively rare, and the industry is still in its infancy, therefore more empirical research is needed to fully quantify and understand the benefits.

2.3 Barriers to Off-site Construction Adoption

Despite the supposed benefits of off-site construction, widespread implementation has yet to occur in the US construction industry. There are many different reasons for this lack of adoption, but according to Feldmann et al., (2022), the most important barriers include a lack of familiarity, misconceptions about the quality of the finished product, higher upfront costs, regulation, design challenges, and difficulty in securing financing. Moreover, many of these hinderances are interconnected and highly complex (Feldmann et al., 2022). For example, the lack of familiarity with off-site construction techniques can contribute to higher upfront costs, which increase difficulty in obtaining financing (Feldmann et al., 2022). Understanding these barriers to off-site construction is imperative for developers, governments, and industry stakeholders to work together to raise awareness, reduce upfront costs, and adjust regulations (Feldmann et al., 2022).

2.3.1 Lack of Awareness

The lack of awareness among construction industry stakeholders poses a significant challenge to the widespread adoption of off-site construction (Feldmann et al., 2022; Razkenari et al., 2020). According to Razenari et al., (2020), the inherent conservativeness of the construction industry makes embracing unconventional or novel techniques difficult. Off-site construction methods have often been met by skepticism of the proposed benefits, resistance to changing techniques, and a strong preference for traditional construction methods (Feldmann et al., 2022). One of the primary misconceptions held by construction professionals about off-site construction is that it is an all-or-nothing strategy; however, this is not the case, because all forms of traditional construction techniques can work in conjunction with some level of off-site construction methods (Wilson, 2019). Ironically, many developers are already using off-site construction solutions without even realizing it (Modular Building Institute Staff, 2017). For example, complex mechanical equipment (e.g., domestic booster pump system) is often palletized and mounted on a skid using in-factory construction methods and then installed in low-profile areas of the building (i.e., mechanical rooms and penthouses) (Modular Building Institute Staff, 2017). With that said, more intricate off-site techniques, such as modular bathroom pods can also be integrated seamlessly into a primarily onsite development project (Wilson, 2019). Wilson (2019) argues that construction professionals require more education about the benefits and applications of off-site construction to dispense with misconceptions and overcome widely held skepticisms.

2.3.2 Regulatory Complexities

Another major difficulty faced by off-site construction is regulatory complexity that can produce challenges in maintaining compliance and ensuring successful implementation (Galante et al., 2017; Razkenari et al., 2020). According to Wilson (2019), off-site projects must meet the same building codes applicable to completely onsite construction projects (i.e., there are no special provisions associated with the use of off-site construction techniques). With that said, the application and approvals process for off-site construction may be different from conventional construction, thus producing confusion for those unfamiliar with the requirements (Wilson, 2019). In local jurisdictions that are less familiar with off-site fabrication methods, additional time for approvals and inspections may be necessary (Wilson, 2019). Moreover, permitting and inspection oversight involves a division of responsibilities among state and local authorities, which can result in friction between administrative organizations and a lack of standardized inspection protocols (Galante et al., 2017; Razkenari et al., 2020). For example, there is not yet a standard process by which building inspectors are required to verify compliance at the most logical stage of production (i.e., prior to modules arriving onsite with plumbing already installed inside the walls) (Galante et al., 2017).

Despite the current regulatory hurdles, there are steps that can be taken to reduce the burden on projects implementing off-site techniques. For example, states can develop dedicated programs that specifically deal with the permitting and approval of off-site construction projects (Wilson, 2019). Furthermore, local inspectors can engage with factories directly earlier in the project timeline in order to become more familiar with the process and comfortable that standards are being met (Galante et al., 2017). Proponents of off-site construction methods argue that regulatory challenges are not insurmountable and can be adapted to in much the same way as zoning laws and other development eligibility requirements (Galante et al., 2017).

2.3.3 Design and Flexibility

An important factor which can present challenges to developers using off-site construction methods are limitations in building design and flexibility. For example, the highest level of prefabrication, modular construction (I will describe modular in more detail in later chapters), is configured with self-contained walls, floors, and ceilings which results in bulkier structures with deeper floors and thicker walls compared to traditional construction (Wilson, 2019). While these characteristics offer benefits in terms of acoustics, energy efficiency, and thermal comfort, they can reduce the usable area and volume of interior space for taller structures if not properly addressed during the design phase (Wilson, 2019). Furthermore, modular construction is not conducive to buildings that require clear spans and high open ceilings (e.g., “big box” retail stores) (Wilson, 2019). Thus, according to Wilson (2019), many modular manufacturers focus on low-to-midrise buildings with a concentration on specific market segments (e.g., multifamily or hotel) to overcome some of the design and flexibility shortcomings.

Architects must adapt their designs to stringent transportation and installation restrictions, either due to regulation or the inherent capacity of logistical systems (e.g., flatbed trailers and cranes) (Galante et al., 2017; Pervez et al., 2021; Hairstans, 2015). Therefore, effective design is imperative for off-site construction, particularly at earlier stages of a project because late design alterations can be prohibitively expensive due to the need for re-work (Hairstans, 2015). In traditional construction, operations are sequential, so design alterations can be accommodated more easily (Hairstans, 2015). However, off-site construction components are prefabricated to exact specifications, thus design changes later in the project are laborious, challenging, and costly (Pervez et al., 2021). Late-stage design changes in off-site construction projects have the potential to erode many of the advantages (e.g., faster project delivery and lower line-item costs) that justify using the technique in the first place.

2.3.4 Financing

In terms of my thesis, the most pertinent hurdle facing off-site construction projects are the challenges associated with financing. The primary issues with financing off-site projects are linked to irregular construction payment schedules, inadequate legal conceptions of collateral, and the proprietary methods used by individual off-site manufacturers (Barry et al., 2020; Hairstans, 2015; Razkenari et al., 2020). An unavoidable characteristic of off-site construction is that more upfront capital is required compared to traditional projects because materials and labor must be purchased sooner in the project lifecycle (Barry et al., 2020; Pervez et al., 2021). For example, the engineering scope may be greater, and therefore more costly, at the start of a project in order to ensure full compliance with building codes (Wilson, 2019). Ironically, this is a side effect that results from one of off-site construction’s biggest advantages (i.e., concurrent completion of project tasks and a compressed timeline), which serves to alter important time sensitive financial metrics such as IRR (Barry et al., 2020). Furthermore, lenders have difficulty obtaining security over their collateral because some courts have maintained that prefabricated components are considered the personal property of the manufacturer as building materials, and therefore, do not become real property until they are delivered to the jobsite (Barrett, 2020). This may force lenders to withhold loan proceeds until after prefabricated components have been delivered and installed on the real property, which puts builders in a bind because they need to pay vendors and purchase materials for the work actively happening off-site (Barrett, 2020). A final issue to consider is that off-site manufacturing is done in a proprietary and non-fungible way in terms of systems, processes, location, and knowledge base, therefore complications arise in the event a developer defaults midway through construction and the bank must find a new developer to take the project over (Barry et al., 2020). Although the issues surrounding the financing are intractable, they are not impossible to overcome, and a major goal of my thesis is to explore these solutions more in-depth, which I will do in later sections.

2.3.5 Conclusion

In conclusion, the adoption of off-site construction in the US construction industry faces several obstacles that hinder widespread implementation. These barriers include a lack of familiarity with off-site construction techniques, higher upfront costs, regulatory complexities, design and flexibility limitations, and challenges in financing. These hurdles are often intricate and interwoven, requiring collaboration between developers, governments, and industry stakeholders to address by raising awareness, reducing costs, modifying regulations, and fostering innovative financing solutions. Despite these impediments, there is potential for overcoming these issues and unlocking the full benefits of off-site construction in terms of speed, efficiency, and quality. By addressing these barriers to adoption, the construction industry can embrace off-site construction as a viable and sustainable approach for future development projects.

2.4 Types of Offsite Construction Techniques

As mentioned above, off-site construction is an umbrella term that refers to several different methods (Galante et al., 2017). In the previous sections regarding the overall benefits and challenges, I considered all forms of off-site construction collectively, juxtaposing them to traditional construction methods more broadly. In contrast, the following chapter will home in on the unique aspects of each specific form of off-site construction, highlighting their strengths while also considering their weaknesses. The objective of this section is to provide a more nuanced understanding of individual off-site construction techniques and comparing them with one another.

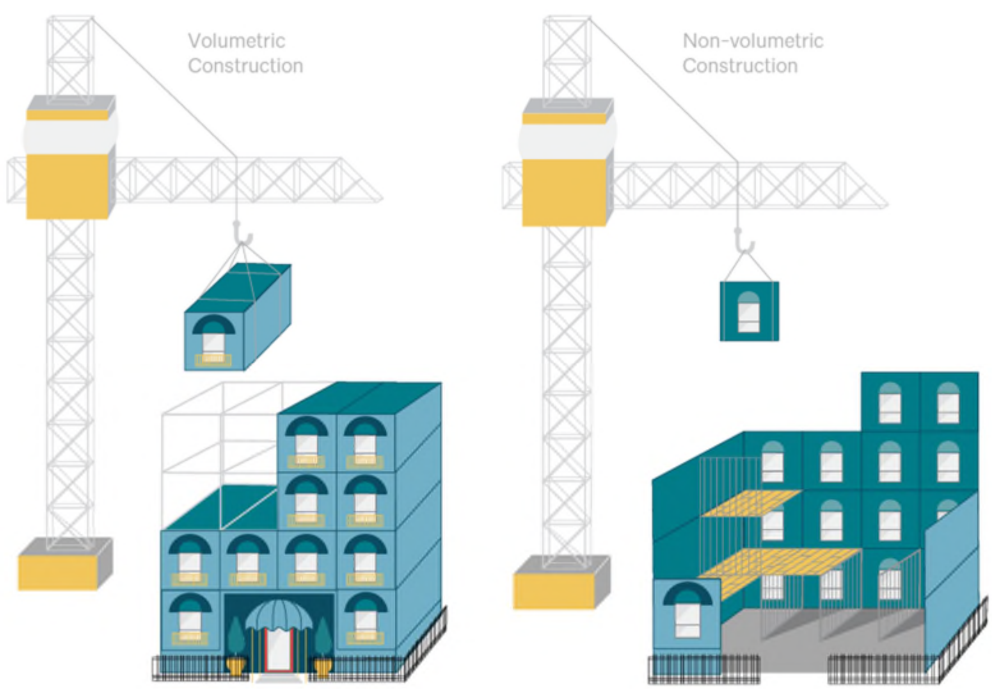

Figure 3. Modular vs. Panelized Visualization

2.4.1 Panelized Systems

Panelized systems, also referred to as "non-volumetric preassembly" systems, involve the off-site prefabrication of two-dimensional building elements, such as wall panels, roof trusses, and sections of the building façade (Hairstans, 2015). These elements are then connected on-site with additional interior work completed such as drywall, appliances, cabinetry, and painting, to finalize a fully finished structure (Lopez & Froese, 2016). These panels can either be open, which are non-insulated, or closed, which are insulated. Moreover, insulated panels can be further enhanced to include additional features like windows, doors, and finishes (Hairstans, 2015).

Panelized systems possess several unique characteristics that make the construction method particularly appealing. Firstly, like other off-site construction methods, panelized systems are much simpler to install compared to traditional building techniques (Bertram et al., 2019). Furthermore, panelized systems have an advantage over 3D modular construction because they are significantly less complex from a logistical perspective (Bertram et al., 2019; Lopez & Froese, 2016). The panels have a flat square configuration, which is more conducive to transportation and allows for greater floor area to be transported per truckload (Bertram et al., 2019; Lopez & Froese, 2016). According to a 2019 report from McKinsey, it costs approximately $8 per square meter to transport 2D panels roughly 250 kilometers compared to almost $45 per square meter to transport the 3D modular equivalent (Bertram et al., 2019). Second, in addition to being more efficient logistically, the configuration of panelized systems during transport makes them safer and less likely to receive damage (Lopez & Froese, 2016). Lastly, panelized systems are smaller, lighter, and less cumbersome than 3D modules, thus they do not require specialized equipment, and can be moved around the construction site using a forklift (Lopez & Froese, 2016). The positive attributes associated with panelized construction techniques have been proven to directly benefit development related KPIs such as project delivery time (Ahn et al., 2022).

2.4.2 Modular or Volumetric Systems

3D volumetric or modular construction techniques involve fully equipped units from the factory that are then integrated into the overall structure onsite (Bertram et al., 2019; Hairstans, 2015; Lopez & Froese, 2016). Modules are manufactured in an off-site factory, delivered to the site, lifted into place by specialized cranes, and finally fastened together and connected to utilities (Bertram et al., 2019). Approximately 90 to 95% of modules can be completed prior to leaving the factory, and therefore, require significantly less onsite labor (Bertram et al., 2019; Lopez & Froese, 2016). For example, a residential module may leave the factory complete with plumbing, electrical, and mechanical systems including major appliances such as showers and dishwashers (Barry et al., 2020; Lopez & Froese, 2016). Modules can be constructed with timber, steel, or concrete, with the latter being slightly less common due to weight induced logistical challenges (Bertram et al., 2019). Some observers have likened the placement of modules to Lego bricks being stacked together to form a building (Bertram et al., 2019). Although this analogy may seem trivial, it fittingly encapsulates the inherent straightforwardness of modular based construction methods.

Assembly-line and automation techniques inherent to offsite modular construction increase efficiency and quality (Galante et al., 2017; Siggner, 2011). These methods decrease the need for specialized labor (e.g., sheet metal and glazing) at the project site, which can be prohibitively expensive, thus saving time and driving down personnel costs (Bertram et al., 2019; Galante et al., 2017; Jeong et al., 2022; Lopez & Froese, 2016). Moreover, the controlled factory environment, which is shielded from the elements, allows for enhanced quality control practices and above-average quality outcomes compared to a traditional construction (Jeong et al., 2022; Siggner, 2011). Furthermore, modular construction is consider safer and is thought to reduce the occurrence of workplace accidents compared to traditional construction methods (Jeong et al., 2022). These tangible benefits seem to make modular construction an appealing solution to pressing societal issues such as housing affordability, and the corresponding lack of supply of homes (Jeong et al., 2022; Thompson, 2019).

Despite the ostensible upside, the positive aspects of modular construction must be considered along with its significant limitations. As alluded to above, the Achilles Heel of modular construction techniques are the difficulties associated with the transportation and logistics of modules going from the factory to the project site (Bertram et al., 2019). Module width is constrained by local or state laws, which typically cannot exceed 3.5 meters without triggering the need for an expensive police escort along the entire route (Barry et al., 2020; Bertram et al., 2019). Therefore, project teams are forced to make tradeoffs: either pay additional transportation costs to allow for larger modules or make the modules smaller. Navigating all state and local transportation codes is very difficult and makes it exponentially more complicated when crossing into differing localities or states (See Figure 4 for an overview of transportation guidelines). For this reason, a “good rule of thumb” for the distance from the factory to the site is between 125 and 500 miles (Barry et al., 2020; Salama et al., 2017).

State	Width	Height	Length	State	Width	Height	Length
Alabama	12' (16')	* (16')	76' (150')	Montana	12'-6" (18')	* (17')	* (120')
Alaska	10' (22')	*	100' (*)	Nebraska	12' (*)	14'-6" (*)	85' (*)
Arizona	11' (14')	* (16')	* (120')	Nevada	8'-6" (17')	* (16')	105' (*)
Arkansas	12' (20')	15' (17')	90' (*)	New Hampshire	12' (16')	13'-6" (16')	80' (100')
Califonia	12' (16')	* (17')	85' (135')	New Jersey	14' (18')	14' (16')	100' (120')
Colorado	11' (17')	13' (16')	85' (130')	New Mexico	* (20')	* (18')	* (190')
Connecticut	12' (16')	14' (*)	80' (120')	New York	12' (14')	14' (*)	80' (*)
Delaware	12' (15')	15' (17'-6")	85' (120')	North Carolina	12' (15')	14'-5" (*)	100' (*)
District of Columbia	12' (*)	13'-6" (*)	80' (*)	North Dakota	14'-6" (18')	* (18')	75' (120')
Flordia	12' (18')	14'-6" (18')	95' (*)	Ohio	14' (*)	14'-10" (*)	90' (*)
Georgia	12' (16')	15'-6" (*)	75' (*)	Oklahoma	12' (16')	* (17')	80' (*)
Idaho	12' (16')	14'-6" (16')	100' (120')	Oregon	9' (16')	*	95' (*)
Illinois	* (18')	* (18')	* (175')	Pennsylvania	13' (16')	14'-6" (*)	90' (160')
Indiana	12'-4" (16')	14'-6" (17')	90' (180')	Rhode Island	12' (*)	14' (*)	80' (*)
Iowa	8' (16'-6")	14'-4" (20')	85' (120')	South Carolina	12' (*)	13'-6" (16')	(125')
Kansas	* (16'-6")	* (17')	* (126')	South Dakota	10' (*)	14'-6" (*)	*
Kentucky	10'-6" (16')	14' (*)	75' (125')	Tennessee	10' (16')	15' (*)	75' (120')
Louisana	10' (18')	* (16-'5")	75' (125')	Texas	14' (20')	17' (18'-11")	110' (125')
Maine	8'-6" (18')	8'-6" (*)	80' (125')	Utah	10' (17')	16' (17'-6")	105' (120')
Maryland	13' (16')	14'-6" (16')	85' (120')	Vermont	15' (*)	14' (*)	100' (*)
Massachuetts	12' (14')	13'-9" (15')	80' (130')	Virginia	10' (*)	15' (*)	75' (150')
Michigan	12' (16')	14'-6" (15')	90' (150')	Washington	12' (16')	14' (16')	*
Minnesota	12'-6" (16')	*	95' (*)	West Virgina	10'-6" (16')	15' (*)	75' (*)
Mississippi	12' (16'-6")	* (17')	53' (*)	Wisconsin	14' (16')	*	80' (110')
Missouri	12'-4" (16')	15'-6" (17'-6")	90' (150')	Wyoming	* (18')	* (17')	* (110')

Figure 4. Module dimensions regulation for truck transportation according to state.

In recognition of these logistical challenges, Bertram et al., (2019) argues that modular construction is most conducive to hotel and affordable housing uses because they are more amenable to smaller modules, which are subject to less strict transportation guidelines. Furthermore, these asset types are particularly well-suited for modular construction because the technique allows for a high level of repeatability, which is beneficial when building a project like a hotel, where modules can be very similar. In addition, modular construction can be advantageous for projects that have many rooms with more intricate finishing, particularly wet rooms such as bathrooms and kitchens (Bertram et al., 2019). Therefore, hotels and multifamily projects, with their high ratio of wet rooms to dry rooms and need for repeatability, are ideal for modular building techniques. Having said that, Bertram et al., (2019) notes that repeatability does not mean all units look the same, rather standardized modules can be pieced together in different configurations which produce a customized end product.

2.4.3 Hybrid Systems

As discussed above, 2D panelized and 3D modular systems each possess their own unique benefits and drawbacks. As a result, hybrid systems have organically developed because they combine multiple approaches and integrate both volumetric and panelized systems in the same project, thereby optimizing the benefits of each system (Bertram et al., 2019; Hairstans, 2015). For residential buildings, the industry best practice dictates that 3D modules are utilized for the higher complexity and value elements of the building, such as kitchens and bathrooms, while 2D-panels are installed for floors and walls in open areas (e.g., living rooms and bedrooms) (Salama, 2017). With that said, hybrid systems can also work well for larger structures such as convention centers, large hotels, industrial buildings, and hospitals (Moilanen, 2023). Another important benefit of hybrid systems is that they allow for some of the flexibility traditionally associated with traditional construction without sacrificing the environmental, economic, or quality benefits of off-site construction (Moilanen, 2023).

The primary challenge to hybridized off-site construction methods is that by adding multiple fabrication processes additional complexity is created in manufacturing, supply chain, logistical, and coordination (Bertram et al., 2019). Salama (2017) argues that architects and developers should diligently choose which method is implemented for each component of the structure early in the design phase of the project according to individual project specifications. Hybrid systems require architects to consider where the panels or modules will be fabricated, each facility's production size limitations, and the transportation constraints for shipping to the site (Moilanen, 2023). Moreover, architects must incorporate owner's aesthetic and architectural preferences and the structural requirements of the project (Moilanen, 2023).

However, hybridized construction does allow for more manufacturing and transportation options, which can aid architects in overcoming the complexities inherent to this method (Moilanen, 2023).

2.4.4 Summary of Off-site Construction Methods

In conclusion, offsite construction encompasses various techniques, each with its own strengths and weaknesses. Panelized systems involve the prefabrication of two-dimensional building elements, offering comparatively better design flexibility and logistical efficiency (Bertram et al., 2019; Lopez & Froese, 2016). Modular or volumetric systems involve fully equipped units integrated onsite, providing increased fabrication efficiency, quality control, reduced costs, and enhanced safety (Galante et al., 2017; Bertram et al., 2019). However, transportation challenges pose a major limitation to this method (Bertram et al., 2019). Hybrid systems have emerged to optimize the benefits of both panelized and modular systems, allowing for flexibility while preserving the advantages of off-site construction (Bertram et al., 2019). Architects and developers must carefully consider project specifications and balance manufacturing, supply chain, and logistical complexities when implementing hybridized methods (Moilanen, 2023). Development teams should be diligent and circumspect when considering what off-site construction method to implement based on project specific needs and criteria.

2.5 Current Best Practices

As alluded to above, many of the challenges associated with offsite construction techniques are linked to a lack of familiarity that is exacerbated by the inherent conservativeness of the construction industry (Razkenari et al., 2020; Smith et al., 2022).

Therefore, the establishment a body of knowledge pertaining to offsite construction methods is crucial for improving awareness, in the hope of inducing wider adoption among current industry professionals (Smith et al., 2022; Wilson, 2019). Based on my review of the literature, I have summarized some of the already established best practices that have been highlighted by industry practitioners and academic experts.

1. Engage the offsite system sub-contractor (i.e., fabricator or manufacturer) early in the project process, preferably at project inception, thereby fostering a strong project partnership. (Hairstans, 2015)
2. Complete detailed design and scope of work as soon as possible (Hairstans, 2015). This will require close integration of information flow between architects, designers, production facilities, and onsite teams. Furthermore, roles and responsibilities should be agreed-upon and clarified for to address issues such as information management and sign-off to ensure accountability and efficiency (Berry et al., 2020; Hairstans, 2015).
3. Establish a program of activities before manufacturing begins. This program should include key elements such as design freeze date, notice period for tolerance checks, delivery timetables for offsite assemblies, and procedures for checking units before accepting handover (Hairstans, 2015).
4. Implement just-in-time delivery of manufactured assemblies, and agreed-upon delivery timetables should be monitored and communicated to the factory and logistics company. Factors such as alternative transport methods, local constraints, and lifting operations plan should be considered and incorporated into the transportation and logistics planning. (Hairstans, 2015).

5. Work closely with state building agencies to ensure inspections and approvals take place both at the development site and the manufacturing facility (Berry et al., 2020).

Implementing these best practices in offsite construction is crucial for maximizing the benefits that it can offer. By engaging the offsite system provider early, ensuring effective design management, establishing a clear program, optimizing transportation and logistics planning, coordinating with manufacturers, and proactively engaging with building code and regulation officials, projects can achieve enhanced environmental sustainability, cost-effectiveness, and improved health and safety outcomes. An essential objective of this thesis is to build upon these best practices and produce additional insights for developers looking specifically at the challenges pertaining to obtaining financing for their off-site construction projects. The intent is that this body of knowledge will contribute to the successful implementation of off-site construction projects and foster its continued growth as a viable construction method.

3. Research Questions

The primary catalyst for this thesis was a June 2022 working paper published by the United States Department of Housing and Urban Development (HUD) and the Office of Policy Development and Research (PD&R), entitled "Offsite Construction for Housing: Research Roadmap." The paper was authored by several experts in the field of offsite construction, who worked extensively with a Project Technical Committee (PTC) that consisted of academics and industry practitioners (Smith et al., 2022). Collectively, the group conducted literature reviews, identified gaps in research, participated in interviews, and moderated breakout sessions during a stakeholder workshop (Smith et al., 2022). The core objectives of the research road map were to:

1. Identify the current state of knowledge about offsite construction for housing.

2. Identify research areas, questions, and knowledge gaps in the industry.

3. Disseminate research needs to the industry, academia, and government.

The roadmap was designed to address all aspects of offsite construction, encompassing single-family, multifamily, dormitory, supportive, affordable, and market-rate housing, while primarily applicable to the residential sector, it also aimed to address barriers in commercial sectors, particularly in hospitality development (Smith et al., 2022). The research roadmap identified several obstacles to offsite construction growth that could be traced back to capital, finance, and insurance markets, that were designed to exclusively support conventional construction methods (Smith et al., 2022). In particular, securing debt capital for offsite construction facilities and individual projects was identified as a major obstacle, in conjunction with a lack of education and awareness within the developer, lending, and insurer communities (Smith et al., 2022). Research subtopics were devised to address lending risk in various housing market segments, determine actual benefits and risks of offsite construction, and provide data and education to instill confidence in the finance industry (Smith et al., 2022). Based on these findings, I have crafted three research questions to build off the insights generated by the road map:

> R_1: What is the quantified project finance risk profile of off-site construction versus traditional construction?

R_2: What are the qualitative determinants that lending institutions are using to assess the risk of off-site construction?

R_3: What data and education are needed for the finance industry to gain confidence and determine that off-site construction for housing has no added risk or lower risk than traditional construction?

4. Research Methods

This section is intended to outline the research methods that I employed to explore the research questions identified above. The study is aimed to understand the project finance risk profile of offsite construction compared to traditional construction (R1), identify the qualitative determinants used by lending institutions to assess the risk of offsite construction (R2), and determine the data and education required for the finance industry to gain confidence in offsite construction's risk profile (R3). To address these questions, the research used a combination of a review of the literature, interviews with industry experts, attendance at a Boston Housing Innovation Workshop hosted by MIT, and site visits to completed projects to gather comprehensive and diverse data for analysis.

4.1.2 Literature Review

The first step in addressing the research questions was to conduct a thorough literature review. I started my review by using the MIT Libraries search tool and Google Scholar to locate academic literature. To find relevant articles I employed keyword searches (e.g., (off*) AND (construction); (modul*) AND (construction); (panel*) AND (construction)). This technique uncovered a plethora of academic publications concerned with all facets of the offsite construction process from design to logistics and assembly. Unfortunately, most of these scholarly sources were highly technical and esoteric in nature and were thus of limited use to my broader review of the literature. Therefore, I located industry reports, professional guides, white papers, and government publications via internet searches which proved to be more helpful for improving my overarching knowledge of offsite construction. Moreover, I relied on other forms of media, such as podcasts and YouTube videos, to further inform my understanding of the topic. In terms of learning about the financing challenges associated with offsite construction techniques, individual project case studies published by project sponsors, lenders, and developers as marketing materials were particularly useful. I tried to be cognizant of the fact that much of information published pertaining to off-site construction methods are composed by proponents and advocates of the methods, therefore I was hesitant to include sources that appeared to be overly biased. Despite this challenge, the literature review serves as a foundation for developing research frameworks and informing the formulation of specific interview questions.

4.1.3 Interviews

Approximately ten experts were selected for semi-structured interviews based on their availability and extensive expertise in several different facets of the offsite construction industry. These interviewees included executives from architecture, finance, development, and manufacturing firms with direct experience in the sector. To harness the network effects among industry insiders, I employed a snowball sampling technique to identify and connect with potential interviewees through previous participants. A particular emphasis was placed on those parties that were involved in securing or providing financing for projects. After asking specific questions, which were carefully designed to elicit information about the financial performance, perceived risks, and comparative advantages of offsite construction (See Appendix for interview guides), I coded interview data to identify themes and insights. From there, I sought to synthesize interview data into categories based on topic to formulate findings.

4.1.4 Working Group Attendance

In pursuit of R3, understanding the data and education needs of the finance industry for gaining confidence in offsite construction, participation in relevant a working group was essential. This working group was comprised of industry experts, representatives of the City of Boston, and members of academia. By attending this working group session, I was able to observe the current level of knowledge and awareness of offsite construction among relevant stakeholders. Additionally, these sessions facilitated discussions on the types of data required to support lending decisions and the education necessary to reduce perceived risks associated with offsite construction.

4.1.5 Site Visits

Complementing the data from the literature review, interviews, and working group attendance, site visits to completed offsite projects were conducted. These visits were vital for gaining an in-depth understanding of the quality of finished products, obtaining a tangible perspective of the end product, and taking pictures of the project.

The combined research methods allowed for a comprehensive exploration of the research questions. The literature review provided a theoretical framework for understanding offsite construction within the broad spectrum of publications. Interviews and working group attendance offered real-world perspectives on the qualitative determinants influencing lending decisions and the educational requirements of the finance industry. Site visits contributed practical insights into qualitative assertions made by the offsite construction sector. The integration of these research methods facilitated a holistic approach to answer R1, R2, and R3, providing valuable recommendations to promote the adoption of offsite construction while addressing perceived risks.

Figure 5. The Graphic Lofts Modular Multifamily Asset in Charlestown, MA. Photo Credit: Bill Coen

5. Discussion

Traditional Construction Lending Perspective:

To gain a more robust understanding of how best to promote offsite methods among construction lenders it is imperative to explore the methodology, perspective, and requirements employed when providing traditional onsite construction financing. Therefore, I interviewed the Head of Debt at a leading real estate investment management firm, who possesses over a decade of experience with traditional construction lending. He was able to provide valuable insights into the risk factors involved in funding conventional construction projects. In general, private equity will compete with banks and insurance companies to provide financing for developments; however, the interviewee stated that private equity firms are generally more willing to tolerate higher advance rates and loan to value (LTV) ratios if they receive commensurate risk mitigation (e.g., higher interest rates and more robust contractual security provisions). This is relevant to the discussion of offsite construction techniques because they are largely viewed as less proven, and therefore, higher risk by the capital markets. Thus, private equity firms have been the primary lenders for offsite development projects up to this point.

For traditional construction loans, borrower quality (i.e., track record), market quality, and asset quality play crucial roles in the assessment of risk, with the probability of leasing or sales in the case of condo projects, representing a significant factor. Construction is inherently higher risk compared to other forms of real estate lending due to project execution risk, leasing or sales risk, and the potential for cost overruns putting the loan out of balance. According to the interviewee, his firm favors targeting industrial warehouse asset projects to finance, partially because of their relatively straightforward construction process, with projects generally being delivered in between nine and twelve months. Moreover, the interviewee emphasized the importance of delivery time as a necessity for investment grade tenants, particularly for industrial and office assets. “Time is huge, control the things you can, and the other stuff is at the mercy of the market.” The interviewee emphasized the fact that a project that takes multiple years could be delivered in an entirely different macro-economic environment from the one that existed when the loan was originated. This insight is pertinent when considering offsite construction because one of the main purported benefits of offsite construction is a quicker and more predictable project timeline.

Notably, the interviewee explained that lenders focus on mitigating risks through well-structured loan agreements, including securing Guaranteed Maximum Price (GMP) contracts, completion or carry guarantees from qualified guarantors, and ubiquitous usage of expert consultants (e.g., architecture, engineering, or construction) both internally and externally. This insight is crucial for offsite construction because some of the perceived risk involved with the method can be managed using specifically adapted loan agreements and provisions, which I will discuss more in-depth later in this section. Furthermore, the interviewee shared that his comfort with the project basis and market knowledge is paramount, thereby ensuring their ability to own and operate the property if necessary. However, it is important to consider that his firm maintains the ability to effectively manage and dispose of real estate assets through internal business units.

Another important topic discussed during the interview was conceptualizing what type of information could be most useful for inducing increased willingness from traditional construction lenders to provide financing for offsite projects. The interviewee contended that additional positive operational performance data relating to offsite construction compared to traditional construction could support the case for their usage. For example, does the employment of offsite techniques offer benefits beyond strictly the construction phase, such as lower maintenance costs, greater useful life, rental premiums, or higher occupancy? Moreover, the interviewee emphasized that there needs to be broader adoption of offsite methods and used the analogy of a new asset class (e.g., self-storage). Once additional confirmation of the benefits is available, then more institutional sponsorship can be garnered for offsite projects, thereby enhancing liquidity. The interviewee concluded by recommending that developers target higher quality sites and markets to further demonstrate success and positively influence perceptions of risk profile for offsite construction methods.

Offsite Construction Lending Perspective:

To bolster my understanding of offsite construction financing, it was imperative for me to interview a lender with practical experience financing projects with a significant offsite component. This interviewee provided valuable insights into the challenges and benefits of financing and implementing offsite construction projects, citing lessons from both successful and unsuccessful experiences with a particular focus on modular methods. He strongly emphasized the importance of conducting a personal due diligence process and limiting reliance on third-party consultants. “You have to see the factory’s inner workings, talk to the people working there, talk to [mid-level staff], and talk to management.” This process is highly involved, requiring lenders to visit a manufacturer multiple times, sometimes at factories located overseas. The interviewee contended that due diligence did not stop after agreeing to a deal, but rather, continued throughout the project timeline to account for unanticipated issues. Several interviewees stressed the fact that once a project has commenced, replacing or removing a manufacturer is essentially impossible. Therefore, determining the financial wherewithal of a manufacturer is paramount because a lender must be comfortable with a factory’s capacity to finish a project, which is highly correlated to their previous experience successfully delivering on their contracts. Moreover, the lender highlighted that to ensure cost control and project success the design should be agreed upon early in the process, and there should be no changes occurring during the manufacturing process. This is a crucial point that I will elaborate upon based on the feedback from design and construction professionals later in this chapter.

Despite the risks and complexities in underwriting offsite projects, the interviewee asserted that these construction methods present a promising response to challenges facing the construction industry going forward. For example, he argued that offsite construction can address the declining numbers of workers entering trades such as plumbing and electrical by utilizing a leaner workforce within a controlled factory environment. Furthermore, the increased sustainability of offsite methods wastes fewer resources and can utilize recycled materials which can better align with environmental initiatives that will become increasingly imperative as the impact of climate change intensifies. With that said, the interviewee acknowledged that the limited understanding among lenders impedes the widespread adoption of offsite construction techniques. He discussed the need for lenders to get comfortable with the fact that their collateral sits in two different locations with modular, and that there are legal protections, insurance policies for materials stored offsite, and contractual provisions (e.g., guarantees) that can ensure that arrangement is equal to traditional construction from a risk profile perspective. Moreover, the interviewee went on to explain that developers may face higher initial interest costs, but the accelerated schedule means a project will reach stabilization sooner and the condensed timeline reduces the risk of unforeseen adverse events occurring (e.g., natural disasters, labor shortages, or economic downturns). Interestingly, both lenders I interviewed agreed that the shorter timeline provided by an offsite construction project could serve to significantly reduce the risk of externally induced adversity.

Design and General Contractor Perspective:

As alluded to in previous sections, offsite construction is not an entirely new construction method, a point that was highlighted by the architect and general contractor involved with this thesis. With that said, offsite techniques are evolving, and more complex projects, such as high-rise modular hotels, are being contemplated and executed upon. One of the major concerns with these complicated modular projects is the site work that is required to stitch together the modules into a coherent structure. The architect I interviewed emphasized that if the onsite configuration process is not executed properly, many of the advantages of offsite construction (e.g., faster timelines and potential cost-savings) can be negated. This challenge is amplified by the fact that these innovative modular methods are relatively new for many developers, contractors, and architects. Thus, offsite construction lenders should seek to work exclusively with development teams that have experience with modular projects to avoid a drawn-out learning curve. Furthermore, the architect I interviewed advocates for the modular manufacturer to sign on as a sub-contractor under the purview of the general contractor to avoid conflict, reduce finger pointing, and ensure the general contractor has ultimately accountability to the developer.

According to the general contractor, successful onsite installation is directly correlated with the level of consistency and standardization of module designs. This assertion was echoed by the architect who argued that modular performance has been limited to date because designers and developers want their projects to possess unique qualities. "Every time you move a bathroom or move a wall, you are reinventing the chassis. Every time you reinvent the chassis, you are essentially reinventing the wheel." A common analogy used by several participants was to envision the erosion of efficiency experienced by a major vehicle manufacturer who continually changed the design of their car models in a short span of time. Therefore, the architect recommends that projects maximize efficiency and cost-effectiveness by establishing a handful of solid module designs that do not change. The general contractor supported this contention asserting that the ideal number of module variants was between four and eight. Furthermore, according to multiple interviewees, module consistency decreases the likelihood of construction defects, increases speed, and ensures inspections occur after each phase of fabrication, thereby delivering a better and more reliable product. Understanding the limitations of design variability in modular construction will require architects and developers to adapt beyond traditional construction methods which generally allow for a comparatively higher degree of flexibility.

Figure 6. Park87 Modular Multifamily Asset in Cambridge, MA. Photo Credit: Bill Coen

Offsite Manufacturer Perspective:

To achieve a wholistic perspective on the difficulties and potential solutions associated with offsite construction lending it was essential to speak with several manufacturers. As discussed in the literature review, a major obstacle to financing offsite construction developments is that they require significantly more capital earlier in the project timeline. In traditional construction a general contractor awards individual tasks to sub-contractors who purchase materials from distributors. These distributors essentially indirectly finance the project through this fragmented system because their contracts are not paid in full until work is completed onsite by sub-contractors who are then paid by the general contractor who receives distributions from a lender on behalf of the developer. In contrast, modular construction projects are more centralized with many sub-contractor tasks being consolidated under one roof, thus the manufacturer is responsible for purchasing the bulk of project materials in the early stages, possibly before ground is broke onsite or the entitlements are fully approved. One interviewee based out of the Northeast conceived of this issue as two sides of the same coin in which the financial burden is either shouldered by the manufacturer or by the developer.

In terms of manufacturing financing, offsite factories are typically undercapitalized because they are asset heavy businesses with low operating margins. Furthermore, the manufacturers face additional working capital constraints because they generally cannot obtain revolving lines of credit, which generally rely on a business' receivables, finished goods, and inventory as collateral. Modular manufacturers are not eligible to receive this form of financing, which is ubiquitous in other manufacturing sectors, because traditional business lenders view their receivables (i.e., cashflows from a real estate development project) as speculative and do not recognize modules as finished goods because they are part of larger structure (i.e., a building). With that said, manufacturers can receive debt capital secured by their inventory; however, according to the interviewee, this financing generally only covers 55 to 60 percent of the expenses leaving a significant shortfall. For developers, closing this gap is highly problematic because construction lenders typically refuse to allow their debt capital to be used for a factory deposit because it is not tangible, and some banks take issue with perceived lack of recourse on prefabricated components that are not attached to the land. Moreover, utilizing developer equity so early in the project can hinder financial metrics (e.g., IRR), which enables a project to "pencil out" in the first place. According to the interviewee, developers are so keen to avoid having to allocate equity to place a deposit of roughly 20 to 25 percent on factory materials that they will pay a premium for the manufacturer to cover the cost.

Another complication brought up by several interviewees is that offsite manufactured materials are perceived as less fungible than other commodity materials used during onsite construction (e.g., lumber or drywall). One offsite manufacturer emphasized that this perception is mischaracterized, citing an example where modules were designed and built for a specific project, but were instead used on a second separate townhouse project. The offsite construction lender I interviewed was more circumspect stating, "modular units are somewhat fungible; however, they are designed for a specific site and project. The only way modules can be fungible is if another project was sufficiently similar (i.e., structure height, lot size, etc.)." This debate is important because the fungibility of materials impacts how lenders perceive their risk as a specific form of collateral. If modules can only be used for a single specific project, then their effectiveness as collateral used to secure debt is severely hampered because they cannot be easily liquidated in the event of default.

In terms of project risk profile for both offsite and onsite projects, cost overruns and an imprecise scope of work can pose catastrophic risks to a construction budget. One major concern for offsite construction arises from inadequate scope delineation between factory and onsite work. According to one interviewee, modular factories have not invested enough time or sophistication in creating a detailed scope of work, leading to discrepancies in bidding, leading to potential cost overruns. This oversight can have significant consequences causing the general contractor to underestimate their bid, which can produce cost overruns and potentially derail a project. The interviewee further recommended addressing this with a thorough preconstruction planning process, breaking down the plans into thousands of lines, clearly defining each trade's responsibilities. Moreover, the shift from traditional onsite construction to modular necessitates a different mindset for onsite laborer as modules function more like finished units, requiring minimal onsite adjustments. “Unlike traditional construction where you can break open a wall to get where you need to go [modular] almost operates like a renovation project.”

Although offsite construction presents some inherent challenges for developers attempting to obtain financing, the techniques can offer several benefits that can lower the risk profile for construction lenders beyond a condensed timeline. For example, in contrast to traditional onsite construction, determining percentage completion is a relatively straightforward process because lenders can very clearly ascertain the progress of manufacturing by visiting the factory counting the completed units and observing the number of unfinished modules at each stage of fabrication (e.g., early, middle, or late). This is crucial because manufacturing represents a significant portion of the construction budget, so lenders gain more clarity over their funds during this process. Furthermore, the use of a uniform manufacturing code allows permitting at the state level (at least in the states where I interviewed manufacturers) for factories, expediting the permitting process. According to several interviewees, the utilization of state level inspection for offsite components provides for a more consistent and streamlined approach to acquiring building permits. Overall, offsite construction streamlines the loan draw and permitting processes, can reduce construction timelines, and offers more certainty in specific areas to construction lenders.

6. Conclusion

This conclusion section is intended to synthesize insights guided by the research questions and gleaned from the literature review and discussion section. The goal is to provide several relevant findings that can help guide future research, support advancements in educational curriculum, share best practices for lenders, and offer potential avenues for solving difficult problems. With that said, it is important to consider the limitations of my research. First, this thesis was conducted over a period of two and a half months. While the condensed timeline allowed me to immerse myself in the subject matter, the period inherently limited the number of interviews I could conduct, workshops I could attend, sites I could visit, and other research related activities. In addition, I strove to locate interviewees that I felt could be objective in sharing their knowledge and experiences. However, it is important to note that most interviewees were connected to the offsite construction industry in some way (lenders, manufacturers, architects, etc.), and therefore may possess a bias that is supportive of those methods. Despite these limitations, I believe the following findings are reliable, accurate, and applicable.

6.1.1 Findings

- **More research needs to be conducted on potential operational benefits associated with buildings that have been constructed using various forms of offsite construction.**

As discussed in the literature review, offsite construction, in particular modular approaches, can offer benefits in regard to unit acoustics, energy efficiency, and thermal comfort (Wilson, 2019). With that said, my interview with a traditional construction lender has exposed that these positive operational attributes of offsite construction are not widely publicized among the broader finance and investment community. Additional research should be conducted to establish an overt linkage between assets built with offsite construction methods and positive operational performance. For example, studies could attempt to measure heating and cooling costs to demonstrate modular units are better insulated, and therefore cheaper to operate. This research effort could generate additional awareness and interest among debt providers in relation to offsite construction methods. Moreover, these studies could increase understanding among lenders about the compensation structures they should seek when considering a non-standard building methodology (i.e., offsite construction).

- **Alternative approaches to the curriculum of design and construction professionals may be necessary to encourage the adoption and improve the implementation of offsite construction techniques.**

One theme that has been evident throughout this thesis is that misconceptions about offsite construction techniques are pervasive and represent a major barrier to increased adoption. For example, some perceive structures built using offsite construction techniques as lower quality (e.g., poor visual appearance, finish, and durability). These unfounded beliefs may contribute to the fact established by this thesis that many architects overestimate the flexibility of offsite construction, in particular modular techniques, thereby erasing many of the advantages attached to these methods. Therefore, according to Wilson (2019), a cultural shift is needed which includes, “alternative approaches like modular offsite methods in the curriculum of architecture and construction education programs.” Moreover, additional research could investigate the resale value of building materials manufactured offsite (i.e., modules) to truly determine if they are viewed as less desirable, and therefore sell at a significant discount to the manufacturing cost. By increasing awareness and understanding of offsite techniques, industry professionals can better introduce and implement these methods in a manner that maximizes their benefits and effectiveness.

- **Lenders considering financing offsite construction projects should be prepared to prioritize a thorough due diligence process that is above and beyond traditional developments.**

Another important insight gleaned from this thesis is that lenders considering financing offsite construction projects should be prepared to prioritize a thorough due diligence process that is above and beyond traditional developments. This should involve personally visiting the project site and factory, in-depth assessments of the factory’s financial wherewithal, and evidence of the manufacturer’s experience in completing similar projects. In particular, the prospective lender should scrutinize a factory's business development and sales pipeline to gauge the likelihood the manufacturer will be able to remain in business throughout project completion and beyond as their assistance may still be required for years afterword (e.g., warranties). Furthermore, adequate storage space at the factory is essential for an offsite manufacturer to allow for just-in-time delivery. This is imperative to ensure delays onsite do not disrupt manufacturing, so factory components can be ready as soon as they are needed, thereby preserving the benefits (i.e., shorter construction timelines). Ideally, incorporating these best practices can assuage some lender concerns tied to offsite construction methods and enable more willingness to engage with these types of projects.

- **Industry leaders need to continue to build upon innovations in contractual, legal, and financial instruments to better support the adoption of offsite methods.**

To address the difficulties in originating and acquiring financing for offsite construction projects, several interviewees shared potential innovations that they have witnessed being employed in the industry. For example, some lenders require recourse on debt used for manufacturing offsite materials, holding developers personally liable until the modules are onsite. Another approach is enabling working capital financing instruments, like revolving lines of credit which remains open for long periods of time even while interest and principal payments are being made, for offsite manufacturers, consolidating financing responsibility within the factory and alleviating the burden on developers. Another solution involves treating modules as "goods" under the Uniform Commercial Code (UCC), enabling lenders to secure their interest in modules during fabrication, even when offsite (Barrett, 2020). Also, challenges arise during offsite construction due to the combination of goods and services because purchase, fabrication, and installation of materials are billed by some manufacturers simultaneously. Despite this, the future could see a shift towards UCC adoption, making offsite projects more appealing to traditional lenders. These solutions along with newly developed innovations solutions can help to overcome the issues associated with financing offsite construction projects.

6.1.2 Conclusion

In conclusion, this thesis has shed light on various aspects of offsite construction projects with a particular emphasis on the role financing has in the process. It is important to keep in mind that facets of offsite construction are not mutually exclusive and therefore must be approached wholistically. While my research has uncovered some valuable insights, I have elevated areas that require further investigation. As readers consider the implications of this research, several questions emerge: How can the finance and investment community become better informed about the operational benefits of offsite construction, and how could this knowledge influence their decisions? How can educational programs adapt their curriculum to foster a cultural shift that embraces and maximizes the potential of offsite construction techniques? In what ways can lenders integrate innovative solutions, such as the Uniform Commercial Code (UCC) approach, to support and facilitate financing for offsite projects? By addressing these questions, the construction industry can forge a path towards more efficient, sustainable, and effective building practices using offsite construction techniques.

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Appendix A

*As discussed in the body of the thesis, interviews were semi structured, I used the following interview guide to structure conversations. However, I incorporated questions based on the direction of the conversation and the individual's role in the industry.

Interview Guide:

1. How are developers overcoming some of the challenges associated with getting modular projects financed? Are there any best practices?
2. Can you discuss offsite construction from the design perspective? Both benefits and drawbacks?
3. What data and education do you think would be necessary for the finance industry to gain confidence and determine that offsite construction has no added risk or lower risk than traditional construction?
4. What rules do you have about manufacturing facilities distance to project sites? Are there any other requirements for project location?
5. What can government agencies do to make getting modular projects done easier? How can they specifically make lenders more confident?
6. What is the risk profile for offsite construction projects vs traditional construction projects?

Appendix B

This file was shared with me by one of the interviewees. It includes a detailed financial model for a hypothetical project that demonstrates how modular construction methods can increase IRR metrics compared to site built.

https://d.docs.live.net/b64158073023385c/Documents/Modular%20v.%20Site%20Built%20Analysis%20.xlsx