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Quantifying "Softer" Benefits from Modularization in Capital Projects: Literature Review

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Abstract: The surge in modular construction's prevalence has prompted a revaluation of its benefits in capital projects. While previous studies excel in quantifying cost and schedule advantages, criticisms have emerged due to their oversight of softer benefits. Safety, improved quality, standardization, risk mitigation, reduced site footprint, and environmental and social gains are often neglected due to their intangibility. The existing literature focuses on the tangible benefits, leaving a critical gap in understanding these subtler advantages. To address this gap, this study proposes a qualitative framework and methods to systematically assess and assign value to these softer benefits, drawing insights from past research, industry reports, and case studies. The research aims to develop a framework to quantify the softer benefits, facilitating a more accurate comparison between modular and stick-built project options. The methodology involves utilizing secondary data on safety metrics, quality, and case studies from published journals and reports. This research provides valuable insights into refining the theoretical framework, enriching scholarly discussions, and establishing a robust foundation for future studies. The research aids industry practitioners by offering a structured approach to include softer benefits in modularization decisions, potentially promoting wider adoption of modular construction through a holistic understanding of its overall value.

Keywords: Advantages, Risk, Footprint, Safety, Standardization, Quality, ESG

1 INTRODUCTION

The trend toward modularization is growing (Kluck and Choi 2023). Modularization is widely embraced in the construction sector and applied across various scales and sectors. Modularization as an executive strategy has captured industry interest, driven by its positive effects on project performance. These encompass advancements in productivity, cost efficiency, schedule adherence, sustainability, quality, and safety measures (Choi 2014; Kluck and Choi 2023; Choi et al. 2019a). Despite the advantages of modularization, it is limited to a lower level or lower extent. The different advantages of modularization are not easily quantifiable or understood. Most previous studies on modular construction have highlighted the benefits of modular construction, including increased productivity, reduced costs, improved quality, safer work environments, reduced site safety exposures, and less environmental impact. However, investigations into modular construction have only examined the cost and schedule benefits, causing a significant gap in quantifying the other softer benefits. These softer benefits are often overlooked in the business case analysis of modularization projects, leading to missed opportunities to achieve project objectives.

Therefore, there is a necessity to quantify these softer benefits, aiding practitioners in making well-informed decisions regarding modular business strategies.

2 RESEARCH OBJECTIVE

This paper aims to highlight the softer benefits of modularization and develop a quantifiable way to assign tangible value to them (based on present and historical metrics) so that a more accurate comparison can be made between the modular and stick-built project options over the entire range of project activities, resulting in a better return on investment. To achieve this goal, the paper lists potential modular benefits by reviewing the CII Safety, Project Controls, Supply Chain Management, Quality Reports, and other published papers and reports; it also highlights the assessment methods or frameworks that can be applied to quantify the subtler benefits of modular construction.

3 RESEARCH METHODOLOGY

This paper adopts the following methodology to achieve the research objectives: 1. problem and need identification, 2. literature review of published projects and past case studies to identify softer modularization benefits, and 3. result and discussion. A detailed explanation of each step can be found below.

3.1 Step 1: Problem and Need Identification.

Many existing studies focus on quantifying tangible, measurable benefits of modularization, such as cost savings and schedule gains. However, there is a significant gap in standard metrics for evaluating the "softer" benefits. Soft benefits are often subjective and qualitative, making it challenging to measure and compare them across different projects. The absence of a standardized framework to assess and quantify these softer benefits limits the ability to make informed decisions and improvements. There is a need to establish a comprehensive framework that allows for the systematic measurement of softer benefits associated with modularization. This study should include indicators or methodologies for assessing these softer advantages. Hence, the relevant research question for this study is: "What assessment methods or frameworks can be applied to quantify the subtler benefits of modular construction in capital projects?"

3.2 Step 2: Literature Review.

The researcher has compiled a list of benefits that modular construction can offer in capital projects (CII 2023a). In order to analyze the differences between tangible and softer benefits in the context of modularization, a systematic review of scholarly articles, books, and reports was conducted. The review also examines existing frameworks and models focusing on tangible outcomes to assess modularization. However, these frameworks have limitations in capturing the holistic impact of modularization, particularly in terms of softer benefits. Therefore, existing methodologies or proposed frameworks that aim to create a comprehensive evaluation approach that includes tangible and intangible benefits were identified. Additionally, validation studies that attempt to test frameworks for measuring softer benefits were sought. Finally, the key findings from the literature review were summarized.

3.3 Step 3: Analysis and Discussion.

Once the literature review was completed, a detailed analysis of the literature was conducted, and the identified framework and matrix are shown in the results section, which discusses the findings in more detail.

4 RESULTS

4.1 Advantages of Modularization.

Several research studies have focused on the advantages of modular construction. Table 1 presents the key benefits of modularization in construction projects and relevant literature references supporting each benefit.

Table 1: Key Benefits of Modular Construction

Key Benefits	Relevant literature
Lower Capital Cost	(Choi 2014; Choi et al. 2019a; O'Connor, O'Brien, and Choi 2015; Kluck and Choi 2023)
Improved Schedule Performance	(Choi 2014; Choi et al. 2019a; O'Connor, O'Brien, and Choi 2015; Kluck and Choi 2023)
Increase Productivity	(Choi 2014; Choi et al. 2019b; O'Connor, O'Brien, and Choi 2015; Kluck and Choi 2023)
Increased Sustainability Benefits	(Choi 2014; Choi et al. 2019b; Kluck and Choi 2023)

Similarly, Table 2 summarizes the literature on the softer benefits of modular construction.

Table 2: Softer Benefits of Modular Construction

Softer Benefits	Relevant Literature
Safety Benefits	(Choi 2014; Choi et al. 2019b; Kluck and Choi 2023)
Standardization Benefits	(Shrestha et al. 2020; Choi et al. 2020a; 2020b)
Quality Benefits	(Choi 2014; Kluck and Choi 2023)
Environment Benefits	(Choi 2014; Kluck and Choi 2023)

Social Benefits	(CII 2023a; Kluck and Choi 2023; Choi et al. 2019b)
Governance Benefits	(CII 2023a; Kluck and Choi 2023; Choi et al. 2019b)
Reduced Site Based Permits	(CII 2023a; Kluck and Choi 2023; Choi et al. 2019b)

Quantifying the hard benefits of modular construction, like the cost and schedule savings, can be straightforward and readily measurable. Extensive research has recommended various equations and methods to quantify these benefits accurately. Past studies have determined the financial advantages of choosing different module yards by comparing labor costs across different construction scenarios. Similarly, past studies have also highlighted that the value of schedule savings can be calculated by considering financial costs, incentives, liquidated damages, or expected revenues per day.

4.2 Existing Frameworks to Quantify Softer Modularization Benefits

4.2.1 Risk/Contingency Benefits.

Modularization transfers numerous risks from on-site operations to module yards, effectively managing diverse uncertainties and lowering contingency requirements. Overall, modularization effectively mitigates risks associated with quality, on-site labor expertise, schedule adherence, and labor expenses. Modularization provides reliability and surety on schedule, cost, and quality (Kluck and Choi 2023). However, it introduces new challenges related to change impacts, transportation logistics, and constrained delivery windows, limiting recovery options in case of delays(CII 2014). Some of the other risk benefits include Permit Issues, Environmental Impacts, Weather Impacts and Political (Choi et al. 2019b). The diminished need for contingency can be viewed as a positive outcome of the risk management and contingency benefits associated with modularization (CII 2023). While modular construction offers various risk and contingency benefits, it is essential to note that each construction project is unique, and factors such as project complexity, site conditions, and local regulations can influence the extent to which these benefits are realized.

4.2.2 Reduced Site Footprint Benefits.

Space is a critical resource on a construction site, along with money, time, materials, labor, and equipment (Sadeghpour et al. 2006). Modular construction can help in the overall reduction of the plot area. Exporting site-based work to an offsite location has been shown to offer a range of benefits for construction projects. One key advantage is the reduction of temporary laydown areas, which can be a significant source of disruption and inconvenience at the construction site (Kluck and Choi 2023). Additionally, the use of modular construction has been found to be a more sustainable option, with reduced impacts on the environment. This includes a decrease in the amount of dust, noise, and air and water pollution, compared to traditional stick-built construction methods. These findings highlight the potential benefits of offsite construction and modular techniques in enhancing construction efficiency and sustainability (Kluck and Choi 2023).

4.2.3 Safety Benefits.

When properly planned, modularization can effectively respond to various safety challenges. The safety benefits can be calculated by comparing the estimated project injury costs at the site with stick-built against the same costs for a modular approach. The estimated project injury costs can be calculated by multiplying the average injury (direct and indirect) costs and the estimated number of injuries based on the historical

injury rate at the site or module yard (i.e., Total Recordable Incident Rate [TRIR], Days Away and Restricted or Transferred (DART), and serious injury incidence rate).

According to CII (2022),

TRIR = "Total Recordable Incident Rate" – TRIR is the number of recordable injuries occurring annually among 100 full-time workers (i.e., 2000 hours per worker per year).

TRIR = (Number of recordable cases) × 200000)/ (Total work hours by all employees) (Eq. 2)

DART = "Days Away and Restricted or Transferred. The DART rate represents the number of DART cases occurring annually among 100 full-time workers (i.e., 2,000 hours per worker per year)."

DART = (Number of DART Cases) × 200,000)/ (Total work hours by all employees)) (Eq.3)

OSHA's Individual Injury Estimator helps assess the impact of workplace injuries and illnesses. See Table 6 for example work injury costs per worker, death, and medical consultation, injury in 2021.

Table 6: Work Injury Cost -2021 (NSC 2021)

Total Cost in 2021	$167.0 Billion
Per Worker	$ 1,080
Per Death	$ 1,340,000
Per medical consultation, injury	$ 42,000

Safety benefits can be calculated by estimating the cost savings resulting from a reduction in TRIR or DART incidents between the factory/yard and site. The formula for safety benefits will be:

Safety Benefits (Reduction in TRIR or DART incidents) × Cost per Incident (Eq.4)

The cost per incident should include both direct and indirect costs associated with each incident.

4.2.4 Standardization Benefits.

While not all modular projects adhere to a standardization strategy, integrating modularization with standardized facility design presents an advantageous opportunity (Shrestha et al. 2020, Choi et al. 2020b). The benefits of standardization encompass various aspects (Choi et al. 2022), including: 1. Designing once and reusing multiple times, 2. Advanced planning for design and procurement, 3. Accelerated responses to schedule requirements, 4. Streamlined engineering for similar sites; 5. Learning curve advantages in fabrication, 6. Procurement discounts through volume and/or early commitment, 7.Cost savings in construction materials management, 8. Learning curve benefits in module installation/site construction, 9. Learning curve advantages in commissioning and start-up, 10. Learning curve benefits in operations and maintenance, 11. Cost savings in O&M materials management, 12. Asset reuse through relocation, and 13. Cost savings in decommissioning. Standardization benefits can be quantified using the Standardization Business Case Analysis Model and Tool developed by CII RT-UMM-01 developed by CII (2019).

4.2.5 Quality Benefit.

According to CII (1989), the cost of rework on industrial projects could take up to 12 percent of the Total Installed Costs (TIC). Proper planning of modularization can improve quality benefits (Choi et al. 2019b) due to higher quality module yard personnel, management setup, time-tested procedures, and optimized production path, among other advantages. The authors found two relevant literature on quantification of quality: (Khadim et al. 2023) and (CII 2001).

According to Khadim et al. (2023):

Cost of Quality (COQ) = COC + COPQ ,where

$$COC = \sum P + \sum A \ ; \quad \text{(Eq. 5)}$$

COC = Cost of Conformance and COPQ = Cost of Poor Quality

$$COPQ = \sum VF + \sum HF \ ; \quad \text{(Eq.6)}$$

VF = Visible Failure Cost and HF= Hidden Failure Cost

$$\sum VF = \sum IF + \sum EF \ ; \quad \text{(Eq.7)}$$

IF= Internal Failure + EF= External Failure

$$\sum HF = \sum ht + \sum hi \ ; \quad \text{(Eq. 8)}$$

ht= hidden tangible and hi= hidden intangible

Similarly, according to (CII 2001), the Total Field Rework Factor (TFRF) is defined as:

TFRF = (Total direct cost of the fieldwork)/ (Total Construction Phase Cost) (Eq. 9)

By calculating the difference between the cost of the module shop/work and the site, the benefits of quality can be quantified.

4.2.6 Environmental Benefits.

Construction activities can produce air, water and noise pollution, which are environmental concerns. As environmental regulations become more stringent and sustainable, it is important for industry leaders to collaborate in the generation of innovative solutions, such as Modular solutions that can help companies understand ESG impacts on projects, how to mitigate them, and how to comply with new environmental regulations worldwide. Regarding modular projects, considering environmental factors can significantly affect costs and savings (Shahi et al. 2024). Modularization can be effective for various environmental challenges, including water, pollution, waste and material, energy, and emissions (Shahi et al. 2024). Environmental benefits of modularization can be divided into benefits related to waste production and the construction process impact on the environment. Some of the environmental benefits that can be quantified are reduced costs for site and neighborhood disturbance, reduced air and water pollution, efficient land use, waste management savings, as well as savings from reuse or relocation (Tzourmakliotou 2021). For a detailed assessment of environmental factors, the ESG modularization assessment tool developed by CII (2023) can also be considered.

4.2.7 Social Benefits.

Social factors are the key decision drivers as well as emerging drivers for modularizations decision (Shahi and Choi 2024; Shahi et al. 2024). Modularization can be effective for various social challenges, including local content, labor conditions, community impact, and laws and regulations. Some other social benefits from modularization include benefits from increased workforce and safety, benefits from improved working conditions on site, reduced community disturbances and benefits from reduced on-site risks (Tzourmakliotou 2021). For a detailed assessment of social factors, the ESG modularization assessment tool developed by CII (2023) can also be considered.

4.2.8 Governance Benefits.

Similar to environmental and social factors, government factors are also the key drivers of modularization (Shahi and Choi 2024). Modularization can effectively address various governance challenges, including politics and geopolitics, cultural implications, shareholders and stakeholders, sustainability metrics, and organization (CII 2023). The governance factors to be considered during the project evaluation include factors like political and geopolitical conditions at the site, cultural implications, ethics and compliance, requirements and engagement of shareholders and stakeholders in the project, human rights due diligence,

and sustainability metrics (Shahi et al. 2024). The ESG modularization assessment tool developed by CII (2023) can also be considered for a detailed assessment of social factors.

5 CONCLUSION AND FUTURE WORK

Based on the available literature, the study presents a systematic framework for quantifying the tangible value associated with modular construction's softer benefits. While metrics for costs, schedules, safety, and quality savings are readily discernible, the quantification of other benefits, such as ESG considerations, risk/contingency factors, and reduced site footprint, proves challenging due to their project-specific nature. A nuanced and context-dependent approach is imperative to precisely evaluate these aspects. Future research endeavors should adopt a collaborative working group initiative involving companies specializing in modular construction, including those in shipyards and fabrication yards. This cooperative effort can facilitate a diversified and industry-specific perspective on the applicability and measurability of identified softer benefits. Recognizing the inherent complexities in quantifying these benefits, a dedicated analysis of survey outcomes is recommended. Moreover, collaborative sessions with other Cost-Benefit Analysis (CBA) entities could enhance the comprehensiveness and applicability of the study. This strategic approach ensures the generalizability of findings and contributes to a deeper understanding of the intricate dynamics surrounding modular construction's softer benefits. Continued investigations of this nature with collaborative input are pivotal for refining methodologies and ensuring the adaptability of modular construction practices across diverse project landscapes, thereby contributing to the scholarly discourse in the field.

6 CONTRIBUTIONS TO THE BODY OF THE KNOWLEDGE

This study addresses the overlooked softer benefits of modularization, emphasizing their importance in modularization decision-making. The study will contribute to creating an assessment framework for capturing these benefits, ultimately enhancing the modularization decision process. This research contributes to refining the theoretical framework, enriching scholarly discussions, and laying a robust foundation for future studies. Similarly, by quantifying "softer" benefits, companies and practitioners can unlock structured and quantifiable approaches to evaluate modular construction's benefits. This research equips industry practitioners with a practical approach to making informed decisions regarding modular construction by incorporating these benefits in business case analysis. The study may encourage wider adoption of modular construction by demonstrating the full spectrum of its benefits.

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