

SAFETY RISK FACTORS ASSOCIATED WITH A LEAN WOOD-FRAMING PREFABRICATION FACILITY: A CASE STUDY

Vishal Sharma¹, Don Mah², Neetu Sharma³, Mohamed Al-Hussein⁴, Ahmed Bouferguene⁵, & Haitao Yu⁶

ABSTRACT

The construction industry in North America has a disproportionate share of job-site incidents. Numerous studies have been performed to identify a multitude of macro and micro factors that impact the safety in construction workplaces. Prefabricated construction in North America is experiencing significant growth, evolving from a niche approach to a mainstream construction method. Due to advances in prefabrication, the construction sector is beginning to undergo a transformation, with favourable impacts on the safety of the construction workforce. Prefabrication has improved the safety and lifestyle of construction workers by lowering fatigue and reducing short- and long-term disability claims. However, despite these improvements, worker safety in prefabrication facilities still lags behind that of other industries operating in highly controlled environments. This paper systematically gathers and analyses safety incident data to identify risk factors associated with a wood-framing prefabrication facility that operates under lean principles. Mitigation measures are recommended to address the identified critical risk factors. The findings of this paper can serve as guidelines for addressing risk factors in similar wood-framing prefabrication facilities operating under lean manufacturing principles.

KEYWORDS

Lean construction, prefabrication, off-site construction, safety, risk.

INTRODUCTION

The construction industry contributes significantly to both global and North American economies. In Canada, construction employs over 1.6 million people and contributes approximately \$162 billion annually, accounting for 7.5 percent of the country's gross domestic product (GDP) (CCA, n.d.). In the United States, with a GDP of roughly \$30 trillion in early 2025, the construction sector contributed approximately \$1.3 trillion, representing about 4.5% of GDP (AGC, 2024). Despite this substantial economic contribution, workplace safety in

¹ Instructor, J.R. Shaw School of Business, Northern Alberta Institute of Technology, Edmonton, Canada, vishals@nait.ca, orcid.org/0009-0004-9617-7640

² Instructor, Construction Engineering Technology, Northern Alberta Institute of Technology, Edmonton, Canada, dmah@nait.ca, orcid.org/0009-0004-5954-9273

³ Assistant Professor, Department of Accounting and Finance, MacEwan University, Canada, sharman52@macewan.ca, orcid.org/0009-0001-4723-4862

⁴ Professor, Department of Civil and Environmental Engineering, University of Alberta, Edmonton, Canada, malhussein@ualberta.ca, orcid.org/0000-0002-1774-9718

⁵ Professor, Campus Saint-Jean, University of Alberta, Edmonton, Canada, ahmedb@ualberta.ca, orcid.org/0000-0003-4629-6620

⁶ Research and Development director, Landmark Group of Companies, Canada, haitaoy@landmarkgroup.ca, orcid.org/0000-0002-7798-4867

construction remains alarmingly poor compared to other industries. In Canada, over 1,000 work-related fatalities were accepted across all the industries in 2023, with the construction industry accounting for a significant portion of that total (Tucker & Keefe, 2025). According to the U.S. Bureau of Labor Statistics (n.d.), in the year 2023, the U.S. construction industry recorded 1,075 fatal work injuries, representing approximately 20% of all workplace fatalities nationwide. In response to these persistent safety challenges, a growing number of construction companies are adopting off-site construction techniques as a viable alternative (Innella et al., 2019 & Choi et al., 2019).

Researchers have examined various aspects of modular/off-site construction. Blismas et al. (2006) proposed a value-based evaluation framework for off-site production to enable more realistic assessment and broader industry uptake. Zohourian et al. (2025) conducted a comprehensive analysis of modular construction to assist decision-makers, professionals, and project managers in understanding the potential of integrating modular construction with technological advancements. Several studies have demonstrated significant productivity gains associated with modular and off-site construction methods (Choi, 2014; Bekdik, 2017). Wuni et al. (2022) systematically reviewed the critical risk factors associated with modular integrated construction, while O'Connor et al. (2015) investigated the relationship between modularization and design standardization to identify opportunities for modularization augmentation.

While several researchers have examined various aspects of lean prefabrication, a notable gap remains in the literature regarding the risk factors specific to lean wood-framing prefabrication facilities. This paper addresses that gap by conducting an in-depth investigation of the risk factors associated with a wood-framing prefabrication facility operating under lean principles. A detailed analysis of safety incident data from a large-scale lean-wood-framing prefabrication facility is conducted to identify and evaluate key risk factors affecting worker safety. Based on this analysis, the paper proposes targeted mitigation strategies to address the most critical risk factors identified.

LITERATURE REVIEW

In Canada, thousands of workers suffer workplace injuries each year. According to data compiled by the Association of Workers' Compensation Boards of Canada (AWCBC, n.d.), a total of 195,148 lost-time claims were reported nationwide in 2024. In the same year, 722 workplace fatalities were recorded (AWCBC, n.d.). Construction consistently ranks among the industries with the highest fatality counts in Canada. Despite employing a relatively small portion of the workforce, the sector frequently accounts for approximately one-third of total workplace fatalities. For instance, in 2023, the construction sector accounted for 32% of workplace deaths, even though it accounted for 5% of the workforce. According to the Christian Labour Association of Canada (CLAC, 2024), approximately 20.2 workers are killed annually for every 100,000 workers.

Given the substantial opportunity to reduce safety incidents, there is a growing consensus within the construction industry that off-site construction can provide a safer working environment. The Construction Industry Institute (CII) defines off-site construction as "the use of off-site construction (including a segregated area onsite) and includes all work that represents substantial off-site construction and assembly of components and areas of the finished project" (CII, 2011). Prefabricated construction in North America has experienced significant growth, transitioning from a niche practice to a mainstream approach. In 2018, the global prefabricated construction market was valued at USD 112.3 billion (Modular Building Institute 2019). Additionally, prefabricated construction's share of the total construction market increased from 2.43% in 2015 to 3.67% in 2018 (Modular Building Institute, 2019).

The need for improved safety practices extends to prefabricated and off-site construction environments. Liu et al. (2020) explored the pathways and the impacts of various factors influencing safety behaviours in off-site manufacturing. Vithanage et al. (2021) conducted a systematic review of safety risks in prefabricated manufacturing, identifying hazards associated with human, organizational, and work-environmental factors. Their study proposed targeted safety management strategies and technology-driven safety measures to mitigate these risks.

Lean construction has been widely recognized as an effective approach to reduce the non-value or destructive activities, including safety-related accidents. Koskela (1992) was among the first to apply lean thinking in the field of construction. According to Wu et al. (2019), lean construction emphasizes value-added practices that can directly or indirectly improve the construction safety. Nahmens & Ikuma (2009) described lean construction as a process of continuous improvement aimed at eliminating waste and achieving excellence in project execution, including safety outcomes. This approach is particularly applicable to the context of prefabrication facilities, where relatively controlled and closed systems provide significant opportunities for process improvement and safety enhancement. When it comes to prefabrication facilities, the implementation of the 5S management method can significantly reduce safety incidents by addressing the root causes of the problem (Bashir et al., 2011). James et al. (2012) demonstrated that applying lean principles can lower worker risk exposure in prefabricated home building, while Ikuma et al. (2011) highlighted the potential integration of safety and lean tools to increase productivity.

Despite these contributions, limited studies have been conducted in the analysis of risk factors related to prefabricated construction, including modular and off-site construction. Pervez et al. (2022) proposed a risk assessment framework to identify, evaluate and prioritize critical risk factors related to the implementation of modular construction in Pakistan. Khan et al. (2024) studied the safety risks associated with the process of manufacturing, transporting, and installing modular structures. Abdul et al. (2021) investigated key risks affecting cost and schedule performance of prefabricated construction projects. The results showed that the top three critical factors affecting both cost and schedule of prefabricated projects were related to the shortage of skilled and experienced laborers, late design changes, and poor site attributes and logistics. Jeong et al. (2021) investigated accident cases related to modular construction and identified the associated safety risk factors. The study evaluated accident cases in the domain of modular construction from the Occupational Safety and Health Administration (OSHA) database. The investigation was based on 107 accident cases, out of which 26 accidents occurred during the manufacturing process and 81 accidents occurred during the construction process. Similarly, Fard et al. (2017) examined safety performance in prefabricated building construction based on 125 OSHA-recorded incidents during manufacturing and on-site activities. However, both studies are largely generic in nature as they rely solely on OSHA accident data. Another key limitation of these studies is the lack of detailed descriptions of incidents and contextual factors surrounding the accidents, constraining deeper insights into root causes and preventive strategies.

METHODOLOGY

“A risk factor refers to any variable, condition, or circumstance that increases the likelihood of a negative event occurring or the severity of its impact” (PMI, 2024). This paper explores the impacts of risk factors associated with operating a wood-framing prefabrication facility based on lean manufacturing principles. A fully automated wood-framing manufacturing facility was selected as a case study. For confidentiality reasons, this facility is hereafter referred as the ‘Case Company’ or the ‘Facility’. The layout of the Facility, including equipment configuration and assembly lines, is designed in accordance with lean principles. A full-time

Research and Development manager is employed by the Case Company to ensure that operational practices follow lean manufacturing principles.

To identify the risk factors associated with the Facility, data was collected from in-house safety incident records. All the records over a three-year period (2020-2022) were collected and entered into a database. Each record was analyzed for completeness and additional clarifications were sought from the Case Company where necessary. The research team ensured that each incident record contained a detailed description of the incident and surrounding factors, enabling accurate identification of underlying risk factors. Risk factors were examined from multiple perspectives, including the severity of incidents, the mode of injuries, the mechanism of injuries, and the location of injuries. These incidents were further analyzed to identify trends across different work areas, such as floors, walls, and roofing assembly lines. These identified trends supported the Case Company in developing targeted measures to manage and mitigate identified risk factors. The findings of this study may serve as practical guidelines for addressing risk factors in similar wood-framing prefabrication facilities operating under lean principles.

DATA COLLECTION

The case company employs more than 200 staff in different operations. Approximately 28% of workers are engaged in construction activities within the Facility, while 26% are engaged in on-site construction activities for the assembly of prefabricated building components. The remaining 46% of employees support construction operations through administration functions, logistics, material handling, and transportation. Within the Facility, workers are divided into specialized crews responsible for different components of the prefabricated buildings. The “Floors” and “Walls” crews build floor and wall panels using various automated machines and hand tools. The “Windows and Doors” crews install windows and doors into the wall panels. The “Manual Build” crew is responsible for customized components, such as decks, stairs, columns, and tall walls. The “Roofing” workers assemble the roof systems within the Facility using engineered truss packages.

A total of 394 safety incidents were reported by the employees over the three-year period from 2020 to 2022. Incidents reported by the supporting staff, such as those working in ‘Office’, ‘Logistics’, ‘Loading’, and ‘Material Handling’ personnel were excluded from this study. Incidents related to ‘Property Damage’ were also excluded from the data set as they did not result in any physical injury. In addition, incidents related ‘Motor Vehicle Accidents’ were also omitted because they were not directly associated with construction activities within the fabrication facility. After applying these exclusion criteria, 162 safety incident records remained for analysis to identify relevant risk factors.

In Alberta, any work-related injury, illness, or disease requiring medical treatment beyond first aid, resulting in lost time from work, or requiring modified duties must be reported to the Workers' Compensation Board (WCB). Out of 162 incidents analyzed, 35% required medical aid, 51% required first aid, and 13% were classified as near-miss events. A total of 62 incidents were reported to the Worker's Compensation Board (WCB), which included one lost-time incident and 25 incidents requiring modified work schedule (Figure 1). None of the reported incidents resulted in a visit to a hospital emergency room.

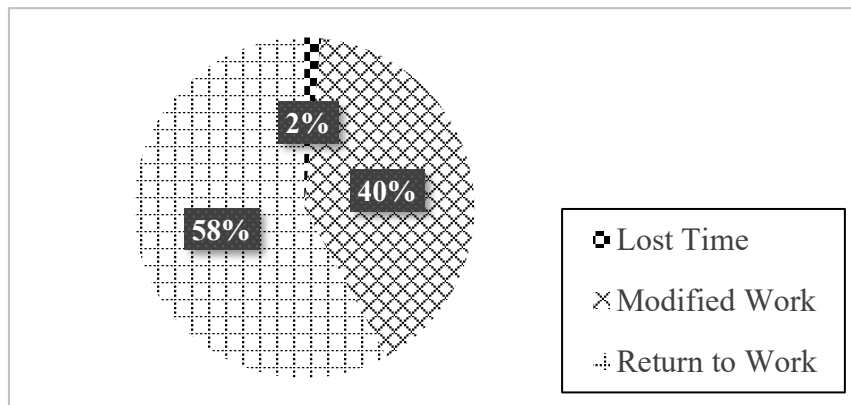


Figure 1: Reported incidents to Workers Compensation Board (WCB)

Table 1 illustrates the detailed analysis of incidents that required medical aid. Out of 57 recorded incidents, 21 (37%) incidents were attributed to ‘Overexertion’, while 19 (33%) incidents resulted from workers being ‘Struck By’ an external object or mechanism. The remaining incidents (30%) were attributed to other causes, such as ‘Struck Against’, ‘Caught Between’, and similar mechanisms.

In terms of types of injuries associated with ‘medical aid’ incidents, 25 (44%) incidents resulted in ‘Sprain/Strain’. ‘Bruising/Contusion’ and ‘Puncture’ injuries were also prevalent, together accounting for 18 incidents (33%) among the medical-aid cases.

Table 1: Analysis of incidents requiring medical aid.

	Struck By	Over Exertion	Fall - Same Level	Struck Against	Caught Between	Bodily Reaction	Fall - Lower Level	Contact w/ Harmful	Other - Sliver
Bruising/Contusion	5	-	1	-	3	-	-	-	-
Foreign Object	2	-	-	2	-	-	-	1	-
Fracture	-	-	-	-	1	-	-	-	-
Occupational Disease	-	-	-	-	-	-	-	1	-
Open Wound	3	-	-	2	-	-	-	-	-
Other	-	-	-	-	-	-	-	2	-
Puncture	9	-	-	-	-	-	-	-	-
Sprain/Strain	-	21	1	-	-	1	2	-	-

Table 2 illustrates the detailed analysis of incidents that required first aid. Out of 84 reported incidents, 38 (45%) incidents were attributed to workers being ‘Struck By’ some external mechanism. ‘Overexertion’ accounted for 13 incidents (15%), followed by ‘Fall’, which resulted in 9 incidents (11%). The remaining 24 incidents (29%) were attributed to other causes, such as ‘Struck Against’, and ‘Caught Between’, among others.

In terms of types of injuries associated with first aid incidents, 33 (39%) incidents resulted in ‘Bruising/Contusion’. ‘Sprain/Strains’ were reported in 21 incidents (25%), while ‘Superficial Wound’ accounted for 14 incidents (17%). The most common types of injuries across first-aid cases were ‘Sprain/Strain’ (28%), ‘Bruising/Contusion’ (26%), ‘Puncture’ (12%) and ‘Wounds’ (12%). Fingers, hands, and lower back were found to be the most vulnerable body parts, collectively accounting for 41% of all reported injuries.

Table 2: Analysis of incidents requiring first aid.

	Struck By	Over Exertion	Fall - Same Level	Struck Against	Caught Between	Bodily Reaction	Fall - Lower Level	Contact w/ Harmful	Other - Sliver
Bruising/ Contusion	16	1	2	6	6	-	2	-	-
Foreign Object	1	-	-	-	-	-	-	1	1
Infection	-	-	-	-	-	-	-	1	-
Open Wound	1	-	1	-	-	-	-	-	-
Puncture	10	-	-	-	-	-	-	-	-
Sprain/Strain	-	12	5	1	-	3	-	-	-
Superficial Wound	10	-	1	1	-	1	1	-	-

SAFETY INCIDENTS: ANALYSIS

When completing the incident report, the Case Company recorded the detailed description of the incident, including the surrounding factors. The research team analyzed these detailed descriptions and surrounding factors to identify the associated risk factors. Where needed, additional clarifications were obtained from the Case Company to supplement the recorded information. The findings were summarized based on the location of injury to facilitate systematic analysis.

UPPER BODY

Injuries associated with the head, face, eyes, and neck were examined first. A total of nine incidents were reported in this category.

1. Face: Facial injuries were primarily caused by foreign objects rebounding toward workers, often resulting from improper use of nailing guns.
2. Neck: Neck injuries were mainly reported as sprains caused by lifting eccentric loads.
3. Eye and head: No risk factors were identified for injuries involving the eyes or head.

For upper body parts, such as shoulders, chest and abdomen, seven incidents were reported. Although no clear trend was identified, the majority of these injuries affected the shoulder region and were primarily associated with overexertion.

LOWER BODY

The research team examined injuries associated with the lower parts of the body, such as hip, groin, thigh, knee and shin. A total of 23 incidents were reported in this category.

1. Knee: Knee injuries were most commonly caused by workers being struck by (or against) something, typically resulting in bruising or contusions. Notably, 65% of the injuries to 'knee' were suffered by workers in the 'Roofing' crew, largely due to working on sloped surfaces.
 - a. Distractions during work contributed to several knee injury incidents.
 - b. Unwarranted use of the knee to support the load was another risk factor associated with the injuries.
2. Thigh: Approximately 65% of the injuries to the thigh were suffered by the workers in the 'Walls' crew.
 - a. Bruising and contusion were the most common injury type.
 - b. Using the thigh to push or stabilize the loads was another risk factor associated with the injuries.

3. Hip, groin and shin: Only five incidents involved these body parts. All the injuries were associated with ‘fall’ due to slips and trips.

UPPER BODY EXTREMITIES

The research team looked at the injuries associated with extremities of the upper body, such as arm, wrist, hand and fingers. A total of 62 incidents were reported in this category.

1. Fingers & hand: Analysis of 47 incident records revealed the following patterns:
 - a. ‘Puncture’ emerged as one of the key injury modes (22 incidents). All the puncture incidents involved driving the nails.
 - b. ‘Pinching’ emerged as another key injury mode (8 incidents). Workers typically caught their fingers between two surfaces during material or equipment handling.
 - c. ‘Bruising/contusion’ emerged as another risk factor (8 incidents). Most of the incidents involved hitting the hand with tools such as a hammer.
2. Arm & wrist: A total of 15 incident records involved the arms or wrists.
 - d. A primary risk factor was being struck by/against something, particularly during material/component handling, typically resulting in bruising or contusions.
 - e. A second risk factor involved falls, leading to arm injuries and wrist sprains.

LOWER BODY EXTREMITIES

The team reviewed injuries associated with the extremities of lower body, such as ankle, foot and toe. A total of 14 incidents were reported in this category. No toe injuries were reported.

1. Ankle & foot:
 - a. Based on 14 records, the major risk factor was ankle sprains. These occurred due to slipping over a slope, stepping on obstructions, rolling the ankle, or stepping off elevated surfaces.
 - b. Injury to foot could be attributed to accidentally dropping heavy objects.

UPPER AND LOWER BACK

The team reviewed 25 incidents related to upper and lower back injuries. Most of the lower back incidents were associated with the ‘Walls’ crew.

1. Lower Back: Of the 16 incidents involving lower back, 11 resulted in modified work schedules. The majority of lower back injuries involved sprain/strain. These injuries occurred while lifting objects such as building materials or components.
2. Upper Back: All three incidents were attributed to overexertion, resulting in sprain and modified work schedules.

RISK FACTORS

This section summarizes the risk factors that can impact the worker’s risk tolerance and, in turn, affect the probability and/or severity of safety incidents. Based on the qualitative analysis of incidents presented in the previous section, the research team identified several risk factors associated with the reported incidents. Please note that one or multiple risk factors may apply to a single incident. The identified risk factors can serve as a starting point or baseline for managing and mitigating risks in similar wood-framing lean prefabrication facilities.

1. Overestimation of capability/experience: This factor relates to the belief that one’s physical strength and experience are sufficient to safely perform a risky task.
2. Familiarity with the task: This factor makes the worker believe that, given the skills and familiarity with the task, no thinking/planning is required to complete the task.

3. Seriousness of outcomes: Workers may not be trained to anticipate the seriousness of the potential outcome. For example, a ‘pinch point’ can potentially lead to crush or amputation.
4. Being in control: Workers have a strong sense of control/mastery over the task, leading to complacency.
5. Cost of non-compliance: The lower the cost of non-compliance, the higher the risk tolerance.
6. Confidence in equipment: Excessive and unwarranted trust in equipment can lead to tool-related incidents, which are one of the major causes of safety incidents in the Facility.
7. Confidence in protection and rescue: Reliance on personal protective equipment or safety systems beyond their intended purpose may result in riskier behaviour.
8. Potential profit and gain from (unsafe) action: This risk factor stems from the desire for increased profit, gain and recognition.
9. Peers accepting risk: Associated with a safety culture where risk-taking is normalized and unsafe behaviour is considered an inherent part of the job.

RISK FACTORS: RESPONSE PLANNING

Risk response planning varies across facilities, as response strategies are highly dependent on factors such as the layout of the facility, nature of work, construction processes, type and conditions of equipment, composition and training of the crew, and safety culture within the organization, among others. Based on the identified risk factors, the Case Company implemented various programs to address the safety incidents.

1. The Case Company initiated a series of safety workshops to educate workers on the factors influencing risk tolerance. By understanding the underlying factors, the aim was to reduce workers’ risk tolerance and, in turn, reduce the safety incidents.
2. The Case Company management holds frequent meetings under the GROW program to improve the safety in and around the Facility. Under the GROW program, for example, one of the completed initiatives was to develop a plan for anchor points installed on floor panels that is cost-effective and meets CSA Standard Z259.17.
3. The Case Company provided Manufacturers’ Health and Safety Association (MHSA) training for crews involved in lifting roof trusses. Two staff members were certified as MHSA instructors and subsequently delivered training to other workers on an as-needed basis.
4. The Case Company implemented a Green Hat program in which all new employees are required to wear green hats for their first three months, making them easily identifiable.
5. All the employees underwent mandatory training on the use of small tools, with particular emphasis on nail guns. The Case Company ensured that all the nail guns are equipped with full sequential triggers, a requirement that also applies to on-site contractors.

CONCLUSION

This paper explored the risk factors associated with a lean wood-framing prefabrication facility. The data collected was drawn from the in-house documentation maintained by the Case Company. Risk factors were analyzed from multiple perspectives, including severity of incidents, mode of injuries, mechanism of injuries, and location of injuries. This multi-dimensional approach enabled the research team to identify trends associated with the risk

factors in a lean wood-framing prefabrication facility. The analysis identified nine key risk factors that impact the risk tolerance of the workers. To mitigate these risk factors, the Case Company organized a series of workshops aimed at educating workers on these risk factors. The intent was to reduce the workers' tolerance for the identified risk factors and create a safer work environment. In addition to the workshops, Case Company implemented measures to reinforce the leadership role of management in strengthening the safety culture within the company. As a result, management increased the frequency of regular meetings to review and implement the safety initiatives within the company. The research team anticipates that the outcomes of this study can serve as guidelines to address the risk factors in similar wood-framing prefabrication facilities.

REFERENCES

- Abdul Nabi, M., & El-Adaway, I. H. (2021). Understanding the key risks affecting cost and schedule performance of modular construction projects. *Journal of Management in Engineering*, 37(4), 04021023. [https://doi.org/10.1061/\(ASCE\)ME.1943-5479.0000917](https://doi.org/10.1061/(ASCE)ME.1943-5479.0000917)
- Associated General Contractors (AGC). (2024, September 4). *The Economic Impact of Construction in the United States and Connecticut*. https://www.agc.org/sites/default/files/users/user21902/CT-US%20construction%20fact%20sheet_2025_V2.pdf
- Association of Workers' Compensation Boards of Canada (AWCBC). (n.d.). *KSM-Year at a Glance*. Retrieved January 01, 2026. <https://awcbc.org/data-and-statistics/key-statistical-measures/ksm-year-at-a-glance>
- Bashir, A. M., Suresh, S., Proverbs, D., & Gameson, R. (2011). A critical, theoretical, review of the impacts of lean construction tools in reducing accidents on construction sites. In *Proceedings of 27th Annual ARCOM Conference, Bristol, UK, Association of Researchers in Construction Management* (pp. 5–7).
- Bekdik, B. (2017). *Improving Productivity in Building Construction – by Repetitions in Products, Processes, and Organisations*. DTU Management. https://orbit.dtu.dk/files/145967313/Baris_Bekdik_PhD_Thesis_20170303_1_.pdf
- Blismas, N., Pasquire, C., & Gibb, A. (2006). Benefit evaluation for off-site production in construction. *Construction Management and Economics*, 24(2), 121–130. <https://doi.org/10.1080/01446190500184444>
- Canadian Construction Association (CCA). (n.d.). *Value of the Industry*. <https://www.cca-acc.com/about-us/value-of-industry/>
- Choi, J.O. (2014). *Links between modularization critical success factors and project performance*. Ph.D. Dissertation. The University of Texas at Austin. <https://repositories.lib.utexas.edu/items/40703c78-8bec-46af-893e-9753f5f1a8a8>
- Choi, J.O., Chen, X. B., & Kim, T. W. (2019). Opportunities and challenges of modular methods in dense urban environment. *International Journal of Construction Management*, 19(2), 93–105, 2019. <https://doi.org/10.1080/15623599.2017.1382093>
- Christian Labour Association of Canada (2024, February 20). *Why Are Construction Workers Dying?* Retrieved January 01, 2026. <https://www.clac.ca/Your-voice/Article/why-are-construction-workers-dying>
- Construction Industry Institute (CII). (2011). *Transforming modular construction for the competitive advantage through the adaptation of shipbuilding production processes to construction*. CII. <https://www.construction-institute.org/transforming-modular-construction-for-the-competitive-advantage-through-the-adaptation-of-shipbuildi>
- Fard, M. M., Terouhid, S. A., Kibert, C. J., & Hakim, H. (2017). Safety concerns related to modular/prefabricated building construction. *International Journal of Injury Control and Safety Promotion*, 24(1), 10–23. <https://doi.org/10.1080/17457300.2015.1047865>

- Ikuma, L. H., Nahmens, I., & James, J. (2011). Use of safety and lean integrated kaizen to improve performance in modular homebuilding. *Journal of Construction Engineering and Management*, 137(7), 551–560.
- Innella, F., M. Arashpour, and Y. Bai. (2019). Lean methodologies and techniques for modular construction: Chronological and critical review. *Journal of Construction Engineering and Management*, 145(12), 04019076. [https://doi.org/10.1061/\(ASCE\)CO.1943-7862.0001712\(open in a new window\)](https://doi.org/10.1061/(ASCE)CO.1943-7862.0001712(open in a new window)).
- James, J., Ikuma, L. H., Nahmens, I., & Aghazadeh, F. (2012). Influence of lean on safety risk exposure in modular homebuilding. In *IISE Annual Conference. Proceedings* (p. 1). Institute of Industrial and Systems Engineers (IISE).
- Jeong, G., Kim, H., Lee, H. S., Park, M., & Hyun, H. (2022). Analysis of safety risk factors of modular construction to identify accident trends. *Journal of Asian Architecture and Building Engineering*, 21(3), 1040–1052. <https://doi.org/10.1080/13467581.2021.1877141>
- Khan, M., Gbiengu, P., Zhang, Z., Nnaji, C., & Namian, M. (2024). Modular construction safety risk mitigation. *Proceedings of 60th Annual Associated Schools*, 5, 193–201.
- Koskela, L. (1992). *Application of the New Production Philosophy to Construction* (Vol. 72, No. 39, pp. 0724-30017). Stanford: Stanford University.
- Liu, Q., Ye, G., & Feng, Y. (2020). Workers' safety behaviors in the off-site manufacturing plant. *Engineering, Construction and Architectural Management*, 27(3), 765–784. <https://doi.org/10.1108/ECAM-03-2019-0136>
- Modular Building Institute. (2019). *2019 Permanent Modular Construction Report*. MBI. <https://growthzonecmsprodeastus.azureedge.net/sites/1933/2021/06/2019-PMC-Report-reduced-2e7fbe0c-01af-44ee-970b-ee5f4654fbb2.pdf>
- Nahmens, I., & Ikuma, L. H. (2009). An empirical examination of the relationship between lean construction and safety in the industrialized housing industry. *Lean Construction Journal*, 1–12. <https://doi.org/10.60164/a2g0h2d4b>
- O'Connor, J. T., O'Brien, W. J., & Choi, J. O. (2015). Standardization strategy for modular industrial plants. *Journal of Construction Engineering and Management*, 141(9), 04015026.
- Pervez, H., Ali, Y., Pamucar, D., Garai-Fodor, M., & Csiszárík-Kocsir, Á. (2022). Evaluation of critical risk factors in the implementation of modular construction. *Plos One*, 17(8), e0272448. <https://doi.org/10.1371/journal.pone.0272448>
- PMI. (2024). *Risk Management in Portfolios, Programs, and Projects: A Practice Guide*. Project Management Institute.
- Tucker, S., & Keefe, A. (2025). *2025 Report on Work Fatality and Injury Rates in Canada*. University of Regina. https://www.researchgate.net/publication/390985834_2025_Report_on_Work_Fatality_and_Injury_Rates_in_Canada
- U.S. Bureau of Labor Statistics. (n.d.). *Number and Rate of Fatal Work Injuries, by Private Industry Sector* [Data set]. U.S. Bureau of Labor Statistics. <https://www.bls.gov/charts/census-of-fatal-occupational-injuries/number-and-rate-of-fatal-work-injuries-by-industry.htm>
- Vithanage, S.C., Sing, M., Davis, P., & Pillay, M. (2022). Systematic review on the identification of safety risks in off-site manufacturing (OSM). *Journal of Engineering, Design and Technology*, 20(4), 935–964, <https://doi.org/10.1108/JEDT-12-2020-0498>
- Wu, X., Yuan, H., Wang, G., Li, S., & Wu, G. (2019). Impacts of lean construction on safety systems: A system dynamics approach. *International Journal of Environmental Research and Public Health*, 16(2), 221.
- Wuni, I. Y., Shen, G. Q., & Mahmud, A. T. (2022). Critical risk factors in the application of modular integrated construction: A systematic review. *International Journal of*

- Construction Management*, 22(2), 133–147.
<https://doi.org/10.1080/15623599.2019.1613212>
- Zohourian, M., Pamidimukkala, A., Kermanshachi, S., & Almaskati, D. (2025). Modular construction: A comprehensive review. *Buildings*, 15(12), 2020.
<https://doi.org/10.3390/buildings15122020>