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IMPACTS OF PREFABRICATION ON CONSTRUCTION WORKERS' WELLBEING: A CASE STUDY

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ABSTRACT

The Industrial Revolution had lasting impacts on our social structures as well as on the built environment. The paradigm shift from a mostly agrarian society dominated by agricultural activities outdoors within a rural setting to working in an indoor environment within an urban setting has radically changed the way of life for individuals, families, and communities around the world. However, until recently, industrialization had not transformed the construction sector to the extent that is had other industrial sectors. Due to advances in modular construction, though, the construction sector is beginning to see transformation, bringing with favourable impacts on the construction workforce. Prefabrication has improved safety in construction; improved the lifestyle of workers by reducing fatigue and short-term and long-term disability claims; lowered the barriers to increased participation of women in the workforce; and enabled those less highly skilled to enter the construction job market. This paper systematically analyzes these trends in reference to a case study of the transformation of a large residential builder from traditional on-site construction to factory-based panelized construction.

KEYWORDS

Industrial Revolution, prefabrication, construction industry, worker well-being, culture and change.

INTRODUCTION

The Industrial Revolution began in the 18th century, driven by mechanization of tools and equipment to advance productivity in manufacturing (Qin et al., 2016). While industrial productivity and safety have increased markedly, though, the effect of industrialization on the construction industry has been more of a trickle than a revolution. Prefabrication in construction, one of the notable effects of the Industrial Revolution, has helped to partially

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address the issues of low productivity, high waste, adverse working conditions, and insufficient quality in construction (Tam et al., 2007). Researchers have also sought to address these inherent issues through the introduction of innovative tools and methods such as Building Information Modeling and Lean Construction (Goyal & Gao, 2018; Feldmann, 2022).

The majority of the research efforts related to prefabrication and lean construction have been focused on technical aspects, while the social impact of prefabrication and lean construction on worker wellbeing is under explored. This paper presents a portion of a broader research study that seeks to address these gaps by analyzing the extent to which prefabrication has (a) improved worker wellbeing in construction (using frequency and severity of safety incidents reported as the metric; (b) lowered the barriers to increased participation of women in the workforce; and (c) enabled those less highly skilled to enter the construction job market. Based on the analysis of the data collected, this research offers first-hand insights into the beneficial effects of prefabrication on workers.

This paper focuses on the first social domain identified as part of the broader study—worker wellbeing. This involved systematically analyzing safety incidents at a case construction prefabrication facility in Canada. This included detailed analysis of the nature of safety incidents for different prefabrication crews. Based on this analysis, prefabrication processes were optimized to reduce the number of safety incidents.

LITERATURE REVIEW

The Industrial Revolution had many beneficial effects on industry and society. Among these have been increased wealth, production output, and standard of living (Muhammad & Yew, 2018). In terms of standard of living, trends brought about by industrialization have included healthier diets, better housing, and more affordable goods. Moreover, opportunities have changed for women with regards to their work (Vaidya et al., 2018). Industrialization led to the shift from the manual labor of the artisan shop to the machine labor of the mechanized factory (Atack et al., 2024). Scholars have identified multiple stages within the broad trend of industrialization. The first Industrial Revolution began in the 1700s with the harnessing of water and steam energy to run machines. The second Industrial Revolution began in the 1870s with the introduction of electrical energy to drive mass production. During this period, the industrial assembly line exponentially increased the production of goods through mechanization (Bahlieda, 2018; Atack et al., 2003). During the 1970s, third Industrial Revolution arrived with rise of electronics and digital automation. The fourth Industrial Revolution, currently underway, is based integration of information technology connecting people seamlessly with the world around them. This stage has introduced a higher level of complexity with regard to integrating production processes and products (Alaloul et al., 2020).

The construction industry has been slow in embracing the Industrial Revolution's innovations. Although other industries, such as the manufacturing sector, have achieved increased efficiencies and other benefits as a result of industrialization, the construction industry has held fast in maintaining traditional construction techniques such as building on site with manual labor and tools. However, in recent years the construction industry has begun to adopt innovations well established by other sectors. For example, factory production of building structures such as prefabricated wall and floor panels has emerged. Alongside the advancement of factory construction, there has also been the adoption of manufacturing machines for cutting materials precisely and efficiently. Indeed, digital manufacturing technologies (DMTs) have the potential to transform the construction industry in terms of productivity (Marinescu et al., 2023). Computer numerical control (CNC) machines have provided the means by which for construction activities to be moved into a controlled factory setting to improve quality, safety, and efficiency (Javaid et al., 2021).

Industrialization has had both beneficial and adverse impacts on worker wellbeing. The Industrial Revolution has led to workers being supplanted by machines in some contexts (Jeehee, et al., 2019). On the other hand, it has also introduced new job opportunities for workers. Automation has complemented labor, raised outputs in ways that lead to higher demand for labor, and enhanced the labor market (Autor, 2015). Given these benefits, the construction industry is opening up to the automation of construction processes (Carbonero et al., 2018).

Lean construction focuses on minimizing waste and maximizing value in construction projects. Central to this approach is the idea of continuous improvement, where the aim is to optimize processes and reduce inefficiencies in every phase of construction (Ballard, 2000). As lean principles have evolved, researchers and practitioners have begun to recognize the inherent advantages to worker wellbeing. Worker wellbeing in lean construction refers to the physical, mental, and emotional health of employees, where the goal is to ensure workers are not only productive but also safely engaged in their work. Studies have shown that lean practices can positively influence worker wellbeing by promoting safer and more productive task execution (Eltahan et al., 2024). Lean construction also aims to reduce the stressors often associated with traditional construction practices, such as long hours, unsafe working conditions, and poor job satisfaction (Bjørn et al., 2012). Studies have concluded that improving production through the application of lean principles naturally leads to enhanced worker safety. Moreover, utilizing lean practices provides the ability to “make safety better” (Gambatese & Pestana, 2014).

METHODOLOGY

This paper explores the impacts of prefabrication on the construction workforce. A large residential builder in western Canada, Landmark Homes, which builds approximately 900 residential units annually, was selected as a case study. ACQBUILT, a fully automated wood-framing manufacturing facility was established over 10 years ago to support Landmark Homes’ transition from an on-site stick-frame builder (having operated within that paradigm for over 35 years) to panelized factory construction. The research presented in the paper was based on data collected from the case company. It is part of a larger study undertaken by the research team which consists of three steps:

1. Define a comprehensive set of social domains and indicators related to the impact of construction industrialization on workers (Step 1)
2. Collect data related to the identified social domains and indicators (Step 2)
3. Analyze and interpret the data (Step 3)

ACQBUILT had robust inhouse system to collect and log the data related to process improvement including safety incidents. The data used in this study was drawn from the extensive in-house documentation maintained by the case company.

IDENTIFICATION OF SOCIAL DOMAINS AND INDICATORS

In analyzing the impact of prefabrication on workers, there is a broad range of social domains and indicators to be considered. To identify the relevant social domains and indicators, the research team consulted with personnel from the case company, including R&D staff, the human resource supervisor, and the safety supervisor. The case company’s R&D team is responsible for establishing, maintaining, and optimizing the prefabrication processes and workflow to meet organizational goals (e.g., safety, efficiency). In addition to this, the R&D team works closely with the safety supervisor to modify the plant processes to reduce safety incidents based on systematic studies. The safety supervisor also works closely with the HR supervisor to report any safety incidents to the regulatory bodies.

A preliminary list of indicators having been established based on a review of the literature, the final list of indicators was determined based on the input from the case company's personnel (i.e., the R&D team, HR supervisor, and safety supervisor), primarily via structured interviews. Case company staff were then consulted to identify the important indicators within the each of the identified social domains. The following social domains and indicators were identified:

1. Worker wellbeing: the question explored regarding worker wellbeing is that working in an industrialized environment (e.g., prefabrication shop) is safer for workers. Here the indicator of wellbeing is decreased frequency and severity of workplace safety incidents.
2. Demographics: industrialized construction offers more opportunity to demographic groups that are underrepresented in traditional construction, such as: women, newcomers to Canada, and older adults.
3. Skills: on-site construction requires a higher skill level than does factory construction. If proven correct, it can also be inferred that industrialization helps to reduce the reliance on skilled labor while achieving a similar quality of work.

The scope of this paper is the identification of the relevant social domains and indicators, as well as the collection and analysis of data on the first social domain identified as part of the broader study—worker wellbeing. Questions regarding demographics and skills are explored in next phase of this research.

DATA COLLECTION

Currently, the case company employs a staff of 200+, among which 65% are directly engaged in construction activities. For the purpose of the present study, these construction workers were categorized into two groups: Group 1, which consists of the 55 workers working in the prefabrication plant, and Group 2, which consists of the 53 workers engaged in on-site construction activities (e.g., the assembly of prefabricated components).

The workers in Group 1 have various responsibilities within the prefabrication plant (Figure 1). The "Floors" and "Walls" crew builds floor and wall panels using various machines and hand tools. "Windows and Doors" workers install windows and doors in the wall panels. The "Manual Build" crew manually builds components such as decks, stairs, columns, and tall walls. Finally, the "Roofing" workers manually build the panelized roofs using engineered truss packages.

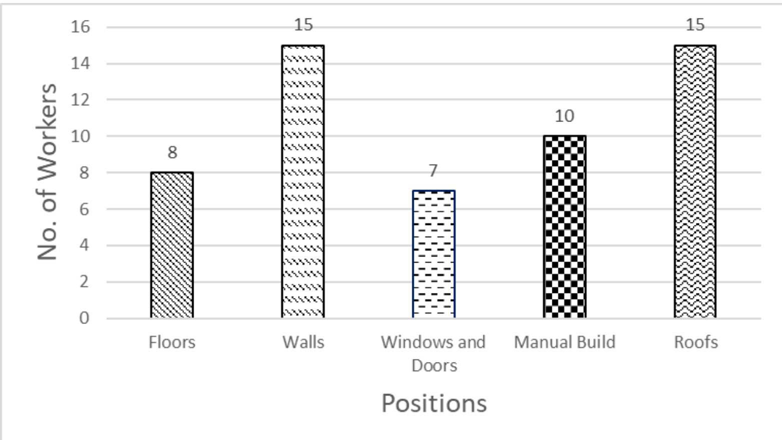

Figure 1: Distribution of workforce in case prefabrication plant (Group 1)

Group 2 workers can be subdivided into one of two subcategories (Figure 2). The "Assembly" crew is responsible for installing the prefabricated panels from the factory on site, while the

"Stick Framing" crew (employed by the sister company) manually builds houses from the ground up with material delivered to the site.

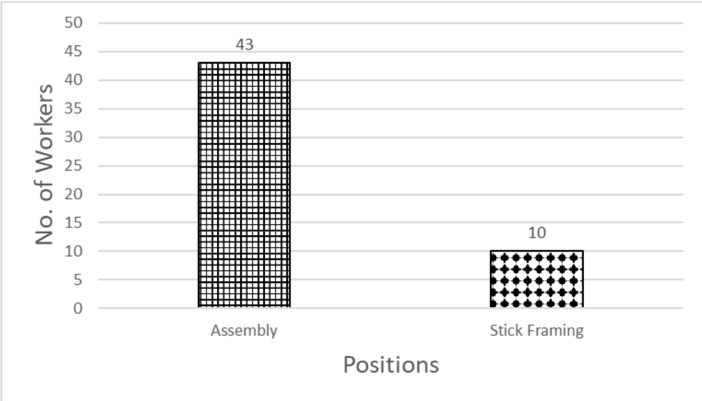

Figure 2: Distribution of workforce on site (Group 2)

Data used in this analysis was collected over a period of three years (2020–2022). During this period, a total of 394 safety incidents were reported by construction workers. Among these, 94 incidents reported by 'Office', 'Logistics', 'Loading', and 'Material Handling' personnel were excluded from the study, as these workers support both study groups (i.e., both Group 1 and Group 2). Moreover, 95 incidents related to 'Property Damage' and 'Motor Vehicle Accidents' were excluded, as they were deemed to be irrelevant to the question being tested. As it is possible that one study group may have put in a greater number of hours than the other, it is relevant to mention that the analysis is based on percentages. Data was collected for both groups and comparative analysis was performed. By studying the deviations in the trends for both groups, inferences were made regarding how prefabrication affects worker wellbeing.

ANALYSIS

This section discusses the results and findings related to the effect of prefabrication on construction workers' wellbeing. This study considered the key indicators of wellbeing identified by the research team in consultation with case company personnel. In specific, the indicators considered were safety incidents (i.e., the number and nature of health and safety incidents reported) and disability measures.

INCIDENTS ACROSS STUDY GROUPS

In terms of absolute numbers, it can be seen that Group 1 (workers at the prefabrication shop) reported 156 incidents against 109 incidents for Group 2 (workers on construction sites). This discrepancy can be attributed to the greater total number of hours worked by Group 1, leading to a higher number of incidents. Moreover, looking at the breakdown of incidents by severity (Figure 3), it can be seen that the incidents reported by Group 1 were generally less severe. For example, for Group 1, only 35% of incidents required 'Medical Aid', whereas, for Group 2, 60% of incidents required 'Medical Aid'. First aid refers to care that can be provided in-house whereas medical aid refers to cases that warrant outside medical care (clinic or hospital). It can thus be inferred that the prefabrication shop provides a safer work environment by reducing the rate of severe injuries, thus positively contributing to the wellbeing of construction workers.

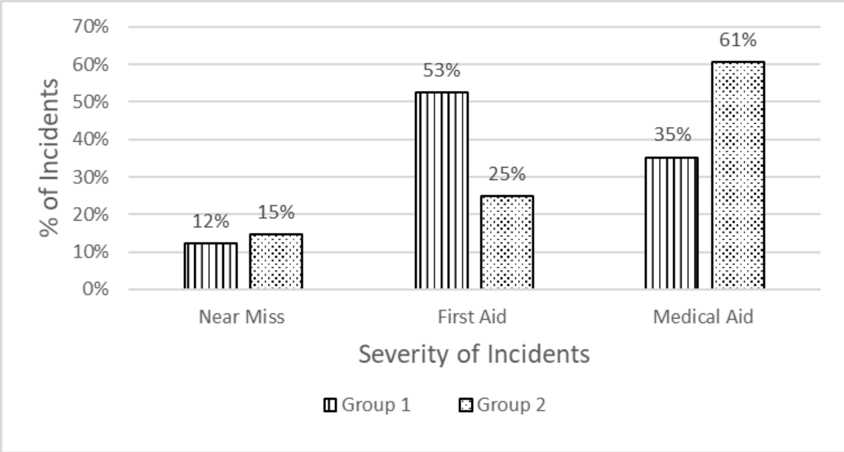

Figure 3: Severity of incidents across the study groups

INCIDENTS BY JOB DESCRIPTION

Incidents in Group 1 (prefabrication shop) were studied in detail to better understand the trends (Figure 4). It was observed that workers engaged in the assembly of prefabricated wall panels had the highest numbers of safety incidents. In terms of absolute numbers, there were 32 instances of workers requiring first aid, and 21 instances of workers requiring medical aid. Incidents involving this subcategory of workers accounted for 37% of total injuries in the prefabrication shop. This was followed by the roofing crew at 21% (15 first aid and 14 medical aid), and the floor crew at 19% (13 first aid and 13 medical aid).

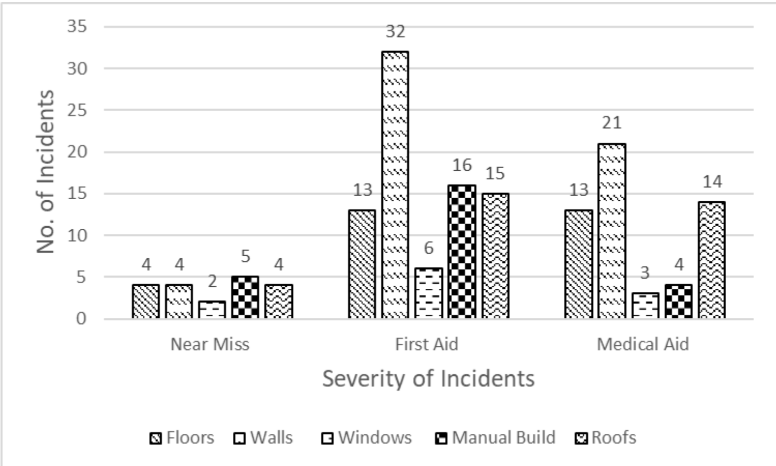

Figure 4: Breakdown of incidents based on severity and crew (Group 1)

Group 1 incident reports were also analyzed to identify whether certain activities were correlated with certain kinds of injuries (Figure 5). For the crew working on the assembly of wall panels, workers were most susceptible to injuries due to 'overexertion', being 'struck by' objects and being 'crushed' between objects. For the wall panel crew, bruising and sprains were found to be the most commonly occurring type of injuries. The roofing crew was most susceptible to injuries due to falls, being 'struck by' objects and 'overexertion'. For the roofing crew, sprains/strains were the most commonly occurring type of injuries. The floor panel crew was the subcategory of workers that sustained the most injuries by being 'struck by' objects. For the floor panel crew, bruising, puncture, and sprain were found to be the most commonly occurring type of injuries.

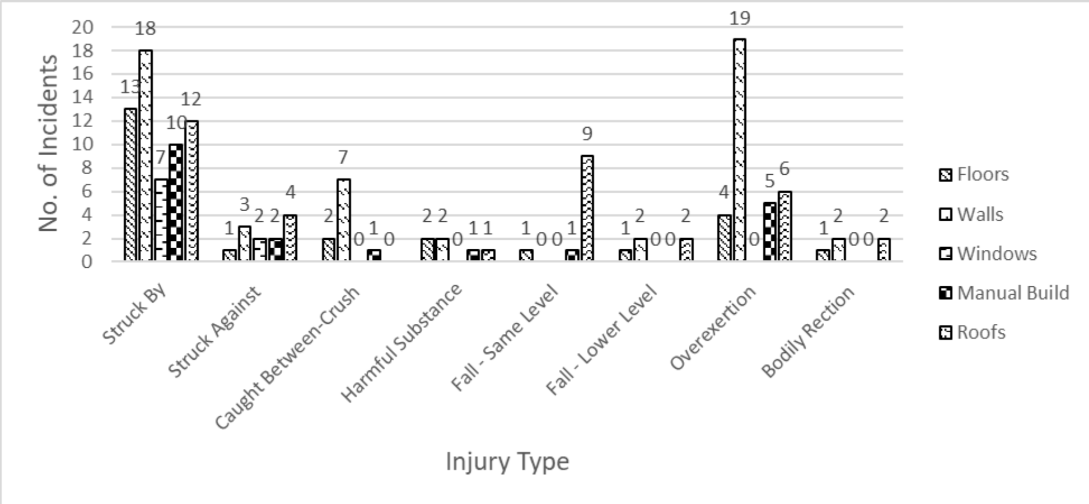

Figure 5: Distribution of injury types by work positions (Group 1)

It should be noted that no data was recorded for Group 2 (on-site workers) that classified the severity of incidents based on job description.

INCIDENTS BY MECHANISM OF INJURY

These workplace incidents were further analyzed to understand the mechanism of the injuries requiring first aid and medical aid (Figure 6). Approximately 48% of total injuries in Group 1 and 42% of total injuries in Group 2 were found to be related to being 'struck by' a moving object.

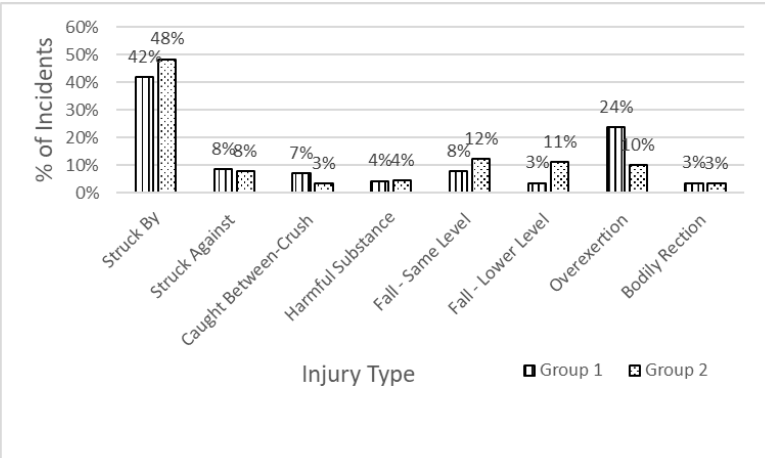

Figure 6: Distribution of injury type by group (Group 1 versus Group 2)

Figure 7 and Figure 8 show the 'nature' and 'location', respectively, of these injuries due to being 'struck by' a moving object. As can be seen, the two groups showed similar trends regarding the nature and location of injuries. But 67% of the total injuries resulted in bruising/contusion and puncture. Approximately 55% of the total injuries are sustained on fingers and hand. 23% of the injuries are sustained on the lower body parts.

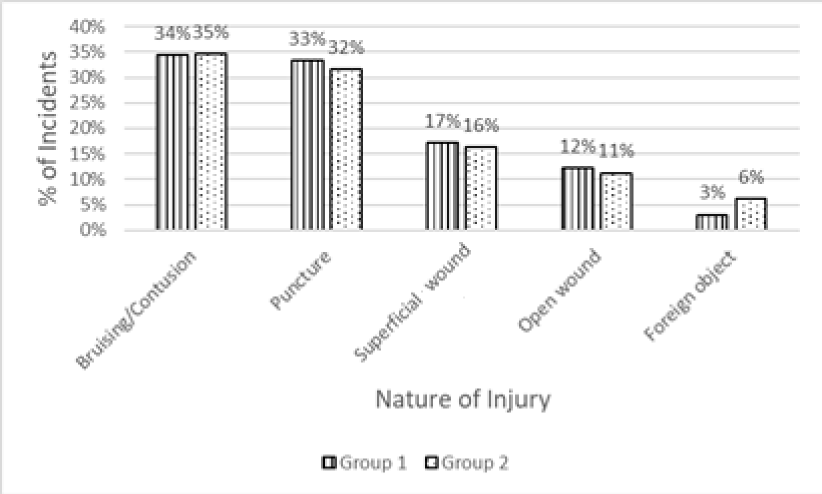

Figure 7: Nature of injuries due to workers being 'struck by' moving entities

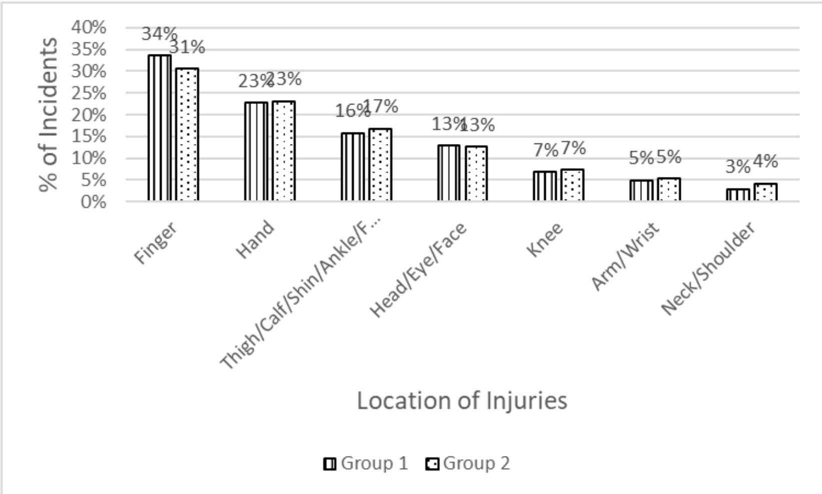

Figure 8: Location of injuries due to workers being 'struck by' moving entities

Injuries sustained due to 'overexertion' were further investigated, with the analysis revealing that Group 1 workers were more prone to injuries related to 'Overexertion' compared to Group 2 workers (24% versus 10% of total injuries, respectively). This observation runs counter to the hypothesis (proposed above) that working in an indoor environment reduces fatigue-related issues. Based on further discussions with case organization, it was concluded that, in the prefabrication shop, workers are exposed to repetitive motions, hence the higher incidence of injuries related to overexertion.

Detailed records of the 'overexertion' injuries were examined, and data was organized and summarized to shed light on the nature and location of the injuries. As presented in Table 1, it was observed that very frequently 'overexertion' injuries resulted from some kind of strain: 59% of the total 'overexertion' injuries were due to lower-back strain, followed by upper-back strain at 14%.

Table 1: Nature of injuries due to 'Overexertion' in Group 1

Hand Strain	Upper Back Strain	Lower Back Strain	Shoulder Strain	Neck Strain	Wrist Strain	Ankle/Knee Strain
5%	14%	59%	7%	2%	9%	5%

For Group 2 (on-site workers), the analysis revealed that 48% of total injuries were due to workers being stuck by moving objects. Group 2 workers were also more prone to fall-related injuries, with 23% of injuries in Group 2 being related to falling incidents (as compared to 12% fall-related injuries in Group 1).

CONCLUSION

This paper explored the impact of prefabrication on construction workers' wellbeing. For this purpose, safety incident data associated with two study groups was analyzed. The data collected was drawn from the extensive in-house documentation maintained by the case company. The research team worked with the case company to compile the incident reports in a database for mining and analysis using descriptive data analysis tools. The analysis confirmed that working in a controlled environment, in this case a prefabrication shop, significantly reduced the severity of safety incidents. Specifically, it was observed that approximately one-third of the prefabrication shop incidents required medical aid, whereas two-thirds of on-site incidents required medical aid.

This study also identified opportunities to reduce incidents in the prefabrication shop environment, thereby further improving the wellbeing of construction workers. For example, the data analysis underscored the need to reduce injuries associated with 'overexertion' and with being 'struck by' objects. To mitigate overexertion, the case company implemented job rotation for some of the crews, while, to mitigate the latter injury type, the case company is exploring the benefits of mandating the use of additional personal protective equipment for the hands. Given that crews working on the prefabrication of wall panels were found to have sustained the greatest number of injuries, the case company is considering introducing equipment to assist the lifting of prefabricated wall panels (to reduce incidents related to lower-back strain). A review of the case company's work practices/culture was also conducted to identify any unintended adverse impacts on workers (e.g., over-emphasis on efficiency leading to burnout and reduced morale). Based on this findings, it can be inferred that use of prefabrication with a focus on worker safety can lead to, improved job satisfaction, and long-term sustainability in construction. In future work, interviews and surveys will be designed to collect data on the other social domains and indicators identified.

REFERENCES

Alaloul, W. S., Liew, M. S., Zawawi, N. A. W. A., & Kennedy, I. B. (2020). Industrial Revolution 4.0 in the construction industry: Challenges and opportunities for stakeholders. *Ain Shams Engineering Journal*, *11*(1), 225–230. https://doi.org/10.1016/j.asej.2019.08.010.

Atack, J., Bateman, F., & Margo, R. A. (2003). Productivity in manufacturing and the length of the working day: evidence from the 1880 census of manufactures. *Explorations in Economic History*, *40*(2), 170–194. https://doi.org/10.1016/S0014-4983(03)00016-0.

Atack, J., Margo, R. A., & Rhode, P. W. (2024). De-skilling: Evidence from late nineteenth century American manufacturing. *Explorations in Economics History*, *91*, 101554. https://doi.org/10.1016/j.eeh.2023.101554

Autor, D. H. (2015). Why are there still so many jobs? The history and future of workplace automation. *Journal of Economic Perspective*, *29*(3), 3–30. https://doi.org/10.1257/jep.29.3.3

Bahlieda, R. (2018). *The Economic Gulag: Patriarchy, Capitalism, and Inequality*. Peter Lang Inc.

Ballard, G. (2000). *The Last Planner System of Production Control.* (Publication No. 4789) [Ph.D. dissertation, University of Birmingham]. https://etheses.bham.ac.uk/id/eprint/4789/1/Ballard00PhD.pdf

Bjørn, A., Belay, A. M., & Seim, E. A. (2012). Construction practices and its effects: A case study at St. Olav's Integrated Hospital, Norway. *Lean Construction Journal*, 2012, 122–149.

Carbonero, F., Ernst, E., & Weber, E. (2018). Robots worldwide: the impact of automation on employment and trade. *ILO Research Department Working Paper #36.* Retrieved January 2, 2025, from https://www.ilo.org/publications/robots-worldwide-impact-automation-employment-and-trade

Eltahan, A., Shehab, L., & Hamzeh, F. (2024). Driving the momentum towards adopting wearable cognitive assistance in Lean Construction 4.0. *Proceedings of the 32nd Annual Conference of the International Group for Lean Construction*, pp. 1182–1194. doi.org/10.24928/2024/0182

Feldmann, F. G. (2022). Towards lean automation in construction—Exploring barriers to implementing automation in prefabrication. *Sustainability*, *14*(19), 12944. https://doi.org/10.3390/su141912944

Gambatese, J., & Pestana, C. (2014). *Connection between Lean Design/Construction and Construction Worker Safety.* CPWR – Center for Construction Research and Training. https://www.cpwr.com/wp-content/uploads/publications_GambateseLeanandSafetyFinalReport-1.pdf

Goyal, M., & Gao, Z. (2018). Integration of building information modeling (BIM) and prefabrication for lean construction. *Proceedings of the International Conference on Construction and Real Estate Management*, pp. 78–84. https://doi.org/10.1061/9780784481721.009

Javaid, M., Haleem, A., Singh, R. P., & Suman, R. (2021). Substantial capabilities of robotics in enhancing industry 4.0 implementation. *Cognitive Robotics*, *1*, 58–75. https://doi.org/10.1016/j.cogr.2021.06.001

Jeehee, M., Yangwoo, K., Sujin, L., Tae-Won, J., Inah, K., & Jaechul, S. (2019). The fourth industrial revolution and its impact on occupational health and safety, worker's compensation and labor conditions. *Safety and Health at Work*, *10*(4), 400–408. https://doi.org/10.1016/j.shaw.2019.09.005

Muhammad, M. B., & Yew, R. A. A. (2018). Socio–economic effects of industrialization in the Society. *International Journal of Environment, Ecology, Family and Urban Studies*, *8*(4), 23–30.

Marinescu, A., Argyle, E. M., Duvnjak, J., Wilson, M. L., Lawson, G., Sharples, S., Hubbard, E., & Justham, L. (2023). The future of manufacturing: Utopia or dystopia? *Human Factors and Ergonomics in Manufacturing & Service Industries*, *33*(2), 184–200. https://doi.org/10.1002/hfm.20976

Qin, J., Liu, Y., & Grosvenor, R. (2016). A categorical framework of manufacturing for industry 4.0 and beyond. *Procedia CIRP*, *52*, 173–178. https://doi.org/10.1016/j.procir.2016.08.005

Tam, V. W. Y., Tam, C. M., Zeng, S. X., & Ng, W. C. Y. (2007) Towards adoption of prefabrication in construction. *Building and Environment*, *42*(10), 3642–3654. https://doi.org/10.1016/j.buildenv.2006.10.003

Vaidya, S., Ambad, P., & Bhosle, S. (2018). Industry 4.0–a glimpse. *Procedia Manufacturing*, 20, 233–238. https://doi.org/10.1016/j.promfg.2018.02.034