

# IDENTIFICATION OF CONSTRUCTION LABOR PRODUCTIVITY FACTORS (CLP) IN MASS TIMBER BUILDING PROJECTS

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**ABSTRACT:** Mass timber is a sustainable building material gaining popularity in the U.S. construction industry as an alternative to conventional materials like concrete and steel. The growth in mass timber projects reflects its recognized benefits, including structural performance, construction speed, environmental sustainability, and aesthetic appeal. However, productivity challenges unique to mass timber construction remain underexplored, especially factors impacting construction labor productivity (CLP). This paper aims to fill this gap by identifying and ranking key factors affecting CLP in mass timber projects from the perspective of U.S. construction professionals. Through a literature review and a survey of construction professionals, this study evaluates productivity factors and ranks them using the Relative Importance Index (RII). Findings reveal that project management factors are the most significant in influencing CLP in mass timber projects, followed by safety factors, materials and equipment factors, labor factors, and environmental factors. Within these categories, critical individual factors include collaboration and communication among project parties, adequacy of planning and risk management, labor supervision, design complexity, assembly system, and change orders. Addressing these aspects could enhance labor productivity, reduce timelines, and improve overall project efficiency. This research not only highlights critical areas for improvement but also supports the broader adoption of mass timber as a viable alternative in the U.S. construction industry.

## 1. INTRODUCTION

Mass timber has emerged as a sustainable and efficient alternative to conventional materials like concrete and steel, gaining traction in the U.S. construction industry. Its advantages include reduced carbon footprint, faster construction timelines, and aesthetic appeal (Ahmed and Arocho 2021; Younis and Doodoo 2022). However, productivity factors unique to mass timber construction remain underexplored, particularly in relation to construction labor productivity (CLP). Understanding the factors influencing CLP in mass timber projects is crucial for optimizing labor efficiency and ensuring project success. This paper aims to identify and rank key factors affecting CLP through a literature review and a survey of construction professionals.

## 2. LITERATURE REVIEW

### 2.1 Mass Timber Building Materials

Mass timber refers to a category of engineered wood products that are used in the construction of buildings and structures. It is an innovative, strong, low-carbon, and sustainable alternative to concrete and steel

(Think Wood, 2023). Mass timber products are created by bonding layers of wood together to form large, solid panels or beams.

There are several types of mass timber products commonly used in construction (Think Wood, 2023):

1. Cross-laminated timber (CLT): CLT is made by stacking alternating layers of lumber boards at right angles and gluing them together. This creates a rigid and stable panel with exceptional strength and dimensional stability. CLT panels are often used for buildings' walls, floors, and roofs.
2. Glued laminated timber (glulam): Glulam is produced by bonding together smaller pieces of lumber with structural adhesives. It is typically used to create large, curved, or straight beams and columns that provide strength and aesthetic appeal.
3. Nail-laminated timber (NLT) is a type of mass timber made by stacking multiple layers of wood face to face and connecting them with nails. Unlike CLT, NLT panels can be assembled on or near the construction site, providing flexibility and convenience in the construction process.
4. Dowel-laminated timber (DLT): DLT is similar to NLT but uses wooden dowels instead of adhesives to bond the layers of lumber. This construction method enhances the aesthetic appeal and allows for easy disassembly and reassembly of panels.

## **2.2 Construction Labor Productivity (CLP)**

Construction productivity, as defined by the output of work per labor hour, is a critical aspect of any construction project, as it directly impacts project schedules, costs, and overall project success. The construction industry is a labor-intensive sector. It relies heavily on manual work and skilled labor to carry out various tasks involved in building, renovating, and maintaining structures. Construction projects typically require a diverse workforce, including carpenters, masons, electricians, plumbers, heavy equipment operators, laborers. Labor productivity accounts for 30 to 50% of the cost of overall construction projects during construction phase (Hanna 2001). Improving productivity in the construction industry has been an ongoing challenge, and understanding the factors that influence productivity is essential for effective project management and performance.

## **2.3 Factors Affecting Construction Labor Productivity**

Numerous studies have been conducted to identify and understand the factors that influence CLP in various construction contexts. This literature review examines several key studies that have investigated the factors affecting CLP in different regions. It's important to emphasize that none of these studies specifically focus on mass timber construction; rather, they were conducted on the traditional building materials in different countries.

Lim and Alum (1995) conducted a study in Singapore and identified 17 factors that influence construction productivity. These factors were categorized into three groups: manpower, environment, and management. Rojas and Aramvareekul (2003) study the factors affecting construction labor productivity in the USA construction industry and identified 18 factors. These factors were classified into four categories: (1) Management Systems and Strategies, (2) Manpower, (3) Industry Environment, and (4) External Conditions. Abdul Kadir et al. (2005) focused on Malaysian residential projects and identified 50 factors affecting CLP. Enshassi et al. (2007) presents 45 factors that have a negative impact on construction labor productivity in Palestine construction industry. These factors were divided into ten groups: manpower, leadership, motivation, time, materials/tools, supervision, project, safety, quality, and external factors. Alinaitwe et al. (2007) studied the factors affecting CLP in Uganda's building industry. A total of 36 factors were identified and ranked by project managers that affect productivity in relation to time, cost, and quality. Kazaz et al. (2008) investigated the factors impacting construction productivity in Turkey. They identified 37 factors categorized into four groups: organizational, economic, physical, and socio-psychological.

Jarkas and Bitar (2012) examined the factors affecting CLP in Kuwait and identified 45 factors classified into four groups: technological, human/labor, management, and external. El-Gohary and Aziz (2014) identified 30 factors influencing CLP in Egypt. These factors were categorized into three groups:

management, human/labor, and industry. Naoum (2016) explored CLP factors in the UK construction industry, categorizing them into four groups: pre-construction, organizational, during construction, and motivational and social. Sen and Verma (2018) studied the factors affecting CLP in the Indian construction industry. He divided the factors into 9 groups: workforce, management team, psychological, schedule compression, material/equipment, supervision, safety, miscellaneous, and external. Hai and Tam (2019) conducted a study in Vietnam and identified 43 factors affecting CLP. These factors were categorized into eight groups, including operation and management, tools and objects, labor conditions, safety, workers, motivation, working time, and environment.

Table 1 summarizes the above studies including the study's country, number of factors investigated, and the major factors affecting CLP based on their Relative Importance Index (RII), which is a quantitative measure used to rank the relative importance of various factors based on their perceived importance by respondents.

Table 1: Literature Summary of the Factors Affecting Construction Labor Productivity

| Study                         | Country   | Number of Studied Factors | Major Factors Affecting CLP based on their RII   |
|-------------------------------|-----------|---------------------------|--|
| (Lim and Alum 1995)           | Singapore | 17                        | Difficulty in recruitment, high labor turnover, absenteeism, communication problems with foreign workers, Inclement weather, health issues, materials shortages, alcoholism, disruption of power/water supplies.   |
| (Rojas and Aramvareekul 2003) | USA       | 18                        | Management skills, scheduling, material and equipment management, and quality control, worker experience, specific activity training, education, motivation, and seniority.  |
| (Abdul Kadir et al. 2005)     | Malaysia  | 50                        | Material shortages, non-payment to suppliers, change orders, late issuance of construction drawings, lack of foreign and local workers, coordination problems with subcontractors, equipment shortages.  |
| Enshassi et al. (2007)        | Palestine | 45                        | Material shortages, lack of labor experience, lack of labor surveillance, misunderstanding between labor and superintendents, drawings and specifications alteration during execution, payment delay, labor disloyalty, inspection delay, working 7 days per week without taking a holiday, tool and equipment shortage.   |
| (Alinaitwe et al. 2007)       | Uganda    | 36                        | Incompetent supervisors, Lack of skills of the workers, Rework (e.g., poor work done), Lack of tools/equipment, poor construction method (e.g., poor sequencing of work items), Poor communication (e.g. inaccurate instructions, inaccurate drawings), Stoppages because of work being rejected by consultants, Political insecurity (e.g. insurgency, wars), Tools/equipment breakdown, Harsh weather conditions |
| (Kazaz et al. 2008)           | Turkey    | 37                        | Quality of site management, material management, on-time payment, systematic flow of work, supervision, site layout, work discipline, amount of pay, occupational education and training, working at similar activities.   |
| (Jarkas and Bitar 2012)       | Kuwait    | 45                        | Clarity of technical specifications, variation/change orders, coordination among design disciplines, lack of labor supervision, design complexity, subcontracting proportion, lack of incentive schemes, leadership of construction managers, stringent inspection, delay in responding to requests for information.   |
| (El-Gohary and Aziz 2014)     | Egypt     | 30                        | Incentive programs, leadership and competency of construction management, labor supervision competency, laborer experience and skill, availability of materials, construction technology, planning and workflow, constructability, clarity of instructions   |
| (Naoum 2016)                  | UK        | 46                        | Ineffective project planning, design errors, variation orders, communication system, work environment, constraints on worker performance, design and buildability-related issues, management/leadership style, procurement method, management information system integration, material management.   |
| (Sen and Verma 2018)          | India     | 19                        | Lack of skill and experience of the workers, Late payment, Poor health of the workers, Low amount of pay, Lack of empowerment, Poor work planning, Design changes, Lack of labor safety, Poor condition of equipment/tools, Ignore safety precautions.   |
| (Hai and Tam 2019)            | Vietnam   | 43                        | Worker experience, labor discipline, salary payment methods, organizational ability, quality of building materials, working tool quality, construction supervision, safety equipment, physical ability, height of the working place.   |

### 3. RESEARCH METHODOLOGY

The aim of this research is to identify critical factors affecting CLP in mass timber projects, and then evaluate these factors using the Relative Importance Index (RII) to determine their influence on CLP.

A literature review was conducted to explore and identify factors influencing CLP in the construction industry. Although the reviewed studies did not specifically focus on mass timber, the identified factors were applicable for evaluating their relevance and impact on productivity in mass timber construction. Based on their RII scores, frequency of occurrence in the literature, and relevance to mass timber construction, a list of 20 factors were identified as important and impactful. These factors were categorized into five groups: project management factors, labor factors, materials and equipment factors, environmental factors, and safety factors. Table 2 shows the categories and the factors.

Table 2: Factors Affecting Construction Labor Productivity (CLP) in Mass Timber

| N  | Category                | Factor  |
|----|-------------------------|---|
| 1  | Project Management      | Design complexity level   |
| 2  |                         | Change orders during construction   |
| 3  |                         | Adequacy of planning and risk management process                                    |
| 4  |                         | Assembly system   |
| 5  |                         | Degree of collaboration and communication among project parties during construction |
| 6  |                         | Competency in labor supervision and management                                      |
| 7  | Labor                   | Specialized skills and training of workers  |
| 8  |                         | Physical fatigue experienced by workers   |
| 9  |                         | Workforce absenteeism rate  |
| 10 | Materials and Equipment | The need for specialized equipment  |
| 11 |                         | Handling and transportation of materials and components                             |
| 12 |                         | Construction technology (construction method and material)                          |
| 13 |                         | Limited availability of mass timber products  |
| 14 | Safety                  | Work at heights and associated safety considerations                                |
| 15 |                         | Site safety measures and practices  |
| 16 |                         | Accidents resulting from poor safety program implementation                         |
| 17 |                         | High/low temperature conditions on-site   |
| 18 | Environmental           | High humidity levels on-site  |
| 19 |                         | Rain  |
| 20 |                         | High wind   |

#### 3.1 Survey Design

A survey questionnaire was designed to ask construction professionals to evaluate the importance of the identified factors. The survey questionnaire was designed using the Qualtrics platform including questions on demographic information and factor assessment. The demographic information includes job title, company's / organization's line of business, years of experience in the construction industry and in mass timber construction, company size, involvement in mass timber projects, and regions where participants worked in on mass timber projects. The RII was employed to rank the identified factors. Participants were asked to rate each factor's importance to CLP in mass timber using a Likert scale of 1 to 5, where 1 is "Not important" and 5 is "Very important."

#### 3.2 Data Collection and Analysis

The survey questionnaire was distributed to construction professionals involved in mass timber projects in the US construction industry. Construction professionals contacts were obtained from different sources

including Woodworks Innovation Network website and company websites. The survey was distributed through the Qualtrics platform, followed by frequent reminders. The survey was sent to a total of 460 contacts and the final number of construction professionals successfully received the survey is 401 after excluding the ones who opted-out from the survey, or didn't receive the survey due to hard or soft bounces. Out of the total individuals received the survey, 43 responses were collected after excluding the uncompleted responses (14 responses). Therefore, the total number of participants in this research is 43 out of 401 with a response rate of 10.7%.

The collected data were analyzed using the RII to determine the relative importance of the identified factors affecting CLP in mass timber projects. RII has been used widely in construction research (Abdul Kadir et al. 2005; Alinaitwe et al. 2007; El-Gohary and Aziz 2014; Enshassi et al. 2007; Hai and Tam 2019; Jarkas and Bitar 2012; Kazaz et al. 2008; Lim and Alum 1995; Naoum 2016; Rojas and Aramvareekul 2003; and Sen and Verma 2018) to rank the importance of different factors in affecting CLP based on respondents' perceptions. The Relative Importance Index can be calculated using the following equation (Eq. 1):

$$RII(\%) = \frac{5(n5) + 4(n4) + 3(n3) + 2(n2) + n1}{5(n1 + n2 + n3 + n4 + n5)}$$

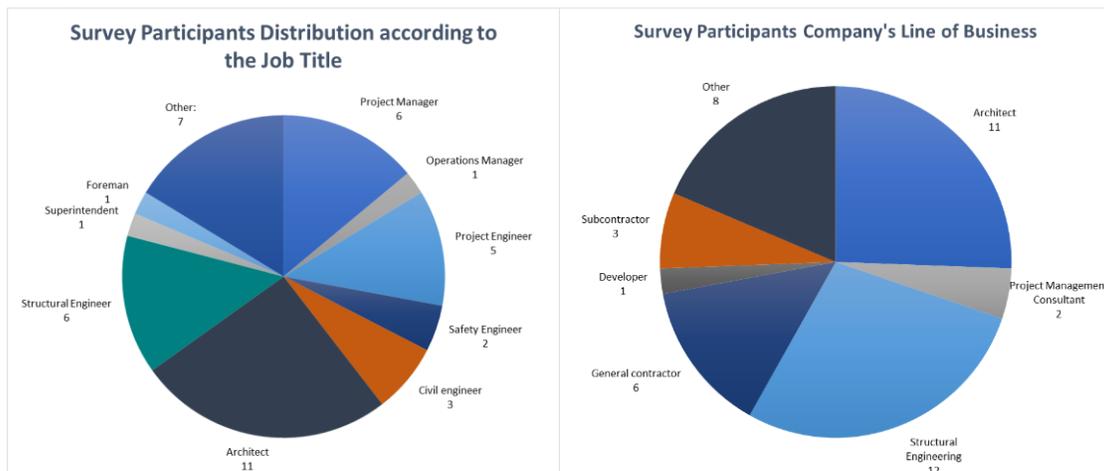
Where n1, n2, n3, n4, and n5 are the number of respondents who selected: 1 for not important; 2 for low important; 3 for neutral; 4 for important; and 5 for very important, respectively.

#### 4. RESULTS AND DISCUSSION

This section provides the results from the survey distributed to construction professionals involved in mass timber in the US construction industry. It starts by presenting the demographic information of participants, followed by the analysis of the factors affecting CLP in mass timber.

##### 4.1 Demographic Information

The survey participants represent diverse roles within the construction industry as shown in Figure 1. The most common job titles are Architects (25.6%), followed by Project Managers and Structural Engineers (14% each). Other roles include Project Engineers, Civil Engineers, Safety Engineers, and various specialized positions. Regarding the company's line of business, the most represented sectors are Structural Engineering (28%) and Architecture (25%). Other industries include Engineering Consulting, Life Safety Consulting, and General Engineering. Participants' experience in the construction industry varies widely. As shown in Figure 2, the majority have over 20 years of experience, followed by mid-career professionals with 6–20 years (28%) and early-career professionals with less than 5 years (16%). Experience in mass timber construction is also diverse, with 1–5 years being the most common (30%). There is notable representation in the 6–10 years and 20+ years categories, reflecting a mix of emerging and seasoned professionals. Participants exhibit a wide geographical distribution on their involvement with mass timber projects as shown in Figure 3. Most of the participants have experience in mass timber projects in the western U.S., followed by the Northeast (16 participants), Midwest (14 participants), and South (11 participants).



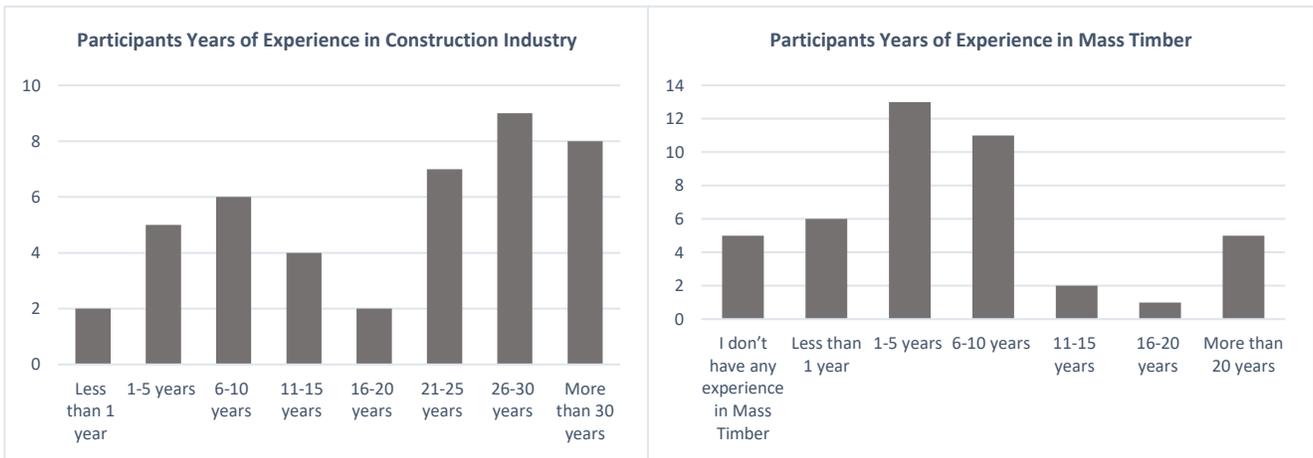


Figure 2: Participants Years of Experience (n=43)

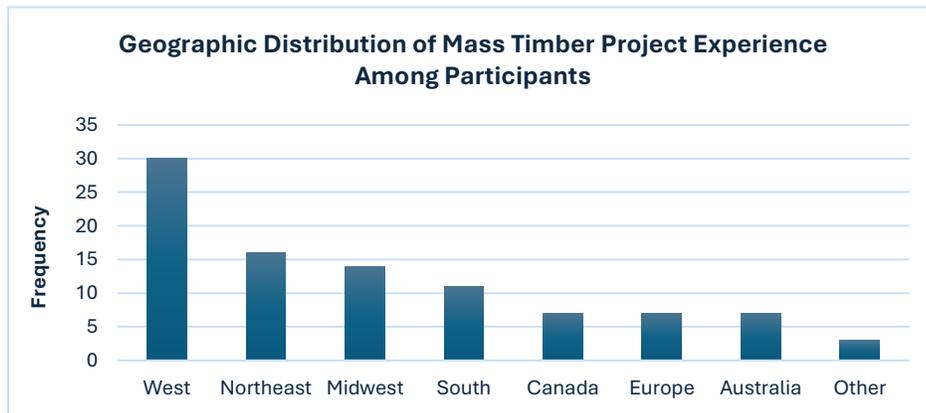


Figure 3: Geographic Distribution of Mass Timber Project Experience Among Participants (n=43)

## 4.2 Relative Importance of the identified factors

The identified factors are classified into five categories: six factors under the Project Management category, three under the Labor category, four under the Material and Equipment category, three under the Safety category, and four under Environmental category. The RII of the factors is calculated using (Eq. 1), and the factors are ranked within their respective category.

### 4.2.1. Project Management Factors

The surveyed construction professionals ranked “Degree of collaboration and communication among project parties during construction” as the most important factor affecting CLP in this category, with a RII of 94.42%. This factor is also ranked first among the 20 factors in this study, which indicates the significant impact of this factor on the efficiency and productivity of construction labor in the mass timber construction industry. The other factors included in this category are adequacy of planning and risk management process, competency in labor supervision and management, design complexity level, and assembly system. The RII and ranks of the six factors classified under the project management category are shown in Table 3.

**Table 3: RII and Ranking of Project Management Factors Affecting CLP in Mass Timber Construction**

| Factors   | RII    | Rank |
|---|--------|------|
| Degree of collaboration and communication among project parties during construction | 94.42% | 1    |
| Adequacy of planning and risk management process                                    | 87.44% | 2    |
| Competency in labor supervision and management                                      | 86.51% | 3    |
| Design complexity level   | 86.05% | 4    |
| Assembly system   | 84.65% | 5    |
| Change orders during construction   | 81.40% | 6    |

#### 4.2.2. Safety Factors

The “Accidents resulting from poor safety program implementation” factor, with a RII of 76.67%, was ranked first in the safety category and 11<sup>th</sup> within the 20 factors in this study. This finding supports the results obtained by Abdul Kadir et al. (2005); Alinaitwe et al. (2007); Enshassi et al. (2007); Hai and Tam (2019); Jarkas and Bitar (2012); and Lim and Alum (1995) who identified this factor among the important factors influencing labor productivity in Malaysia, Uganda, Gaza strip, Vietnam, Kuwait, and Singapore, respectively. Accidents during construction have substantial impacts not only on productivity, but also on the health and well-being of workers. Accidents resulting from poor safety program implementation can lead to significant delays, increased costs, and, most importantly, injuries or fatalities. This highlights the importance of effective safety protocols and their careful implementation in construction projects. The other factors included in this category are site safety measures and practices, and work at heights and associated safety considerations. The RII and ranks of the safety factors are shown in Table 4.

**Table 4: RII and Ranking of Safety Factors Category Affecting CLP in Mass Timber Construction**

| Factors   | RII    | Rank |
|---|--------|------|
| Accidents resulting from poor safety program implementation | 76.67% | 1    |
| Site safety measures and practices                          | 76.19% | 2    |
| Work at heights and associated safety considerations        | 74.76% | 3    |

#### 4.2.3. Materials and Equipment Factors

The “Construction technology (construction method and material)” factor, with a RII of 79.52%, was ranked first in the materials and equipment category and eighth in the total factors. This factor supports the findings obtained by El-Gohary and Aziz (2014); and Enshassi et al. (2007) who identified this factor within the importance factors affecting CLP in Egypt and Palestine. The other factors included in this category are handling and transportation of materials and components, limited availability of mass timber products, and the need for specialized equipment. The RII and ranks of the materials and equipment category are shown in Table 5.

**Table 5: RII and Ranking of Materials and Equipment Factors category Affecting CLP in Mass Timber Construction**

| Factors  | RII    | Rank |
|--|--------|------|
| Construction technology (construction method and material) | 79.52% | 1    |
| Handling and transportation of materials and components    | 78.57% | 2    |
| Limited availability of mass timber products               | 70.95% | 3    |
| The need for specialized equipment                         | 66.19% | 4    |

#### 4.2.4. Labor Factors

The “Specialized skills and training of workers” factor, with a RII of 80.95%, was ranked first in the labor factor and ranked the seventh within the 20 factors in this study. The importance of this factor is supported by the findings of El-Gohary and Aziz (2014); Hai and Tam (2019); Jarkas and Bitar (2012); and Naoum (2016), which emphasize the critical role of skilled labor in construction productivity. In mass timber construction, specialized training is essential due to the unique handling and installation requirements of prefabricated components. Ensuring workers have the necessary skills and training is vital for maintaining quality and efficiency in construction. The other factors included in this category are physical fatigue experienced by workers, and workforce absenteeism rate. The RII and ranks of the labor category are shown in Table 6.

Table 6: RII and Ranking of **Labor Factors** category Affecting CLP in Mass Timber Construction

| Factors                                    | RII    | Rank |
|--|--------|------|
| Specialized skills and training of workers | 80.95% | 1    |
| Physical fatigue experienced by workers    | 68.10% | 2    |
| Workforce absenteeism rate                 | 65.71% | 3    |

#### 4.2.5. Environmental Factors:

The “Rain” factor was ranked first in the environmental category, with a RII of 77.62%, and ranked tenth among the 20 factors affecting CLP in mass timber construction. The significance of rain as a factor affecting construction productivity is highlighted in studies by Abdul Kadir et al. (2005); Hai and Tam (2019); Jarkas and Bitar (2012); Kazaz et al. (2008); Lim and Alum (1995); and Rojas and Aramvarekul (2003). These studies illustrate how adverse weather conditions can lead to delays, material damage, and increased costs if projects are not planned early to overcome these challenges. In mass timber projects, rain poses unique challenges because timber can be damaged by moisture. This emphasizes the need for effective protective measures and careful scheduling to mitigate its impact. The other factors included in this category are high wind, high humidity levels on-site, and high/low temperature conditions on-site. The RII and ranks of the factors classified under the environmental category are shown in Table 7.

Table 7: RII and Ranking of Environmental Factors category Affecting CLP in Mass Timber Construction

| Factors                                 | RII    | Rank |
|---|--------|------|
| Rain                                    | 77.62% | 1    |
| High wind                               | 75.24% | 2    |
| High humidity levels on-site            | 67.14% | 3    |
| High/low temperature conditions on-site | 65.24% | 4    |

#### 4.2.6. Overall Importance of Surveyed Productivity Factors and Group Rankings

The overall importance of surveyed productivity factors is summarized in Table 8. It shows that the top 6 ranked factors affecting CLP in mass timber construction fall under the project management category. This indicates that effective coordination, strategic planning, and proactive risk management are essential for optimizing labor efficiency. Factors such as communication, supervision, and design complexity play a crucial role in minimizing delays and ensuring smooth project execution. Addressing these aspects can significantly improve productivity, reduce costs, and enhance the feasibility of mass timber adoption in construction.

Table 8: Overall RII and Ranks of Productivity Factors Affecting CLP in Mass Timber

| Factors   | Category                | Total | RII    | Rank |
|---|-------------------------|-------|--------|------|
| Degree of collaboration and communication among project parties during construction | Project Management      | 43    | 94.42% | 1    |
| Adequacy of planning and risk management process                                    | Project Management      | 43    | 87.44% | 2    |
| Competency in labor supervision and management                                      | Project Management      | 43    | 86.51% | 3    |
| Design complexity level   | Project Management      | 43    | 86.05% | 4    |
| Assembly system   | Project Management      | 43    | 84.65% | 5    |
| Change orders during construction   | Project Management      | 43    | 81.40% | 6    |
| Specialized skills and training of workers  | Labor                   | 43    | 80.93% | 7    |
| Construction technology (construction method and material)                          | Materials and Equipment | 43    | 79.53% | 8    |
| Handling and transportation of materials and components                             | Materials and Equipment | 43    | 78.14% | 9    |
| Rain  | Environmental           | 43    | 77.21% | 10   |
| Accidents resulting from poor safety program implementation                         | Safety                  | 43    | 76.74% | 11   |
| Site safety measures and practices  | Safety                  | 43    | 76.28% | 12   |
| High wind   | Environmental           | 43    | 74.88% | 13   |
| Work at heights and associated safety considerations                                | Safety                  | 43    | 74.42% | 14   |
| Limited availability of mass timber products  | Materials and Equipment | 43    | 70.70% | 15   |
| Physical fatigue experienced by workers   | Labor                   | 43    | 68.37% | 16   |
| High humidity levels on-site  | Environmental           | 43    | 66.98% | 17   |
| The need for specialized equipment  | Materials and Equipment | 43    | 66.05% | 18   |
| Workforce absenteeism rate  | Labor                   | 43    | 65.12% | 19   |
| High/low temperature conditions on-site   | Environmental           | 43    | 65.12% | 19   |

## 5. CONCLUSION

This study identifies and ranks the key factors influencing construction labor productivity (CLP) in mass timber projects based on insights from industry professionals. The findings reveal that project management factors hold the greatest impact on CLP, followed by safety, materials and equipment, labor, and environmental considerations.

The most critical factor identified in this study is the degree of collaboration and communication among project parties during construction, which highlights the necessity of strong coordination and stakeholder engagement. Effective communication can significantly reduce delays and rework, leading to streamlined project execution. Additionally, the adequacy of planning and risk management processes ranked second, demonstrating the importance of proactive scheduling and contingency strategies to prevent disruptions.

The study also highlights the significance of skilled labor in mass timber construction. The need for specialized skills and training emerged as a key labor factor, emphasizing the requirement for workforce development programs tailored to the unique characteristics of mass timber projects. Similarly, handling and transportation of materials and components ranked among the top factors, indicating that enhancing logistical processes could significantly improve productivity in mass timber construction due to its prefabricated nature. Environmental factors, particularly rain, were identified as a notable factor, affecting material integrity and on-site efficiency.

Overall, this research provides valuable insights for industry stakeholders seeking to improve CLP in mass timber projects. Addressing high-impact factors can lead to enhanced productivity, reduced project durations, and improved cost efficiency.

The main limitation of this study is the relatively low survey response rate (10.7%), which may limit the generalizability of the findings. However, 40% of respondents have over 25 years of experience in the construction industry, lending credibility to the results. Future studies should aim for a larger and more diverse sample for more robust conclusions. Future research should examine productivity across the full life cycle of mass timber projects, from design to construction. It can include site observations to study

productivity at activity level and identify real-time challenges and key productivity factors. Comparative studies with precast concrete would be insightful, given the similarities in their off-site fabrication methods.

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