An empirical study of working conditions on construction sites affecting productivity and safety of equipment operators in Ho Chi Minh City, Vietnam

Nguyen Le Minh Long1, \* Truong Van Luu2

1, 2 HCMC Open University, Vietnam

\*Corresponding author, email: long.nlm@ou.edu.vn

**Abstract****.** Productivity and labor safety when using machines and equipment during construction is one of the issues that contractors always focus on to bring production efficiency, ensure progress, and increase competitive advantage in their operations. This study aims to identify and evaluate the effects of working conditions on the productivity and safety of users of machines and equipment on construction sites in Ho Chi Minh City. Through the presentation of survey results and analysis, 172 questionnaires were collected. The results of the exploratory factor analysis (EFA) have shown five factors: (1) the organization of the construction process; (2) the personal factors of the operator; (3) The working environment at the construction site; (4) Managerial and executive processes; and (5) The quality of machines and equipment. Construction contractors can use the results of this study to improve productivity and improve working conditions to ensure labor safety in the production process.

***Keywords:***Construction management; construction sites; equipment operators; labor safety; productivity; safety.

1. Introduction

Nowadays, the construction industry plays a crucial role in the growth and development of any economy. Just like in developing countries, the construction industry has played an important role in the country's general economy through its contribution to creating revenue, capital formation, and creating jobs to support the gross domestic product (GDP) and national socioeconomic development (Khan et al., 2014). In Vietnam, Ho Chi Minh City is one of the highly populated cities that requires a lot of construction activities to accommodate the growing population. One of the concerns of contractors in this city, as in many other cities, is that the quality of machinery and equipment significantly affects productivity and safety on the construction site.

The construction industry is associated with various challenges, including low productivity and safety concerns. Productivity and safety are interconnected factors that affect the success of construction projects. Enhancing productivity requires improving the efficiency of operations while ensuring safety involves minimizing the risk of accidents and injuries. Construction companies recognize that productivity and safety are the two most crucial factors affecting project success (Alzahrani & Emsley, 2013). For decades, machines and equipment have been incorporated into construction sites to provide efficient and effective results. The quality of machines and equipment and their impact on productivity and safety on construction sites cannot be overstated, as it significantly affects the project's overall outcome. One of the primary advantages of using machines and equipment is that it enhances productivity on construction sites. The use of machines reduces the time taken to complete tasks, which can increase the number of projects handled within a given timeframe, leading to increased profitability.

Ensuring productivity and safety on the construction site comes from many important factors. This has been pointed out by many authors, and this study aims to clarify what those factors are and the extent of their impact on productivity and labor safety.

1. Literature Review

Labor productivity is understood as the ability to complete work or the ability to create products in a unit of time (Tarantino, 2005), productivity can be defined in many ways. In construction, productivity is usually taken to mean labor productivity, that is, units of work placed or produced per man-hour. The inverse of labor productivity, man-hours per unit (unit rate), is also commonly used (Halligan, 1994), productivity activities are highly dependent on the quality of machines and equipment used on the site (Yazdani et al., 2021). High-quality machines can complete tasks faster, with minimal errors, and have a higher output rate. In contrast, low-quality machines can be slow, prone to breakdowns, and require frequent maintenance, leading to project delays. High-quality equipment reduces the risk of accidents, improves accuracy, and ensures smooth operations, directly impacting productivity.

The safety of workers on construction sites is paramount, and the quality of machines and equipment plays a significant role in ensuring their safety (Zou & Zhang, 2009). Low-quality equipment can be hazardous to workers as it can malfunction or break down, causing harm to workers. High-quality machines and equipment have safety features that minimize worker accidents and injuries (Singh & Misra, 2021). When it comes to productivity and safety when using machines, the authors provided insights into the quality of machines and equipment. Such as completeness and efficiency of use, stable balance of the machine (Kuykendall, 2007); the equipping of modern safety and operation parts (Pornthepkasemsant & Charoenpornpattana, 2019) These factors performed well will help the working process go smoothly, on the contrary when the quality is poor, it will lead to reduced productivity and unsafety (Mas, 2008).

The working environment on the construction site significantly impacts the productivity and safety of equipment operators. Due to the nature of the construction industry, workers must often operate heavy machinery and equipment in hazardous environments. The safety and productivity of these workers are directly affected by their working conditions, which include everything from the quality of equipment to the availability of rest breaks (Sitompul, 2019). Production environmental issues characteristic of the construction industry can be mentioned as weather conditions where the project takes place (Lee et al., 2021); Work overhead (Jaffar et al., 2011); Under deep digging pits (Zhou et al., 2018); Working posture such as restrained, cramped, warped (Wang et al., 2020) & (Jaffar et al., 2011); Noise, dust, chemicals, radiation, and microclimate conditions (Lee et al., 2015). Environmental problems directly or indirectly affect equipment operators, making them more difficult to operate, once these negative impacts are not controlled, they will make them work less efficiently and risk labor safety leading to possible accidents.

Another factor that has a huge impact is managerial and executive processes. The project team must plan and schedule every task and activity on the site beforehand, taking into consideration the available resources, deadlines, and budget. Planning and scheduling ensure that everyone on the site understands their role and responsibilities, and they can allocate their time and resources accordingly. Effective planning also helps to identify potential bottlenecks and resource constraints early, allowing teams to address issues proactively and minimize delays. Factors related to managerial and executive processes include equipment operation management process, Organization of monitoring, and alerts carried out (Laitinen & Ruohomäki, 1996), Repair, warranty, maintenance, and replacement of machines and equipment (Bevilacqua & Braglia, 2000), Division of labor and assignment, Managerial and operational processes affect productivity and safety (Zhang et al., 2023). In fact, if the management is poor, communication with employees becomes disrupted, and ineffective monitoring and warning reduce productivity and unsafety.

On the construction site, the organization of construction is an important problem because it helps the work of working groups to coordinate and fully implement and smooth, productivity will be met, and safety issues are guaranteed. The neatness of the construction site is set up (Sawacha et al., 1999); Next is efficiency in use the equipment to perform construction according to the design (Chaturvedi et al., 2018);Combined with the organization of construction sections and routes (Sawacha et al., 1999); Working in a reasonable duration of the shift (Zhang et al., 2023) and are equipped with appropriate and safe personal protective equipment (Desjardins-David, 2011), Effective communication and collaboration among stakeholders are also vital in productive construction sites. All parties involved in the project, including the owner, designers, contractors, and subcontractors, must communicate effectively to ensure the project progresses as planned. Collaboration is especially crucial when changes or unforeseen circumstances arise on the site, requiring quick and decisive actions to avoid delays.

The availability of skilled labor is another crucial factor in productive construction sites. Skilled laborers bring a level of expertise and experience to the site, resulting in high-quality workmanship and faster project delivery (Kazaz, 2008). Hiring unskilled or inexperienced workers can lead to errors, rework, and delays, severely impacting productivity. Therefore, ensuring that the project team recruits and trains highly skilled and experienced personnel before beginning work on the construction site is essential. Therefore, factors from themselves and the family situation of operators also affect their ability to work, which affects productivity and safety when they work. The factors indicated by the authors relate to the factor from the self and the family circumstances of the operator, such as operator's level of training and expertise (Flin, 2017), receiving specialized training will help them control the equipment better; attention to work, when that good focus leads to better productivity and safety; The health of them also ensures they work efficiently and does not tire them out leading to unsafety (Ma et al., 2021); Benefits, remuneration and the relationship between the operator and colleagues is also an encouragement as well as helping them to work properly and responsibly (Zhang et al., 2023); Also to mention the circumstances of their family life, when they are not under pressure from that factor, they will be in a comfortable mood at work (Holland, 2006); Their personal personality, temper, impulsivity, or conversely compliance with safety or cooperation duties and regulations as well as a dynamic personality also affects the ability to complete the assigned work (Brandhorst & Kluge, 2021).

To assess the factors and correlations between the groups of factors, the study surveyed the opinions of 172 participants (ensuring the requirement for a sample number greater than 5 times the number of variables surveyed) according to the sample survey ((Hair Jr., 1998) as cited in (Yeh & Huang, 2009). Based on previous studies and practical factors, the authors proposed 24 independent variables listed in Table 1.

**Table 1.** The 5 key Effects of working conditions on productivity and safety of equipment operators and their 24 associated items (Nguyen and Luu, 2023).

| **Factor** | **Associated item** | **Abbreviation** | **Reference** |
| --- | --- | --- | --- |
| The quality of machines and equipment(FACT\_1) | Completeness and efficiency of use | MACHIN1 | (Kuykendall, 2007) |
| The stable balance of the machine | MACHIN2 | (Kuykendall, 2007) |
| The equipping of modern safety and operation parts. | MACHIN3 | (Pornthepkasemsant & Charoenpornpattana, 2019) |
| The working environment at the construction site(FACT\_2) | Weather conditions where the project takes place | ENVIRO1 | (Lee et al., 2021) |
| Work overhead, under deep digging pits | ENVIRO2 | (Jaffar et al., 2011) & (Zhou et al., 2018) |
| Working posture (restrained, cramped, warped) | ENVIRO3 | (Wang et al., 2020) &(Jaffar et al., 2011) |
| Noise, dust, chemicals, radiation, and microclimate conditions | ENVIRO4 | (Lee et al., 2015) |
| Managerial and executive processes(FACT\_3) | Equipment operation management process | MANAGE1 | (Laitinen & Ruohomäki, 1996) |
| Organization of monitoring and alerts is carried out. | MANAGE2 | (Laitinen & Ruohomäki, 1996) |
| Repair, warranty, maintenance, and replacement of machines and equipment. | MANAGE3 | (Bevilacqua & Braglia, 2000) |
| Division of labor and assignment | MANAGE4 | (Zhang et al., 2023) |
| Organization of the construction process(FACT\_4) | The tidiness of the construction site | ORGANI1 | (Sawacha et al., 1999) |
| Use the machine to perform construction according to the design | ORGANI2 | (Chaturvedi et al., 2018) |
| Duration of the shift | ORGANI3 | (Zhang et al., 2023) |
| Organization of construction sections and routes | ORGANI4 | (Sawacha et al., 1999) |
| Equip personal protective equipment | ORGANI5 | (Desjardins-David, 2011) |
| Capacity, spirit, and personal factors of the operator(FACT\_5) | Operator's level of training and expertise | PERSON1 | (Flin, 2017) |
| Attention to the work of the operator. | PERSON2 | (Ma et al., 2021) |
| The health of the equipment operators | PERSON3 | (Ma et al., 2021) |
| Income regime, benefits, remuneration | PERSON4 | (Zhang et al., 2023) |
| The relationship between the operator and colleagues | PERSON5 | (Zhang et al., 2023) |
| The personality of the operator | PERSON6 | (Brandhorst & Kluge, 2021) |

1. Research Methodology

In the study, the research steps are shown in Fig.1.

Literature Review of working conditions and productivity, safety of equipment operators

Factors and items affecting working conditions.

Survey relevant relevant audiences through questionnaires

Cronbach's Alpha coefficient test and EFA analysis

Analysis Results

Discussions, Suggestions, and Conclusions

**Fig. 1.** Research steps of the study (Nguyen and Luu, 2023).

Step of literature review to better understand the factors affecting the productivity and safety of conditions on the construction site. For a broad synthesis, more than 30 diverse papers were chosen from which to extract elements to build a preliminary research model and make questionnaires to survey relevant audiences.

In this study, when designing the questionnaire, a 5-level Likert scale is used to survey factors according to Table 1. applicable to a variety of respondents, the scale varied from (1) no influence, (2) low influence, (3) medium influence, (4) high influence, and (5) very high influence.

Relevant audiences are surveyed conveniently and they are people who directly work on construction sites such as civil, transport, industrial, security, and defense projects and construction projects in rural areas on the edge of the city, 172 survey samples were collected for analysis.

The descriptive statistic was carried out with 172 valid samples, the under-30 age group was 44.77%, from 30 to under 40 years old was 36.47%, from 40 to under 50 years old was 14.52%, and 5.23% from 50 years old. In terms of training level, 61.63% graduated from university, 18.02% graduated from college and 20.35% graduated from high school. In terms of working positions, 4.65% are construction business owners, 14.53% are middle leaders, 31.98% are managers, and administrative staff and 48.48% are workers directly using machines and equipment at the construction site. In terms of work experience, 43.02% worked less than 3 years, 13.37% from 3 to 5 years, 15.12% from more than 5 years to 10 years, and 28.49% over 10 years.

The reliability of the Likert scale in the study was assessed by intrinsic consistency through Cronbach's Alpha coefficient, a formula according to Nunnally (1978):

 $∝=\frac{N\*ρ}{1+ρ\left(N-1\right)}$ ()

*With: ρ is the average correlation coefficient between the asking items representing the average* correlation between all pairs of questions examined.

If a measurement variable has a Corrected-Total Correlation variable correlation coefficient ≥ 0.3, then the variable is satisfactory (Hoang & Chu, 2008). By convention, if the coefficient of α is greater than or equal to 0.8, a set of questions used for measurement is evaluated as good, Cronbach's Alpha coefficient values are considered acceptable as follows: From 0.8 to close to 1: very good scale, from 0.7 to close to 0.8: the scale is well used; 0.6 and above: qualifying scale (Hoang & Chu, 2008).

The EFA step aims to shorten the dataset to support a more meaningful set of variables and still contain much of the content of the original set of variables ((Hair Jr., 1998) as cited in (Yeh & Huang, 2009). In this study, the original five factors with 24 variables were analyzed by EFA to be reduced to five factors with 23 reordered component variables and omitted variables that did not make sense in the entire original set of variables. In addition, the study ranked the critical order of variables based on the mean value of the variables retained after EFA analysis, SPSS software version 22.0 and MS Excel are the two tools that support this.

The original proposed research model is presented in Fig. 2.

**Fig. 2.** Original proposed research model (Nguyen and Luu, 2023).

The quality of machines and equipment (FACT\_1)

The working environment at the construction site (FACT\_2)

Managerial and executive processes (FACT\_3)

Organization of the construction process (FACT\_4)

Capacity, spirit, and personally of the operator (FACT\_5)

Productivity and safety of equipment operators

1. Research Findings and Factor Analysis

By testing Cronbach's Alpha through the SPSS 22.0 tool the analytical indicators are presented in table 2. In terms of Reliability Statistics, Cronbach’s Alpha=0.958 and Cronbach's Alpha Based on Standardized Items=0.959.

**Table 2.** Summary of analysis results after Cronbach's Alpha test, arranged in order of mean.

| Variable name | N | Min | Max | Mean | Ranking | Std. Deviation | Corrected Item-Total Correlation | Cronbach's Alpha if Item Deleted |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MACHIN3 | 172 | 3 | 5 | 4.33 | 1 | .496 | .507 | .958 |
| MACHIN2 | 172 | 1 | 5 | 4.32 | 2 | .569 | .507 | .958 |
| ENVIRO3 | 172 | 3 | 5 | 4.27 | 3 | .716 | .653 | .957 |
| MANAGE1 | 172 | 3 | 5 | 4.23 | 4 | .702 | .647 | .957 |
| MANAGE3 | 172 | 3 | 5 | 4.21 | 5 | .677 | .635 | .957 |
| ENVIRO1 | 172 | 3 | 5 | 4.20 | 6 | .746 | .641 | .957 |
| ENVIRO2 | 172 | 3 | 5 | 4.18 | 7 | .698 | .684 | .956 |
| PERSON2 | 172 | 1 | 5 | 4.16 | 8 | .935 | .747 | .956 |
| MACHIN1 | 172 | 3 | 5 | 4.15 | 9 | .684 | .641 | .957 |
| PERSON7 | 172 | 1 | 5 | 4.13 | 10 | .943 | .799 | .955 |
| PERSON3 | 172 | 1 | 5 | 4.13 | 11 | .936 | .762 | .955 |
| ENVIRO4 | 172 | 3 | 5 | 4.11 | 12 | .721 | .623 | .957 |
| PERSON1 | 172 | 1 | 5 | 4.10 | 13 | .905 | .697 | .956 |
| MANAGE2 | 172 | 3 | 5 | 4.06 | 14 | .710 | .668 | .957 |
| ORGANI1 | 172 | 1 | 5 | 3.99 | 15 | 1.051 | .718 | .956 |
| MANAGE4 | 172 | 3 | 5 | 3.96 | 16 | .678 | .611 | .957 |
| ORGANI2 | 172 | 1 | 5 | 3.96 | 17 | 1.039 | .740 | .956 |
| ORGANI5 | 172 | 1 | 5 | 3.95 | 18 | .990 | .789 | .955 |
| ORGANI4 | 172 | 1 | 5 | 3.85 | 19 | 1.013 | .737 | .956 |
| ORGANI3 | 172 | 1 | 5 | 3.85 | 20 | .985 | .776 | .955 |
| PERSON4 | 172 | 1 | 5 | 3.79 | 21 | .938 | .713 | .956 |
| PERSON5 | 172 | 1 | 5 | 3.73 | 22 | .956 | .706 | .956 |
| PERSON6 | 172 | 1 | 5 | 3.72 | 23 | 1.016 | .744 | .956 |
| PERSON8 | 172 | 1 | 5 | 3.62 | 24 | 1.105 | .712 | .956 |

Based on the results listed in Table 2. the variables recommended from the beginning have been preserved, in this analysis, Cronbach's Alpha if the Item Deleted are all suitable, Corrected Item-Total Correlation is greater than 0.6 so the scale of this study meets the reliability requirements and can continue for next steps.

Preliminarily, out of the initial 24 variables of five factors, by mean ranking, 5 variables recorded the highest impact on the productivity and safety of equipment operators: (1) The equipping of modern safety and operation parts; (2) The stable balance of the machine; (3) Working posture (restrained, cramped, warped); (4) Equipment operation management process; (5) Repair, warranty, maintenance, and replacement of machines and equipment.

EFA analysis over 2 rounds, the variable PERSON1 is eliminated, from the initial 24 proposed variables to the next 23 variables. Factor analysis is appropriate when KMO 2nd EFA analysis reaches a fairly high value (0.931), (0.5 ≤ KMO ≤ 1) and Bartlett's Test of Sphericity (Sig. value of Bartlett's Test of Sphericity = 0.000) are all satisfied (Hoang & Chu, 2008). As such, the collected dataset is compliant with EFA. Principal Component Analysis extraction method with Varimax rotation. Observed variables with Communalities and Factor loading >0.55 should stop analysis. Table 3, and Table 4 presents the results of EFA.

**Table 3.** Total Variance Explained after the 2nd EFA analysis.

| Com-ponent | Initial Eigenvalues | Extraction Sums of Squared Loadings | Rotation Sums of Squared Loadings |
| --- | --- | --- | --- |
| Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 11.888 | 51.687 | 51.687 | 11.888 | 51.687 | 51.687 | 4.195 | 18.240 | 18.240 |
| 2 | 1.495 | 6.498 | 58.185 | 1.495 | 6.498 | 58.185 | 4.091 | 17.789 | 36.029 |
| 3 | 1.298 | 5.645 | 63.829 | 1.298 | 5.645 | 63.829 | 3.263 | 14.186 | 50.215 |
| 4 | 1.109 | 4.820 | 68.649 | 1.109 | 4.820 | 68.649 | 2.840 | 12.350 | 62.565 |
| 5 | 1.020 | 4.433 | **73.082** | 1.020 | 4.433 | 73.082 | 2.419 | 10.517 | 73.082 |
| 6 | .760 | 3.305 | 76.387 |  |  |  |  |  |  |
| … |  |  |  |  |  |  |  |  |  |
| 23 | .113 | .492 | 100.000 |  |  |  |  |  |  |
| Extraction Method: Principal Component Analysis. |

**Table 4.** Rotated Component Matrix after the 2nd EFA analysis.

| Variables | Component |
| --- | --- |
| 1 | 2 | 3 | 4 | 5 |
| ORGANI2 | .863 |  |  |  |  |
| ORGANI4 | .763 |  |  |  |  |
| ORGANI1 | .727 |  |  |  |  |
| ORGANI3 | .672 |  |  |  |  |
| ORGANI5 | .651 |  |  |  |  |
| PERSON2 | .570 |  |  |  |  |
| PERSON5 |  | .812 |  |  |  |
| PERSON6 |  | .807 |  |  |  |
| PERSON4 |  | .798 |  |  |  |
| PERSON8 |  | .744 |  |  |  |
| PERSON7 |  | .537 |  |  |  |
| PERSON3 |  | .513 |  |  |  |
| ENVIRO2 |  |  | .758 |  |  |
| ENVIRO4 |  |  | .725 |  |  |
| ENVIRO3 |  |  | .717 |  |  |
| ENVIRO1 |  |  | .593 |  |  |
| MANAGE3 |  |  |  | .702 |  |
| MANAGE2 |  |  |  | .676 |  |
| MANAGE1 |  |  |  | .627 |  |
| MANAGE4 |  |  |  | .612 |  |
| MACHIN2 |  |  |  |  | .839 |
| MACHIN1 |  |  |  |  | .706 |
| MACHIN3 |  |  |  |  | .614 |
| Extraction Method: Principal Component Analysis.Rotation Method: Varimax with Kaiser Normalization. |
| a. Rotation converged in 7 iterations. |

The results of EFA analysis after the second round eliminated one variable (PERSON1), the process of rotating the factor formed five factors, the change of variables in the factors only one rearrangement of variables: Attention to the work of the operator (PERSON2) classified as the organization of the construction process.

After EFA, the analysis results established five factors including (1) the Organization of the construction process with 6 variables; (2) personal factors of the operator with 6 variables; (3) The working environment at the construction site with 4 variables; (4) Managerial and executive processes with 4 variables; (5) The quality of machines and equipment with 3 variables. These five factors reflect the impact of working conditions on the productivity and safety of equipment operators on the construction site where respondents work. The research model is shown in Fig. 3. is like the original proposed research model.

Organization of the construction process (FACT\_1)

Personal factors of the operator (FACT\_2)

The working environment at the construction site (FACT\_3)

Managerial and executive processes (FACT\_4)

The quality of machines and equipment (FACT\_5)

Productivity and safety of equipment operators

**Fig. 3.** The research models (Nguyen and Luu, 2023).

1. Discussion And Suggestions

From the results compiled above, several proposed solutions aimed at improving working conditions and overcoming the causes of reduced productivity and labor safety of equipment operators according to the importance of factors include:

**Solution about Organization of the construction process.**

In the construction site, contractors need to design, arrange, and always ensure that the construction site is tidy, so that, when not being blocked, workers easily manipulate the means of machinery to ensure efficiency and safety for others and themselves; Working with equipment should comply with the approved design, and must be based on the best plan; The managers need to allocate working time properly, and have a rest regime between shifts enough for workers to work effectively; Deployment of reasonable construction sections and routes, avoiding overlap between groups of workers, in which the work related to machines and equipment requires minimizing work interruption, hindering its working efficiency. When technical and sanitary measures are applied on the construction site but do not fully anticipate the risks that come from the complex working conditions of the construction industry, equipment operators should be equipped with quality personal protective equipment, technically qualified and suitable for their work.

**Solution about personal factors of the operator**

In worker recruitment, having information and check the health of candidates, employers need to comply with the legal provisions of health care regime and check-ups operator’s heath every 6 months or once a year during the project period. Organizing the departmental or personnel taking over the medical work at the project; Having income and welfare policies that both ensure compliance with the law and are enough to encourage them to work with peace of mind, from there, they will have more effort and stick with the work they undertake; One of the important issues at the project is the relationships between the parties involved, namely the relationship between the workers at the project, once these relationships are positive or less conflicted, it will lead to better coordination and vice versa, and it will reduce productivity and unsafety. Contractors need to have the necessary monitoring and, promptly intervene in disagreements that tend to worsen, through activities to strengthen the relationship between employees with collective activities and harmonious work distribution mechanisms, the right people will make the environment more friendly, the relationship between the parties becomes more transparent and acceptable to each other; The personality of the operator is directly related to the operation process, some individuals tend to be difficult to cooperate and be conservative, so in the process of organizing construction site activities, the contractor needs to observe them to have the appropriate job assignment, make sure not to hinder production as well as give them comfort when working; Developing safety regulations, and occupational safety signage, have a labor safety department at the construction site to monitor the compliance of workers, and have strict penalties when they do not comply with labor safety. In addition, having information about the family life of the equipment operators because these are also variables that affect their productivity, must visit and support their lives when their lives are poor or having a sad problem, what part will give them feel secure to work and stick with the project.

**Solution about the working environment at the construction site.**

Installing a weather monitoring station can help monitor weather conditions in real-time, allowing for better planning and preparation for severe weather. Providing suitable work equipment such as raincoats, boots, and gloves, designing covered work areas, and using cooling systems in hot climates can help maintain a comfortable working temperature. Providing regular training programs on safety precautions in extreme weather conditions can help raise workers' awareness and reduce weather-related injuries; Equipping with personal protective equipment when working at high altitudes such as anti-slip shoes, seat cones, and seat belts when working overhead, covering trenches, and digging pits with heavy-duty covers that can prevent accidents and improve worker safety; Using handy devices such as adjustable chairs, armrests, and legroom can improve workers' posture, reduce fatigue, and minimize the risk of back injuries. In addition, it is necessary to replace the use of modern, automated machines to minimize direct human labor.

Implementing ventilation in enclosed work areas can help eliminate stagnant air and improve indoor air quality, monitor radiation exposure, and provide protective gear that can ensure worker safety and prevent long-term health problems. This can lead to better health for workers and increased productivity. In addition, providing personal protective equipment such as hard hats, gloves, goggles, and earmuffs to protect workers from overhead work, dust, and noise. Implement dust control measures such as the use of water spray, ventilation systems, and dust masks, preventing respiratory problems. Using fewer toxic chemicals, implementing proper storage, and handling procedures, and providing protective gear can reduce the risk of chemical exposure for workers. Regulating temperature, humidity, and airflow in work areas can prevent heat stress, hypothermia, and other related health hazards.

**Solution about managerial and executive processes.**

The contractor needs to issue an Equipment Operation Management Process, which is widely disseminated to the relevant people to know and take it seriously; There is an assignment of the human resources department to carry out the organization of monitoring and setting up the alerts system to help the operation of the Equipment be safe; Establish procedures for repair, warranty, maintenance, and replacement of machinery and equipment, and have a record of storage and tracking for repair, and planned maintenance to ensure its operational efficiency and safety. The division of labor must ensure the right people, the right level of training, and sufficient working time.

**Solution about the quality of machines and equipment.**

The variables of completeness and efficiency of the use of machinery and equipment have an impact on productivity and safety, so equipping complete machines with fewer failures and errors so that their operators can work more smoothly and safely.

In addition, the stable balance of the machine is not maintained, its working efficiency is reduced, and the risk of accidents and damage to the machine is increased. Therefore, ensuring the balance and stability of the machine, the location of the machine needs to be considered to meet the effective operation of the machine. This is also a variable that greatly affects the productivity and safety of equipment operators. Finally, the equipping of modern safety and operational parts has the greatest impact on the productivity and labor safety of equipment operators. Contractors must pay attention when purchasing new or renting machines, they need to check safety parts are secure and properly designed and checking any damage or lack, equipment must also be modern and served well for production.

1. Conclusions

From the literature review, five factors with 24 variables were suggested, after Cronbach's Alpha and EFA analysis, the data boiled down to 23 attribution variables in five factors like the original proposal. Five leading factors of effects of working conditions on productivity and safety of equipment operators on construction sites include: The organization of the construction process (6 variables); Personal factors of the operator (6 variables); Personal factors of the operator (6 variables); The working environment at the construction site (4 variables); Managerial and executive processes (4 variables); The quality of machines and equipment (3 variables).

Through ranking based on the mean value, also identified the top five variables with strong influences of working conditions on productivity and safety of equipment operators on construction sites including: The equipping of modern safety and operation parts; The stable balance of the machine; Working posture (restrained, cramped, warped); Equipment operation management process; Repair, warranty, maintenance, and replacement of machines and equipment.

Through discussion, the study suggested five groups of solutions with 23 component recommendations to help contractors improve working conditions to improve productivity and ensure the labor safety of operators of construction machines and equipment. Despite the scientific contributions, the limitation of this study is that the scope of local research is small, further studies need to develop the contributions and overcome the limitations of research.

**References**

Alzahrani, J. I., & Emsley, M. W. (2013). The impact of contractors’ attributes on construction project success: A post construction evaluation. *International Journal of Project Management*, *31*(2), 313-322. <https://doi.org/10.1016/j.ijproman.2012.06.006>

Bevilacqua, M., & Braglia, M. (2000). The analytic hierarchy process applied to maintenance strategy selection. *Reliability Engineering & System Safety*, *70*(1), 71-83. [https://doi.org/10.1016/s0951-8320(00)00047-8](https://doi.org/10.1016/s0951-8320%2800%2900047-8)

Brandhorst, S., & Kluge, A. (2021). When the Tension Is Rising: A Simulation-Based Study on the Effects of Safety Incentive Programs and Behavior-Based Safety Management. *Safety*, *7*(1). <https://doi.org/10.3390/safety7010009>

Chaturvedi, S., Thakkar, J. J., & Shankar, R. (2018). Labor productivity in the construction industry. *Benchmarking: An International Journal*, *25*(1), 334-356. <https://doi.org/10.1108/bij-11-2016-0171>

Desjardins-David, I., & Arteau, J. (2011). Evaluation of personal protective equipment used for work: considerations and proposed methodology - the criteria to be checked. ÉTS researchers’ publications,

Flin, R., & O'Connor, P. (2017). *Safety at the sharp end: a guide to non-technical skills*. CRC Press.

Hair Jr., J. F., Anderson, R. E., Tatham, R. L., & Black, W. C. (1998). *Multivariate Data Analysis*. Prentice Hall.

Halligan, D. W., Demsetz, L. A., Brown, J. D., & Pace, C. B. (1994). Action-response model and loss of productivity in construction. *Journal of Construction Engineering and Management*, *120(1)*(120(1)), 47-64.

Hoang, T., & Chu, N. (2008). *Analysis of research data with SPSS*. Hong Duc Publishing House.

Holland, D. W. (2006). The effect of shiftwork related fatigue on the family life of train operators: Implications for safety and health professionals [Research Article]. *Work*, *26*, 115-121.

Jaffar, N., Abdul-Tharim, A. H., Mohd-Kamar, I. F., & Lop, N. S. (2011). A Literature Review of Ergonomics Risk Factors in Construction Industry. *Procedia Engineering*, *20*, 89-97. <https://doi.org/10.1016/j.proeng.2011.11.142>

Kazaz, A., Manisali, E., & Ulubeyli, S. (2008). Effect of basic motivational factors on construction workforce productivity in turkey. *Journal of Civil Engineering and Management*, 95-106.

Khan, R. A., Liew, M. S., & Ghazali, Z. B. (2014). Malaysian Construction Sector and Malaysia Vision 2020: Developed Nation Status. *Procedia - Social and Behavioral Sciences*, *109*, 507-513. <https://doi.org/10.1016/j.sbspro.2013.12.498>

Kuykendall, C. J. (2007). *Key factors affecting labor productivity in the construction industry* University of Florida.

Laitinen, H., & Ruohomäki, I. (1996). The effects of feedback and goal setting on safety performance at two construction sites. *Safety Science*, *24*(1), 61-73. [https://doi.org/10.1016/s0925-7535(96)00070-7](https://doi.org/10.1016/s0925-7535%2896%2900070-7)

Lee, J. S., Son, S., Kim, S., & Son, K. (2021). Correlation analysis of safety climate and construction productivity in South Korea. *Int J Occup Saf Ergon*, *27*(2), 589-596. <https://doi.org/10.1080/10803548.2020.1741279>

Lee, S. C., Hong, J. Y., & Jeon, J. Y. (2015). Effects of acoustic characteristics of combined construction noise on annoyance. *Building and Environment*, *92*, 657-667. <https://doi.org/10.1016/j.buildenv.2015.05.037>

Ma, H., Wu, Z., & Chang, P. (2021). Social impacts on hazard perception of construction workers: A system dynamics model analysis. *Safety Science*, *138*. <https://doi.org/10.1016/j.ssci.2021.105240>

Mas, A. (2008). Labour Unrest and the Quality of Production: Evidence from the Construction Equipment Resale Market. *Review of Economic Studies*, *75*(1), 229-258. <https://doi.org/10.1111/j.1467-937X.2007.00461.x>

Pornthepkasemsant, P., & Charoenpornpattana, S. (2019). Identification of factors affecting productivity in Thailand’s construction industry and proposed maturity model for improvement of the productivity. *Journal of Engineering, Design and Technology*, *17*(5), 849-861. <https://doi.org/10.1108/jedt-10-2017-0109>

Sawacha, E., Naoum, S., & Fong, D. (1999). Factors affecting safety performance on construction sites. *International Journal of Project Management*, *17*(5), 309-315. [https://doi.org/10.1016/s0263-7863(98)00042-8](https://doi.org/10.1016/s0263-7863%2898%2900042-8)

Singh, A., & Misra, S. C. (2021). Safety performance & evaluation framework in Indian construction industry. *Safety Science*, *134*. <https://doi.org/10.1016/j.ssci.2020.105023>

Sitompul, T. A., & Wallmyr, M. . (2019). *Using Augmented Reality to Improve Productivity and Safety for Heavy Machinery Operators: State of the Art* The 17th International Conference on Virtual-Reality Continuum and Its Applications in Industry,

Tarantino, G. C. (2005). *Imputation, estimation, and prediction using the Key Indicators of the Labour Market (KILM) data set*.

Wang, P., Wu, P., Wang, X., Chen, X., & Zhou, T. (2020). Developing optimal scaffolding erection through the integration of lean and work posture analysis. *Engineering, Construction and Architectural Management*, *27*(9), 2109-2133. <https://doi.org/10.1108/ecam-04-2019-0193>

Yazdani, M., Kabirifar, K., Fathollahi-Fard, A. M., & Mojtahedi, M. (2021). Production scheduling of off-site prefabricated construction components considering sequence dependent due dates. *Environ Sci Pollut Res Int*. <https://doi.org/10.1007/s11356-021-16285-0>

Yeh, T.-F., & Huang, L.-C. (2009). An Analysis of Floral Consumption Values and Their Difference for Genders and Geographic Regions. *HortTechnology*, *19*(1), 101-107. <https://doi.org/10.21273/hortsci.19.1.101>

Zhang, Z., Guo, H., Gao, P., Wang, Y., & Fang, Y. (2023). Impact of owners’ safety management behavior on construction workers’ unsafe behavior. *Safety Science*, *158*. <https://doi.org/10.1016/j.ssci.2022.105944>

Zhou, Y., Li, C., Zhou, C., & Luo, H. (2018). Using Bayesian network for safety risk analysis of diaphragm wall deflection based on field data. *Reliability Engineering & System Safety*, *180*, 152-167. <https://doi.org/10.1016/j.ress.2018.07.014>

Zou, P. X., & Zhang, G. (2009). Comparative Study on the Perception of Construction Safety Risks in China and Australia. *Journal of Construction Engineering and Management*, *135*(7), 620-627. [https://doi.org/10.1061/(asce)co.1943-7862.0000019](https://doi.org/10.1061/%28asce%29co.1943-7862.0000019)