

A Measurement Model of Labor Productivity in High-Rise Building Construction Projects

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Abstract. Construction labor productivity is a critical determinant of project performance in residential high-rise construction, particularly within dense urban environments. This study empirically examines the hierarchical structure of factors influencing labor productivity in Thai residential high-rise construction projects located in Bangkok and its metropolitan areas. A quantitative approach was employed using questionnaire data collected from 336 construction personnel, including engineers, site supervisors, and skilled workers. Confirmatory factor analysis was applied, with a second-order measurement model used to capture the multidimensional nature of labor productivity. The results validate a five-factor first-order structure comprising Equipment/Tools, Materials, Safety, Motivation, and Weather, which collectively constitute an overarching productivity construct. Among these factors, Equipment/Tools shows the highest standardized loading, highlighting its prominent role in urban high-rise construction. The second-order CFA provides a quantified hierarchy of productivity determinants, offering insights beyond conventional single-level analyses. The findings are context-specific and should be interpreted within the scope of Thai residential high-rise construction projects. Practically, the validated hierarchical structure supports more informed prioritization of productivity-related factors under typical resource constraints in high-rise projects. This study contributes to construction management research by operationalizing labor productivity as an empirically grounded hierarchical construct and provides a foundation for future contextual extensions.

Keywords: measurement model, labor productivity, high-rise building

1. Background and Rationale

The construction industry is considered one of the crucial components of the economy in every country worldwide, especially developing countries [1]. This is because every sector relies on construction as part of business investment. It has been stated that the construction sector can contribute around 15-20% of a country's Gross Domestic Product (GDP) [2, 3]. Given that this industry involves relatively high investments, it significantly impacts a country's economy. Therefore, the productivity of construction organizations remains one of the most interesting and crucial issues in both developed and developing countries' construction sectors [4]. In terms of cost savings and efficient resource utilization, developed countries recognize the importance of economic growth and social welfare. Developing countries, which face issues such as unemployment, inflation, and resource shortages, strive to make the most of their resources to achieve economic growth and improve the lives of their citizens [5].

Generally, productivity in the construction sector often reflects direct labor productivity. This is because the construction industry heavily relies on and utilizes a large amount of labor [6, 7]. A significant portion of construction budgets is typically allocated to labor costs, accounting for approximately 30-50% of the total project cost. Consequently, poor labor productivity in construction can cause excessive costs and time spent on construction projects. However, several international researchers have reported that the construction industry has relatively lower productivity growth rates than other industries [8, 9]. Moreover, there are challenges related to both quantitative and qualitative labor shortages. Therefore, labor is critical because any enterprise might use the most advanced technology or machinery and have excellent management to produce the best goods or services. However, without workers to operate the technology, even the best laid systems cannot succeed [10]. Having highly productive Labor at each stage of a construction project is crucial for its success. Despite numerous research efforts on labor productivity, academics and practitioners still need more consensus regarding improvement strategies and universally applicable performance metrics in construction. Therefore, to truly demonstrate the success of a country or organization, stakeholders in the construction industry, including owners, public and private sectors, contractors, project managers, skilled workers, and laborers, must be actively involved in improving productivity [11, 12].

Therefore, to demonstrate a country or organization's success, those involved in the construction industry should focus on improving labor productivity. This research aims to identify the significant factors affecting labor productivity in the construction industry by examining the validity of the measurement model and determining the weight of the importance of each factor component (observed variables) on the different aspects (latent variables) that impact the decline in labor productivity in construction projects. This is done using structural equation modeling with the measurement model.

Although numerous studies have investigated factors influencing construction labor productivity, most existing research has primarily focused on identifying factors or ranking their subjective importance using descriptive or multi-criteria methods. Limited attention has been given to empirically validating the underlying measurement structure and hierarchical relationships among productivity-related factors, particularly through second-order confirmatory factor analysis. Moreover, empirical studies focusing on residential high-rise construction in dense urban environments, such as Bangkok and its metropolitan areas, remain relatively scarce.

From a theoretical perspective, this study builds upon classical productivity and management theories while operationalizing them within contemporary construction practice. Adam Smith's principle of division of labor and Frederick Taylor's scientific management theory emphasize the role of appropriate tools, standardized methods, and systematic control in enhancing worker

efficiency, concepts reflected in the Equipment/Tools and Safety dimensions of the proposed model. In addition, human-centered perspectives underscore the importance of motivation and environmental conditions, supporting the inclusion of Motivation and Weather as distinct latent factors. Accordingly, this study develops and validates a second-order measurement model that empirically quantifies the hierarchical structure of labor productivity factors in the specific context of Thai residential high-rise construction projects (eight stories or more), thereby extending existing knowledge beyond conventional single-level analyses.

2. Review of Previous Studies

Labor is a vital resource in building a project. Both in terms of the amount of labor and the total cost of the entire project lost to labor costs. This is because a construction project's success depends on the workers' productivity. Productivity is, therefore, one of the critical elements of every company's success and competitiveness in the construction industry market [13]. The decline in labor productivity across the country is a cause for concern. Although there are many studies on labor productivity, there still needs to be a consensus among academics and practitioners on the definition and measurement of construction effectiveness [14, 15].

Attar et al. [16] studied the factors affecting labor productivity and methods to improve productivity in India. They identified and categorized various factors into 15 groups: Design factors, Planning factors, Material factors, Equipment/tool factors, Worker factors, Health and safety factors, Supervisor factors, Working time factors, Project factors, Quality factors, financial factors, Leadership and coordination factors, Organizational factors, Owner and consultant factors and Other external factors. The grouping of factors by Attar et al. is like that of Soekiman et al. [17], who identified 113 variables affecting construction labor productivity and categorized them into 15 groups of factors based on their characteristics: Design, Planning, Materials, Equipment, Labor, Health and Safety, Supervision, Working time, Project, Quality, Finance, Leadership, and coordination, Organization, Owner/Consultant and External factors. Shashank et al. [18] analyzed vital factors affecting changes in labor productivity in construction projects, categorizing them into eight groups with 34 factors. Material factors were among the top three groups affecting labor productivity, consistent with the research of Johari and Kumar [19], who examined and ranked factors for improving labor productivity in Egypt's construction industry. They categorized the factors into: Labor group, Management Group, Environmental group, Motivation Group, Material/equipment group, Scheduling group, Safety Group and Work quality group. In the study of construction projects in Zimbabwe [11], the top five factors identified as most important for increasing labor productivity were the availability of materials, delayed payment of salaries and wages, project suitability/adequacy, lack of equipment, supervisory capability, and lack of worker skills. These identified factors were then categorized into: Construction site factors, Equipment factors, Material factors, Management factors, Labor factors, Motivation factors and Technical factors.

Over the past several years, research has identified numerous critical factors that can serve as foundational elements for consideration and selection in research questionnaires impacting labor productivity in the construction industry. This applies to both developed countries, such as Canada [20], the UK [21], New Zealand [22], and developing countries, such as Nigeria [23, 24], Malaysia [25], Palestine [26], Kuwait [27], Sri Lanka [28], Turkey [29], Trinidad and Tobago [30], Yemen [31], Egypt [4], Zimbabwe [11], and Uganda [32]. Labor productivity is influenced by both external and internal factors, comprising 116 factors grouped into 8 categories.

The researcher constructed a measurement model to extract variables by determining the construct reliability (PC) or the value representing the latent variables. This should be greater than 0.7. Additionally, each measurement model's variance extracted (PV) must be greater than 0.5. The relationships between the observed and latent variables were determined based on a review of related research. The indicator or observed variables should have a factor loading between 0.5 and 1.0 [33]. After the variable extraction process, seven latent variables or main components remain. 1. Materials, 2. Equipment/Tools, 3. Safety, 4. Motivation and 5. Weather. There are 35 observed subcomponents or variables left, as shown in Table 1.

Although previous studies have identified a wide range of labor productivity factors across different countries, most have relied on descriptive analysis or simple ranking techniques. Few studies have empirically validated the hierarchical structure and relative importance of these factors using second-order measurement models, particularly within the context of residential high-rise construction in Thailand.

3. Method

The research process is defined in six steps, which are detailed as follows:

3.1. Identifying Population and Sampling

The population in this research consists of construction workers classified by industry from 2013 to 2019 throughout Thailand, totaling 1,125,400 people [45].

A portion of the population was selected to represent the population under study for data collection through questionnaires. The researcher determined the sample size using Taro Yamane's formula to set the population proportion and the sample's margin of error from the actual population value [46]. Krejcie and Morgan [47] suggested calculating the sample size for a known population with a 95% confidence level, allowing a 5% sampling error. Therefore, the calculated sample size is approximately 400 units. To prevent the mistakes from incorrect or incomplete responses, an additional 200 units were reserved, making a total sample size of 600 units. The researcher selected the sample for the questionnaire based on nonprobability sampling using convenient sampling, allowing the researcher to collect data readily. After data collection, the researcher used purposive sampling [48] to select the sample questionnaires. Accordingly, the sampling approach should be interpreted as a non-probability, site-access-based strategy rather than a statistically representative random sample. The procedures were applied to ensure contextual relevance and data quality within accessible residential high-rise construction sites, rather than to generalize findings to the entire construction workforce in Thailand.

Table 1: Compilation of labor productivity factors affecting construction projects

Criteria	Factors	Reference
1. Materials	1.1 Materials have not arrived onsite yet (V1b)	[11,34,35]
	1.2 Lack of material (V12b)	[4,18,36]
	1.3 Insufficient or poor material handling (V3b)	[11]
	1.4 Unsuitability of materials storage location (V4b)	[18,37,38]
	1.5 Low quality of raw materials (V5b)	[18,37,38]
2. Equipment/ Tools	2.1 Lack of proper tools and equipment on-site (V1c)	[18,36,39]
	2.2 There are frequent tools/ equipment breakdowns due to aging or poor maintenance (V2c)	[11,32,40]
	2.3 Suitability or adequacy of equipment/tools (V3c)	[11,32,39]
	2.4 Old and Inefficiency of equipment/tools (V4c)	[11, 39-41]
	3.1 Accidents (V1e)	[18,26,41]
3. Safety	3.2 Violation of safety precautions (V2e)	[18,26,41]
	3.3 Management does not support safety planning (V8e)	[42]
	3.4 Lack of site safety resources (V9e)	[38]
	3.5 No safety engineer in site (V10e)	[18]
4. Motivation	4.1 Delay in salary payment (V3j)	[4,5,11,28,]
	4.2 Bonus at the end of project or year (showing appreciation at the end of the project and year) (V7j)	[11,28,35]
	4.3 Canteen for employee (Good food for free or at a reduced price) (V9j)	[5,28]
	4.4 Medical care (Having a particular hospital to attend in case of illness or subsidizing the cost of hospital bills) (V10j)	[11,28,35]
	4.5 Accommodation (Provision of physical accommodation, package as subsidy to rent apartment) (V11j)	[28]
	4.6 Working hours (working 8 hours per day) (V14j)	[35]
	4.7 Public holidays (V15j)	[35]
5. Weather	5.1 Cold, Humidity (V1p)	[4,30,42,43, 44]
	5.2 Rain (V2p)	
	5.3 High Temperature (V3p)	

3.2. Data Collection

Data was collected using questionnaires from workers in residential construction projects in Bangkok and surrounding provinces, where each project being built is similar or nearly identical. Workers were selected based on nonprobability sampling at site level principles, specifically simple random sampling. The response rate for the questionnaires was 336. Berdie and others [49] suggested that a response rate of over 50% is acceptable and considered good. This research found a response rate of 56%, which is deemed suitable and allows the data to be further analyzed.

In this study, high-rise building projects are operationally defined as residential buildings with eight or more stories, consistent with standard classifications in the construction management literature. Accordingly, all sampled projects were residential high-rise developments that met this criterion and were located in Bangkok and its surrounding metropolitan areas. Therefore, the results are not intended to represent productivity conditions in rural construction projects or other project types with different labor structures and operational environments. This scope definition was applied to ensure consistency between the study context and the empirical data collected.^{2,1} Accordingly, the findings should be interpreted within the context of urban residential high-rise construction projects in Bangkok and its metropolitan areas.

3.3. Development of Research Tools

Before the researcher uses the tools or questionnaires in the actual field, to ensure that the questionnaires are valid, relevant, and reliable, the following procedures must be conducted in the questionnaire:

a. The validity of the questionnaire was tested using the Index of Item-Objective Congruence (IOC), which must have an IOC value greater than 0.50, according to the opinions of five experts. In this research, the overall IOC value is 0.81, indicating that the factors align with the research objectives and can be used to collect data from the sample group [50].

b. The reliability of the questionnaire, which had an IOC value greater than 0.50, was tested with a population of 30 individuals who were not part of the sample group but had similar characteristics to the sample group. The researcher used Cronbach's Alpha Coefficient [51] and found that the Alpha Coefficient was 0.961, which is greater than 0.7. This indicates that the questionnaire is reliable and suitable for further data collection.

3.4. Model Structure

A second-order confirmatory factor analysis was employed to reflect the inherently multidimensional nature of construction labor productivity. While first-order CFA is appropriate for validating relationships between observed variables and their corresponding latent constructs, it does not explicitly capture the hierarchical relationships among multiple interrelated productivity dimensions. In this study, factors such as Equipment/Tools, Materials, Safety, Motivation, and Weather are conceptually interdependent and collectively represent overall labor productivity rather than isolated effects. The second-order CFA allows these first-order factors to be modeled as manifestations of a higher-order productivity construct, thereby enabling the

empirical assessment of both sub-factor validity and their relative contributions to overall productivity. This hierarchical modeling approach provides a more informative and decision-oriented representation than simpler single-level CFA models.

The adoption of a second-order confirmatory factor analysis in this study enables the empirical validation of both primary productivity factors and their underlying sub-components, allowing for a quantified hierarchical assessment that extends beyond conventional factor identification approaches. The measurement model examines the relationship between multiple observed variables and latent variables. Based on previous research studies and the variable extraction process, the researcher identified Five main components: 1. Material 2. Equipment/Tools 3. Safety 4. Motivation and 5. Weather, making up a total of 24 observed variables. The analysis of the measurement model using the AMOS program will include the following symbols:

a. An observed variable is one the researcher can directly collect data on from the sample group. This data is secondary data. The symbol representing an observed variable can be a rectangle or a square, as shown in Figure 1.



Figure 1: Observed variable symbol

b. A latent variable is a variable that cannot be directly measured but is inferred from observed variables. It can be represented by an ellipse or a circle, though an ellipse is commonly used, as shown in Figure 2.



Figure 2: Latent variable symbol

c. A variable representing the measurement error of an indicator variable or observed variable is denoted by an ellipse or circle with the letters 'e' or 'r.' A circle with the letter 'e' is commonly used, as shown in Figure 3.

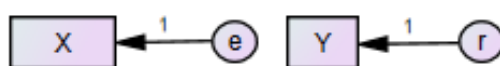


Figure 3: Error variable symbol

d. A straight arrow represents a causal relationship or factor loading, as shown in Figure 4.

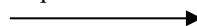


Figure 4: Linear relationship arrow symbol

e. The factor loadings in each model are set to "1" for one value.

A thorough study of documents and past research related to the foundational theoretical framework needs to be conducted. Then, continuous linear relationship measurement models must be created between latent and observed variables. These indicators reflect different aspects or dimensions of the primary construct, consisting of 5 models. Create a second-order latent variable with arrows pointing to the first-order latent variables and assign error terms to all first-order latent variables from f1 to f5. This will result in a second-order confirmatory factor analysis model, as shown in Figure 5.

3.5. Variable reduction

Variable elimination to improve model fit is a crucial process that must be carried out carefully, as selecting inappropriate variables may affect the model's validity and reliability. The principles applied by the researcher in this model include the following considerations:

a. Factor Loadings Verification [52]: Observed variables with factor loadings below 0.50 should be considered for removal, as low factor loadings indicate a weak relationship between the observed variable and the latent variable, reducing convergent validity. Five variables were removed.

b. Correlation Verification: Observed variables with excessively high correlations (greater than 0.85) with other variables, which could compromise the model's reliability, were considered for removal. Variables with correlations approaching one may lead to the following issues: 1) Regression weights may fluctuate significantly, or some parameter estimates may become statistically insignificant. 2) The direction of relationships between variables may not align with theoretical expectations. 3) Standard errors may increase, reducing the confidence in parameter estimates. 4) The model fit may deteriorate (Poor Model Fit) [53]. A total of four variables were removed.

c. Examination of Residuals: Observed variables with abnormally high differences between the predicted values from the model and the actual data (residuals) should be considered for removal. Residual values exceeding ± 2.58 are considered abnormally high at a 99% confidence level. These values can be examined in the Standardized Residual Covariances output window. High residual values indicate a poor fit between the data and the model [54]. A total of four variables were removed.

3.6. Model Modification Indexes (M.I.)

The researcher's model, based on a review of relevant past studies, must be tested for its fit with the data collected from the sample group. Model fit verification is necessary to determine whether the developed model aligns with empirical data. The model can be adjusted to correct estimation errors caused by the measurement tools used. These modifications do not affect the model's

structural framework based on the hypothesis. Adjustments can be performed by drawing relationships between variables as suggested by the software, using Modification Indices (M.I.). The M.I. value represents the expected reduction in the chi-square test statistic if a new parameter is estimated, thereby improving the model's alignment with empirical data. Once the model is refined, it must meet the following fit criteria: The chi-square test statistic should be lower than the threshold chi-square value, or the relative chi-square should be less than 2. Fit indices (GFI, AGFI, CFI, TLI, and NFI) should be greater than 0.95. Error indices (RMSEA, RMR, SRMR) should be lower than 0.05. Additionally, all parameter estimates in the measurement and structural equation models must be statistically significant ($|t| > 1.96$) and theoretically meaningful [52]. If these conditions are met, the developed structural equation model can be concluded to be consistent with the empirical data.

Table 2: Analysis results of the relationships using regression coefficients of sub-factors affecting labor productivity

Latent variable	Materials		Equipment/Tools		Safety		Motivation		Weather		R ²
Indicator variable	β_i	S.E.	β_i	S.E.	β_i	S.E.	β_i	S.E.	β_i	S.E.	
V1b	0.733	0.060									0.604
V2b	0.720	0.058									0.583
V3b	0.843	0.058									0.798
V4b	0.712	0.054									0.569
V5b	0.706	-									0.559
V1c			0.848	-							0.719
V2c			0.790	0.053							0.624
V3c			0.653	0.051							0.426
V4c			0.737	0.055							0.543
V1e					0.818	-					0.669
V2e					0.829	0.054					0.687
V8e					0.726	0.058					0.527
V9e					0.821	0.056					0.674
V10e					0.656	0.067					0.430
V3j							0.848	-			0.898
V7j							0.795	0.051			0.791
V9j							0.564	0.048			0.398
V10j							0.702	0.051			0.616
V11j							0.750	0.055			0.704
V14j							0.648	0.050			0.526
V15j							0.667	0.044			0.556
V1p									0.850	-	0.583
V2p									0.758	0.078	0.773
V3p									0.590	0.097	0.391
Chi-Square = 112.593, df = 94, relative Chi-Square = 1.198, p-value = 0.093, RMSEA = 0.024, RMR = 0.039, GFI = 0.973, NFI = 0.983, TLI = 0.992, CFI = 0.997											

4. Research Findings and Results

The results of the second-order confirmatory factor analysis provide empirical evidence of the hierarchical relationships among labor productivity factors and their observed variables. Rather than merely confirming the presence of commonly reported factors, the study quantifies their relative importance through statistically validated factor loadings at both the construct and sub-component levels. The majority of survey respondents were male, accounting for 73.2%, and the predominant age group was between 31 and 40 years old (45.2%), followed by the 41 to 50 age group (23.2%). The project's most common type of work was bricklaying/plastering, making up 43.5%. Most respondents had between 1 and 10 years of experience in their field. The second-order confirmatory factor analysis model results identified five key factors influencing construction labor productivity, along with 24 indicator variables, as shown in Table 2 and Table 3.

Therefore, based on Table 3, the analysis of the relationship components of factors affecting construction labor productivity using AMOS software yielded the following model fit indices: Chi-Square = 112.593, df = 94, relative Chi-Square = 1.198, p-value = 0.093, RMSEA = 0.024, RMR = 0.039, GFI = 0.973, NFI = 0.983, TLI = 0.992, and CFI = 0.997. The model fit indices meet the specified criteria: the Relative Chi-Square value should be less than 2; the statistical significance level (p-value) should be greater than 0.05; the Root Mean Squared Error of Approximation (RMSEA) and Root Mean Squared Residual (RMR) values should be less than 0.05; and the Goodness of Fit Index (GFI), Tucker-Lewis Index (TLI), Normal Fit Index (NFI), and Comparative Fit Index (CFI) should all be more significant than 0.95 [55].

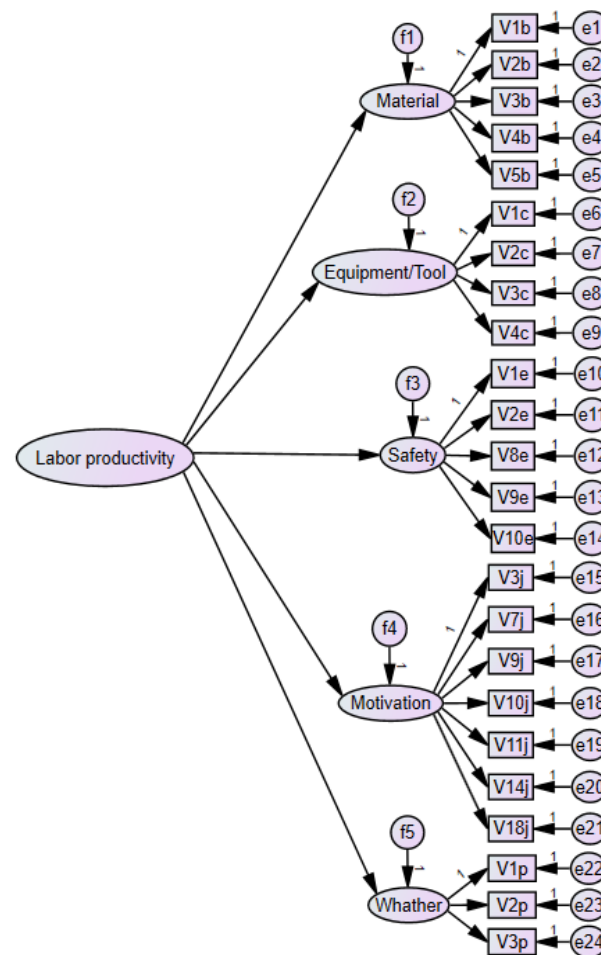


Fig. 5 Second-order confirmatory factor model

Table 3: Regression coefficients of key factors affecting construction labor productivity

Criteria	Labor Productivity		R^2	AVE	CR
	β_i	S.E.			
1. Materials	0.910	0.060	0.828	0.554	0.861
2. Equipment/Tools	0.971	-	0.942	0.578	0.845
3. Safety	0.903	0.054	0.815	0.598	0.880
4. Motivation	0.786	0.060	0.618	0.642	0.925
5. Weather	0.507	0.076	0.227	0.644	0.842

Thus, Labor Productivity consists of five key components, with Equipment/Tools being the most significant, followed by Materials, Safety, Motivation, and Weather, respectively. Considering the weight values of each component from Table 2:

The highest-weighted indicator for Materials is V3b, followed by V1b, V2b, V4b, and V5b, respectively.

The highest-weighted indicator for Equipment/Tools is V1c, followed by V2c, V4c, and V3c, respectively.

The highest-weighted safety indicator is V2e, followed by V9e, V1e, V8e, and V10e, respectively.

The highest-weighted indicator for Motivation is V3j, followed by V7j, V11j, V10j, V15j, V14j, and V9j, respectively.

The highest-weighted indicator for Weather is V1p, followed by V2p and V3p, respectively.

5. Conclusion

This study contributes to the construction management literature by providing a quantified and empirically validated hierarchy of labor productivity¹ within the context of Thai residential high-rise construction projects in urban areas. Although several identified factors align with those reported in prior studies, their relative importance and structural relationships differ when examined through a second-order measurement model. The findings demonstrate that the dominance of certain factors and sub-components is context-dependent, reflecting the operational characteristics of high-rise construction in dense urban environments. This hierarchical and quantified structure provides a more rigorous basis for managerial decision-making than conventional factor listing or subjective ranking methods.

Summary of Model Validation for Key Indicators of Construction Labor Productivity: The validation of the Labor Productivity model, which analyzes the relationships between 24 observed variables and five latent variables, revealed that the model aligns well with empirical data. The correlation between observed variables within each component was statistically significant at 0.05 ($p < 0.05$). This indicates that all five latent factors positively influence construction labor productivity and that all 24 sub-components are appropriately classified as part of labor productivity. The ranking of key components affecting labor productivity

is as follows: Equipment/Tools (highest importance)-0.971, Materials-0.910, Safety-0.903, Motivation-0.786, and Weather-0.507. These findings are consistent with the theories of Smith [56] and Taylor [57], which highlight those efficient tools and equipment enhance work performance, reduce time consumption, and minimize process inefficiencies.

Additionally, they align with the research of Juran and Gryna [58], which states that investing in modern tools and equipment significantly improves production quality and speed. Similarly, Afolabi AO et al. found that equipment and tools have the highest direct positive impact on labor efficiency, as high-quality and appropriate tools help increase work speed, reduce fatigue, lower accident risks, and enhance worker safety [59, 60]. Furthermore, the analysis identified Materials as the second most important factor. The weighting coefficients indicate that availability, sufficiency, and quality of materials help reduce waste, shorten production time, and improve labor efficiency. This aligns with Deming's [61] principle, which states that standardized materials help reduce production errors, as well as Chopra and Meindl's [62] findings, which emphasize that effective material management directly impacts labor productivity and organizational competitiveness.

Based on the analysis, developing and improving equipment and tools for readiness and efficient material management are clear strategies for enhancing labor productivity within an organization. Investing in these two factors should be a key focus in strategic planning to strengthen the organization's long-term competitiveness.

6. Application of Research Findings

The dominance of the Equipment/Tools factor, as reflected by its high standardized loading (0.971), indicates that equipment-related conditions constitute a primary leverage point for enhancing labor productivity in residential high-rise construction projects. In practical terms, this quantified hierarchy suggests that, under resource constraints, construction managers should prioritize the adequacy, reliability, and task suitability of equipment before allocating additional resources to other productivity-related factors. In dense urban high-rise environments, inefficiencies in lifting systems, material-handling equipment, or tool availability can quickly translate into idle labor time and workflow disruptions. Therefore, strategic equipment planning and preventive maintenance should be considered core productivity-enhancement strategies rather than supplementary investments.

These practical implications are derived from residential high-rise construction contexts and may require adjustment when applied to other project types or non-urban construction environments.

7. Limitations and Future Research Directions

7.1. Study Limitations

This study has several limitations that should be considered when interpreting the findings. First, the empirical data were collected exclusively from residential high-rise building projects located in Bangkok and its surrounding metropolitan areas. While this focus enhances contextual relevance, it may limit the generalizability of the results to other regions of Thailand, particularly rural areas or provinces with different labor conditions and construction practices.

Second, the study employed a non-probability (convenience) sampling approach for initial site and respondent selection. Although this approach facilitated access to active construction sites, it may affect sample representativeness, as participation depended on availability and accessibility rather than random selection. Consequently, the derived factor hierarchy should be interpreted as context-specific rather than universally applicable.

Third, the use of self-reported questionnaire data introduces the possibility of response bias, including subjective judgment and recall bias. In addition, the cross-sectional research design captures labor productivity factors at a single point in time, limiting the ability to examine causal relationships or productivity dynamics across different project stages.

Taken together, these limitations indicate that the proposed measurement model reflects labor productivity conditions specific to urban residential high-rise construction in Thailand, rather than a generalized model applicable to all construction contexts.

During the measurement model refinement process, eleven observed indicators were removed due to low standardized factor loadings, high inter-item correlations, or large residuals that adversely affected overall model fit. These indicators primarily represented overlapping or redundant measurements within their respective first-order constructs rather than theoretically distinct productivity dimensions. Significantly, the removal of these indicators did not alter the model's conceptual structure, as all five first-order latent factors remained intact and were represented by multiple empirically valid indicators. The refined measurement model is therefore interpreted as a more parsimonious representation of labor productivity determinants within the studied context, rather than a reduction of theoretical scope. Future studies may re-examine the excluded indicators under different construction contexts, project types, or data collection approaches to further assess their relevance and stability.

7.2. Directions for Future Research

To address these limitations, future research should expand data collection to include diverse geographical regions and project types, such as low-rise residential, commercial, or infrastructure projects, to enhance the external validity of labor productivity measurement models.

Future studies are also encouraged to adopt probability-based sampling techniques to improve representativeness and reduce selection bias. In addition, longitudinal research designs could be employed to capture changes in labor productivity factors across different construction phases and to assess causal relationships better.

Furthermore, integrating objective productivity indicators, site observations, or mixed-method approaches could help triangulate self-reported data and strengthen measurement robustness. Expanding the model to incorporate organizational, managerial, and technological variables may also provide a more comprehensive understanding of productivity determinants in complex construction environments.

Table 4: Indicators removed during measurement model refinement

Removed indicator			
Indicator variable		Criteria	Primary statistical reason
1	V3e	Safety	Large standardized residuals
2	V4e	Safety	High inter-item correlation
3	V5e	Safety	Large standardized residuals
4	V6e	Safety	Large standardized residuals
5	V7e	Safety	Low standardized factor loading
6	V1j	Motivation	High inter-item correlation
7	V2j	Motivation	High inter-item correlation
8	V4j	Motivation	Large standardized residuals
9	V5j	Motivation	Large standardized residuals
10	V6j	Motivation	Low standardized factor loading
11	V8j	Motivation	Low standardized factor loading
12	V12j	Motivation	High inter-item correlation
13	V13j	Motivation	Low standardized factor loading

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