Enhancing Workforce Productivity in Reinforced Concrete Construction: An Integrated Relative Importance Index Analysis and Monte Carlo Approach (Case Study: Darma Bangsa School)

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ABSTRACT

Labor productivity profoundly affects the time and cost efficiency of construction projects. This study identifies and analyses the factors affecting the productivity of reinforced concrete construction workers at the Darma Bangsa School project in Bandar Lampung to optimise workforce performance. The study employs the Relative Importance Index (RII) and Monte Carlo simulation to model the influence of diverse factors on overall production and to identify areas need enhancement. Data obtained from a 5-point Likert scale questionnaire were analysed utilising SPSS v.29 and Microsoft Excel. The findings demonstrate that Accurate and Realistic Planning and Scheduling (X2.5) display the greatest variability, with a standard deviation of 0.924, indicating a substantial impact on worker productivity. The mean total productivity was 3.90, with a standard deviation of 0.291, signifying stable worker performance. Hence, the Monte Carlo simulation employed for simulating uncertainty and variability of components effectively evaluated and offered management insights for formulating plans to improve skills, experience, and supervisory efficacy. These findings provide more precise managerial strategy for mitigating hazards and enhancing efficiency in construction projects within this region.

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1. INTRODUCTION

Labor productivity is a critical determinant of efficiency in construction projects, directly impacting both time and cost [1]. Labor productivity refers to the ability of workers to perform a specific task or job [2]. In this context, labor refers to workers as defined by SNI (Standar Nasional Indonesia), which denotes individuals employed to carry out particular tasks in a project or industrial activity. In the context of reinforced concrete structures, variations in worker performance can lead to significant project delays and budget overruns.

Recent studies emphasize the importance of improving labor productivity in reinforced concrete construction through better resource management, skills development, and planning [3] [4]. For instance, Lindhard et al. (2025) identified incomplete designs, worker skills, and project management competence as major productivity drivers in Asian construction projects [5]. Likewise, Sun et al. (2023) demonstrated that lean construction and process efficiency significantly influence labor performance [6].

The present research explores the factors that impact the productivity of workers engaged in reinforced concrete construction, with the Darma Bangsa School project in Bandar Lampung serving as a case study. In the construction industry, where time and cost are critical factors, optimizing worker productivity can provide significant advantages. Therefore, contractors are required to measure and enhance the productivity of reinforced concrete construction workers on ongoing projects to achieve targets in terms of quality, time, and cost [7].

This study analyzes the factors influencing reinforced concrete construction worker productivity to identify key areas for improvement and optimization. The research employs a combined approach using the Relative Importance Index and Monte Carlo simulation to provide insights into the factors requiring prioritization. Ultimately, this study aims to contribute to the development of enhanced managerial strategies for construction project management, mitigating risks and maximizing worker productivity.

2. METHODS

This study employed a quantitative research design using a questionnaire as the primary data collection instrument. The questionnaire consisted of multiple-choice questions utilising a 5-point Likert scale (1-5), where 1 represented "Strongly Unimportant" and 5 represented "Strongly Important". The questionnaire was developed based on a review of existing literature and focused on factors influencing reinforced concrete construction worker productivity (as detailed in Table 1).

To ensure validity, the questionnaire design was informed by recent studies such as those by Lindhard et al. (2025) and Sun et al. (2023) which identified critical productivity factors such as labor skill, material location, planning efficiency, and supervision quality [8] [5] [6].

Data collected from the questionnaire were analysed using SPSS version 29 and Microsoft Excel. SPSS was used for descriptive statistics, correlation analysis, and regression analysis, while Excel was used for data organisation, calculations for the Relative Importance Index and Monte Carlo Simulation.

Table 1. Research Factors and Variables

No	Factor	Variable	Ref.
1	Labor Factor (X_1)	Skills in performing tasks ($X_{1.1}$)	[2] [7]
		Age during work ($X_{1.2}$)	[9]
		Training and expertise (workers, foremen, supervisors) ($X_{1.3}$)	[10] [11]
2	Management Factor (X_2)	Leadership and managerial competence ($X_{2.1}$)	[12]
		Effective communication among workers ($X_{2.2}$)	[12]
		Worker supervision ($X_{2.3}$)	[9]
		On-site management ($X_{2.4}$)	[12]
		Accurate and realistic planning and scheduling ($X_{2.5}$)	[12]
3	Motivation Factor (X_3)	Labor wages ($X_{3.1}$)	[13] [14]
		Wage payments ($X_{3.2}$)	[12]
		Work accident insurance ($X_{3.3}$)	[12]
4	Project Execution Factor (X_4)	Number of workers ($X_{4.1}$)	[15]
		Experience in the construction field ($X_{4.2}$)	[9]
		Rework due to issues or design changes ($X_{4.3}$)	[11] [4]
		Unclear or frequently chaning instructions during execution ($X_{4.4}$)	[12]
		Availability of materials on-site ($X_{4.5}$)	[9]
5	Eksternal Factor(X_5)	Construction permits ($X_{5.1}$)	[12]
		Material fluctuations ($X_{5.2}$)	[12]
6	Material and Equipment Factor (X_6)	Condition and quality of materials and equipment ($X_{6.1}$)	[15] [9]
		Compliance with standards and equipment efficiency ($X_{6.2}$)	[16]
		Adequacy of equipment on-site ($X_{6.3}$)	[17]
7	Enviromental and Working Condition Factor (X_7)	Limited workspace ($X_{7.1}$)	[9]
		Working condition (e.g. hazardous areas, noise, toxic exposure, lightning, ventilation, temperature, ground condition) ($X_{7.2}$)	[15]
8	Technical Factor (X_8)	Level of design complexity ($X_{8.1}$)	[3]
		Clarity of design and technical specifications ($X_{8.2}$)	[3]
		Use of modern construction methods and technologies ($X_{8.3}$)	[18]
9	Time Factor (X_9)	Frequency of overtime work ($X_{9.1}$)	[4]
		Worker punctuality ($X_{9.2}$)	[17]
		Adequate rest time ($X_{9.3}$)	[15]
10	Work Safety Factor (X_{10})	Compliance with safety protocols ($X_{10.1}$)	[19]
		Safety equipment availability ($X_{10.2}$)	[15] [11] [9]
		Safety signs availability ($X_{10.3}$)	[20] [10]

2.1 Data Collection and Analysis

2.1.1 Questionnaire Distribution and Expert Sampling Criteria

The research questionnaire was distributed to pre-selected respondents using expert sampling. The criteria for expert selection in this study were as follows:

1. Involvement in the Darma Bangsa School construction project.
2. Holding a position within the Darma Bangsa School project as a project manager, site engineer, supervisor, or foremen.
3. Possessing in-depth knowledge of reinforced concrete structural work.

2.1.2 Validity Test

A validity test was conducted using factor analysis with SPSS v.29 software. The research instrument was considered valid if it met the following criteria: a Kaiser-Meyer-Olkin value above 0.5 with a significance level of less than 0.05 (sig < 0.05), eigenvalues factor greater than 1, and loadings factor greater than 0.5.

2.1.3 Reliability Test

A reliability test was performed to ensure the consistency of the research instrument. The questionnaire was deemed reliable if the Cronbach's Alpha value exceeded 0.7 (Alpha > 0.7).

2.1.4 Relative Importance Index Analysis

Calculations and analysis using the Relative Importance Index method were performed to prioritize the key factors influencing worker productivity. This analysis employed a Likert scale, as shown in Table 2 below.

Table 2. Likert Scale

Category	Intervals
Strongly Unimportant	1.00 –1.80
Unimportant	1.90 –2.60
Neutral	2.70 –3.40
Important	3.50 –4.20
Strongly Important	4.30 –5.00

$$RII = \frac{\Sigma\omega}{A \times N} \quad (1)$$

Where,

RII : relative Importance Index
ω : respondent's weight
A : maximum number on Likert scale
N : total number of respondents

2.1.5 Monte Carlo Simulation

Monte Carlo simulation is a statistical method that models and predicts the impact of uncertainty in a given system or process. It involves random experimental sampling. In a 2019 research study by S.R.S. Panjaitan [21], a Monte Carlo simulation was used to optimise the construction schedule of hotel, minimising project duration through critical path analysis. This work demonstrates the technique's sustainability for modelling and analysing real-world systems and situations.

The following are the key steps in implementing the Monte Carlo simulation in this research:
1. Probability distribution determination: Define appropiate probability distributions based on the available data.
2. Convert the probability distribution into cumulative frequencies, which will serve as a guide for grouping random number intervals.
3. Iteration and calculation: perform multiple iterations to generate random numbers for each factor, then calculate the total productivity as influenced by these factors.
4. Statistical analysis: Analyse the iteration results using descriptive statistical analysis techniques, such as calculating the mean, standard deviation, and range, to interpret findings.

The Monte Carlo simulation employed the following equations, as detailed by Sugiyono [21]:

Nomal Distribution (Gaussian):

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right) \quad (2)$$

Where,
μ : mean
σ : standard deviation

- Uniform Distribution:

$$f(x) = \frac{1}{b-a}, a \leq x \leq b \quad (3)$$

Where,
a : lower bound
b : upper bound

- Random Sampling:

$$X = a + (b-a) R \quad (4)$$

Where,
R : a random number between 0 and 1

- Total Productivity:

$$Productivity = \frac{F_1+F_2+F_n}{n} \quad (5)$$

Where,
F_n : random value from the probability distribution
n : number of factors

- Mean:

$$\mu = \frac{\sum_{i=1}^{N} X_i}{N} \quad (6)$$

- Standard Deviation:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(X_i-\mu)^2}{N}} \quad (7)$$

Where,
X_i : result of each iteration
N : number of iterations

3. RESULTS AND DISCUSSION

3.1 Questionnaire Validity Test

Tables 3 reveals that of the 32 variables tested across 10 factors, 5 were deemed invalid. Subsequent analysis utilized only the valid variables.

Table 3. Validity Test Result

Variable (statement)	*Pearson Correlation*	r's table (0,05 and df = 8)	Annotation
$X_{1.1}$	0,681	0,6319	Valid
$X_{1.2}$	0,532	0,6319	Invalid
$X_{1.3}$	0,871	0,6319	Valid
$X_{2.1}$	0,176	0,6319	Invalid
$X_{2.2}$	0,186	0,6319	Invalid
$X_{2.3}$	0,815	0,6319	Valid
$X_{2.4}$	0,770	0,6319	Valid
$X_{2.5}$	0,660	0,6319	Valid
$X_{3.1}$	0,763	0,6319	Valid
$X_{3.2}$	0,787	0,6319	Valid
$X_{3.3}$	0,798	0,6319	Valid
$X_{4.1}$	0,670	0,6319	Valid
$X_{4.2}$	0,862	0,6319	Valid
$X_{4.3}$	0,897	0,6319	Valid
$X_{4.4}$	0,838	0,6319	Valid
$X_{4.5}$	0,883	0,6319	Valid
$X_{5.1}$	0,681	0,6319	Valid
$X_{5.2}$	0,769	0,6319	Valid
$X_{6.1}$	0,826	0,6319	Valid
$X_{6.2}$	0,704	0,6319	Valid
$X_{6.3}$	0,970	0,6319	Valid
$X_{7.1}$	0,691	0,6319	Valid
$X_{7.2}$	0,762	0,6319	Valid
$X_{8.1}$	0,746	0,6319	Valid
$X_{8.2}$	0,195	0,6319	Invalid
$X_{8.3}$	0,878	0,6319	Valid
$X_{9.1}$	0,676	0,6319	Valid
$X_{9.2}$	0,551	0,6319	Invalid
$X_{9.3}$	0,702	0,6319	Valid
$X_{10.1}$	0,686	0,6319	Valid
$X_{10.2}$	0,865	0,6319	Valid

3.2 Questionnaire Reliability Test

As shown in Table 4, reliability testing indicate that 6 out of 10 factors met the reliability criteria and were subsequently used in data analysis.

Table 4. Factor Reliability Test Result

Factor	N	Croncbach's Alpha	Annotation
X_1	2	0,586	Fairly reliable
X_2	3	0,906	Reliable
X_3	2	0,398	Poor
X_4	5	0,853	Reliable
X_5	2	0,103	Very poor
X_6	3	0,791	Reliable
X_7	2	0,110	Very poor
X_8	2	0,659	Reliable
X_9	2	0,311	Poor
X_{10}	3	0,794	Reliable

3.3 Relative Important Index Analysis

RII analysis was performed on questionnaire responses from 10 respondents (Table 5). Each response was weighted according to the three evaluation criteria detailed in Table 6.

Table 5. Questionnaire Result

Var.	1	2	3	4	5	6	7	8	9	10
X1.1	5	5	4	5	5	5	4	5	5	4
X1.2	5	4	2	5	2	4	4	2	4	1
X2.3	4	5	5	5	4	4	5	2	5	5
X2.4	5	5	5	4	5	5	4	5	3	3
X2.5	5	5	5	5	4	4	5	5	5	2
X3.1	5	4	4	5	5	5	5	5	4	2
X3.2	4	4	4	4	2	3	4	4	5	5
X4.1	4	4	4	4	5	5	4	4	4	1
X4.2	5	5	5	5	5	5	4	5	5	3
X4.3	5	5	4	4	5	1	2	4	4	5
X4.4	4	4	5	5	4	1	4	4	4	3
X4.5	5	4	4	4	5	4	4	4	4	3
X5.1	2	4	4	4	2	2	4	4	3	3
X5.2	5	3	2	3	1	3	2	2	3	3
X6.1	5	2	4	4	5	4	4	4	4	2
X6.2	5	4	4	5	4	4	4	4	4	2
X6.3	5	4	4	5	5	4	4	4	4	4
X7.1	4	3	4	4	4	4	3	4	4	3
X7.2	4	3	2	5	5	4	4	4	3	4
X8.1	2	5	2	5	2	4	4	4	4	5
X8.2	5	5	4	4	5	4	2	4	5	3
X9.1	4	4	5	4	4	4	1	2	3	2
X9.2	5	4	4	5	4	4	5	4	4	2
X10.1	4	5	2	4	4	4	2	5	5	2
X10.2	5	4	2	5	2	2	4	4	4	3
X10.3	4	4	2	4	2	1	2	4	4	4

Table 6. Respondent Evaluation Weights

No.	Score (w_iS_i) Education level	Years of work experience	Professional Certification	Total	Weight
1	24	40	30	94	0,160
2	18	40	30	88	0,150
3	18	8	18	50	0,075
4	6	40	12	58	0,085
5	6	16	12	34	0,099
6	12	40	12	64	0,058
7	18	40	18	60	0,109
8	24	40	12	76	0,102
9	18	24	18	20	0,130
10	6	8	6	58	0,034
Total				588	1

Table 7 presents the RII analysis results, calculated using equation and incorporating the factor weightings specified in Table 6.

Table 7. Analysis Result

Factor	Variable	RII (%)
Labor Factor (X_1)	$X_{1.1}$	88,2
	$X_{1.3}$	65,7
Mean		77,0
Management Factor (X_2)	$X_{2.3}$	83,4
	$X_{2.4}$	83,4
	$X_{2.5}$	85
Mean		83,9
Project Execution Factor (X_4)	$X_{4.1}$	75,3
	$X_{4.2}$	88,2
	$X_{4.3}$	75,3
	$X_{4.4}$	73,7
	$X_{4.5}$	78,6
Mean		78,2
Material and Equipment Factor (X_6)	$X_{6.1}$	73,8
	$X_{6.2}$	77,0
	$X_{6.3}$	81,8
Mean		77,5
Technical Factor (X_8)	$X_{8.1}$	72,2
	$X_{8.3}$	78,6
Mean		75,4
Work Safety Factor (X_{10})	$X_{10.1}$	72,2
	$X_{10.2}$	69,0
	$X_{10.3}$	62,5
Mean		67,9

3.4 Monte Carlo Simulation

The Monte Carlo simulation in this study models the distribution of worker productivity based on the combined effects of key contributing factors. These factors, identified through Relative Importance Index analysis and selected for their significant impact on productivity are the top five factors presented in Table 8.

Table 8. Factor Ranking

Rank	Factor	RII (%)	Mean	Standard Deviation
1	Skills in performing tasks ($X_{1.1}$)	88,2	4,7	0,458
2	Experience in the construction field ($X_{4.2}$)	88,2	4,7	0,640
3	Accurate and realistic planning and scheduling ($X_{2.5}$)	85,0	4,5	0,922
4	Workers supervision ($X_{2.3}$)	83,4	4,4	0,916
5	On-site management ($X_{2.4}$)	83,4	4,4	0,800

Each factor is modeled using a normal distribution, chosen for its sustainability to symmetric data centered around a mean. This distribution is appropriate for factors exhibiting natural variation without strict limitations. After assigning distributions, the Relative Importance Index values were incorporated into the Monte Carlo simulation, which was run for 1,000 iterations in Microsoft Excel. The result is presented in Table 9 below.

Table 9. Iteration Results

Iteration	$X_{1.1}$	$X_{4.2}$	$X_{2.5}$	$X_{2.3}$	$X_{2.4}$	Total Productivity
1	4,85	4,96	3,87	4,17	3,79	3,72
2	5,00	4,25	3,94	3,97	3,15	3,49
3	5,38	5,47	5,55	4,22	4,33	4,28
4	5,13	4,47	3,54	4,65	4,40	3,81
5	5,70	4,17	4,58	4,51	4,06	3,95
1000	4,50	4,05	5,29	5,27	3,86	3,93
Mean	4,68	4,72	4,49	4,44	4,39	3,90
Std. Dev.	0,474	0,661	0,924	0,901	0,766	0,291

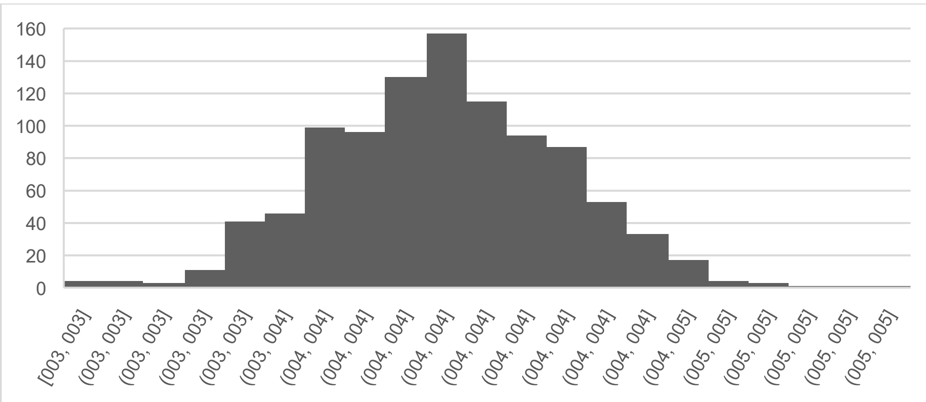

Figure 1. Histogram of Productivity Distribution

4. CONCLUSION

The Monte Carlo simulation optimised the productivity of reinforced concrete workers, yielding an average total productivity of 3.90 with a standard deviation of 0.291. Individual factor variables, from Skills in Performing Tasks (X1.1) to Field Management (X2.4), exhibit average values between 4.39 and 4.72. Realistic Work Planning and Scheduling (X2.5) demonstrated the highest variability, with a standard deviation of 0.924, indicating a more fluctuating influence on total productivity compared to other factors. The relatively low standard deviation of total productivity suggests a stable level of variation, implying consistent worker productivity despite fluctuations in other factors.

Therefore, the Monte Carlo simulation facilitates variability analysis for each factor and enables the identification of targeted strategies for productivity enhancement, such as improving skills, experience, planning, and supervision.

Skills, experience, planning, and effective supervision influence the productivity of reinforced concrete workers. Regular training or recruiting certified workers can enhance technical skills, whereas job rotation programs accelerate on-the-job experience and development. Realistic planning and scheduling, supported by Building Information Modelling (BIM) technology, optimises resource allocation. Effective supervision through supervisor training and real-time monitoring, coupled with efficient communication and field management, minimises downtime and ensures smooth project execution.

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