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Productivity Analysis of Red Brick Wall Installation: Comparing Field Data with Regulatory Standards and Future Trends

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Abstract. Infrastructure and building construction are essential sectors driving economic growth, contributing significantly to job creation, technological advancement, and economic development. This research aims to measure the productivity of labor in installing red brick walls and compare it with standards set by regulations. Utilizing observation and data collection methods, followed by comprehensive data analysis, this study assesses on-site labor productivity and benchmarks it against standards from the Ministry of Public Works and Public Housing (PUPR). Additionally, simple forecasting models, such as linear regression, are employed to predict future productivity trends. The findings reveal higher on-site productivity compared to regulatory benchmarks, potentially due to superior management practices, advanced techniques, and favorable working conditions. The predictive model (y = 0.2828x + 5.5273) indicates a positive productivity trend over time, despite daily fluctuations influenced by various factors. The research underscores the importance of aligning field practices with regulatory standards and provides insights into construction sector policy developments. The results offer valuable data for improving the efficiency and effectiveness of construction projects and inform future policy recommendations to enhance labor productivity in the industry.

Keywords: Labor productivity, red brick wall installation, forecasting models, linear regression, productivity analysis, PUPR Regulations

INTRODUCTION

Infrastructure and building construction are essential sectors that drive economic growth. These sectors contribute significantly to job creation, technological advancement, and economic development. Types of activities in construction encompass various operations such as the construction of office buildings, residential housing, highways, bridges, tunnels, airports, seaports, and utility installations like water supply lines, electricity, gas, and telecommunications. Each type of activity has specific processes and involves various stages, such as planning, design, material procurement, and construction execution. Understanding the types of work in construction and the factors that affect productivity is crucial for improving efficiency and effectiveness in the building process. Increased productivity allows for the completion of construction projects on time, within budget, and with high quality, which in turn enhances the competitiveness of this sector and its contribution to the national economy.

In the construction world, various materials and techniques evolve with technological advancements and the need for more efficient and sustainable buildings. Modern construction projects employ various activities that significantly enhance productivity. For instance, red brick walls, concrete, and reinforced concrete provide essential structural integrity, while formwork systems streamline the shaping and curing of concrete. Additionally, advanced flooring techniques ensure durability and efficiency in building construction.

Red brick walls are still commonly used in construction because they have several advantages, such as sturdy, durable, and easy to obtain. Installing red brick walls is vital in building construction for residential and commercial projects. This activity requires skilled personnel and careful planning to achieve optimal quality, time, and cost results. To ensure the efficiency and effectiveness of the construction process, measuring labor productivity in installing red brick walls is very important.

Labor productivity in red brick wall installation work is often still not optimal. Several factors, such as lack of worker skills and experience, use of inefficient work methods, lack of supervision and coordination, unsupportive working environment conditions, and other factors such as fatigue, weather, and material availability, can cause this [1][2][3].

Over time, regulations related to labor productivity and wages in the construction sector have undergone various changes and adjustments. Through the Ministry of Public Works and Public Housing (PUPR), the government of Indonesia has issued several regulations to set productivity standards and labor wages. Some of these regulations are: Minister of Public Works and Public Housing Regulation Number 28/PRT/M/2016, Minister of Public Works and Public Housing Regulation Number 28/PRT/M/2018, Minister of Public Works and Public Housing Regulation Number 1 of 2022, and Minister of Public Works and Public Housing Regulation Number 8/PRT/M/2023. These regulations reflect the government's efforts to improve the construction industry's efficiency and productivity and adapt to technological and methodological developments. However, conditions in the field often differ from those stipulated in the regulations, necessitating research to understand the extent to which the standards outlined in these regulations are applied and relevant to actual field conditions.

This research aims to measure the level of productivity of installing red brick walls in the field and compare it with the standards set by regulations. Additionally, this study analyzes simple forecasting models like linear regression to predict future productivity values.

Therefore, this study will provide an overview of the alignment between field practices and regulatory standards, provide insight into construction sector policy developments, and provide future policy recommendations. We hope this research will obtain valuable data and information to improve the efficiency and effectiveness of construction projects and provide input for developing policies and standards in the construction sector.

LITERATURE REVIEW

Productivity

Each individual may interpret the term "productivity" differently. Productivity is the correlation between tangible or physical outcomes (comprising goods and services) and the resources employed. Essentially, productivity serves as a metric for efficiency in production, gauging the ratio between output (what we produce) and input (what we utilize)) [4].

The construction industry aims to improve productivity, especially in labor-intensive tasks like bricklaying. This study measures on-site productivity for installing red brick walls and compares it with regulatory benchmarks to understand workforce efficiency. By using linear regression analysis, the research also predicts future productivity trends. These insights help identify the impact of management practices, techniques, and working conditions on productivity. However, there remains a research gap in fully understanding the factors behind productivity fluctuations and their long-term effects on efficiency.

Productivity in the construction industry critically determines project success. It reflects how efficiently and effectively resources like labor, materials, time, and technology are utilized. In construction, various indicators measure productivity, including project completion speed, incurred costs, quality of the final result, and workplace safety. Productivity refers to the ability to generate outputs from a set of inputs. In everyday conversation, we often talk about how efficient or useful various land or natural resource reserves are or how productive, hardworking individuals are. Here, we discuss productivity in a limited way – as the quantitative relation between labor and other inputs in production and the consequent output of goods and services. Labor productivity, for example, refers to how many production units we obtain per labor unit. The absolute magnitude may not always mean much, but if, over time, Enhancements in labor productivity are evident when the same labor inputs result in increased output. [17].

Thus, we can formulate productivity as follows.

$$P = \frac{O}{I} \tag{1}$$

Where
P = productivity
O = output
I = input

The volume of work represents the value of output in the context of construction. Hence, its units can be m³, m², m³, etc., depending on the type of work. Meanwhile, the input value in the construction context consists of the amount of time, labor, materials, and so on, depending on the productivity value being sought [7].

In this study, we aim to determine the labor productivity in red brick wall installation work, so we use the following formula:

$$P = \frac{V}{t \times n} \tag{2}$$

Where
P = labor productivity (m^2/OH); t = duration of work (hours); n = number of workers (individuals).

TABLE 1. Research gap.

Aspect	**Current Research**	**Reference**	**Topic**
Productivity Measurement	Measuring on-site productivity for installing red brick walls and comparing it with regulatory standards.	1. [5], [2] 2. [6] 3. [7] 4. [4] 5. [8] 6. [9]	1. Brick walls 2. Masonry 3. Column 4. Comparison PUPR 5. Bricklaying 6. Ceramic Floor
Analysis Methodology	Using linear regression analysis to predict future productivity based on existing data.	1. [5],[10], [11] 2. [2] 3. [6],[7] 4. [12] 5. [1] 6. [13] 7. [14] 8. [3]	1. ANN 2. Method Productivity Delay Model 3. Work Sampling 4. Per Floor per Gross 5. Productivity rating method 6. Time motion study 7. Kinematic data and deep learning 8. RII Method
Management Practices	Found that good management and advanced techniques contribute to higher productivity.	[5][2][6][7][15]	significant improvements in labor productivity, ensuring the successful and timely completion of construction projects.
Labor Efficiency	Recording lower labor time per unit area than standards, indicating high efficiency.	[5][2][6][7][15]	integrating advanced prediction models with higher efficiency
Daily Variability	Showing daily productivity fluctuations around the trend line, reflecting natural variability in productivity data.	[16][2]	Using daily productivity data

The Productivity Standards Based on The Ministry of Public Works and Housing Regulations

According to the Ministry of Public Works and Housing Regulations, the standard productivity value is established to ensure efficiency and quality in the construction industry. Below is an explanation of the productivity standards regulated in various Ministerial Regulations: (1) Minister of Public Works and Public Housing Regulation Number 28/PRT/M/2016: This regulation governs the guidelines for unit price analysis in public works. The productivity standards for labor and material usage are set for various types of construction work, such as road, bridge, and building construction. The regulations ensure that each project stays within the planned budget and timeframe by optimizing resource utilization [18]. (2) Minister of Public Works and Public Housing Regulation Number 28/PRT/M/2018: This regulation updates the existing standards and includes adjustments for new technologies and construction methods. Productivity standards are more detailed for specific tasks, covering aspects such as the number of workers, duration, and use of heavy equipment. These changes are made to enhance efficiency and accuracy in cost and time estimation for construction projects [19]. (3) Minister of Public Works and Public Housing Regulation Number 1 of 2022: This regulation emphasizes the importance of occupational safety and health (OSH) and productivity. The productivity standards also consider safety factors, ensuring productivity improvements do not compromise worker safety and health. It includes supervision and risk management guidelines in construction projects [20]. (4) Minister of Public Works and Public Housing Regulation Number 8/PRT/M/2023: This latest regulation introduces innovations in the use of digital technology and automation in construction. Productivity standards are updated to include Building Information Modeling (BIM), drones for surveying, and other automation technologies. The purpose of this regulation is to encourage the adoption of the latest technologies that can increase the productivity and quality of construction outputs while reducing project time and costs [21].

Each of these regulations provides guidelines and standards to improve the efficiency, effectiveness, and quality of construction projects in Indonesia. By adhering to these standards, construction projects are expected to be carried out more professionally, safely, and efficiently.

RESEARCH METHOD

Work Sampling Method

The Work Sampling Method involves an observer randomly selecting times to observe workers and their activities based on predetermined random numbers. The work sampling means the observer is not constantly present and observing the workers' activities. The observer uses random observations to conclude whether an event happened. It will also be apparent that the more random numbers or observation time, the greater the likelihood that the activity information will be close to the actual picture. In other words, the stronger the basis for the conclusion. The notes taken at each observation show various activities and the frequency of observed activities. Studying the frequency of each activity allows us to determine how worker groups allocate their time. This work sampling method is more time-efficient and cost-effective and requires less labor than other data collection methods [7]. Critical points of the work sampling method are (1) Work Sampling is a random observation method for studying work activities, (2) Observations are made at predetermined random times, (3) The more observations made, the more accurate the results, and (4) Work Sampling is a time, cost, and labor-efficient method.

Data Collection Method

Data gathering is an essential step preceding data analysis. Primary data collection involves direct observation at the construction site. Secondary data sources include images of brick wall construction, work productivity data, and the Ministerial Regulation of PUPR.

The data collection for this research was conducted by directly observing the Building construction project at Yogyakarta. The observations in this study focused on installing red brick walls. The researchers conducted the observations for seven days, conducting three daily sessions: session one from 10:00 to 10:15 WIB, session two from 13:00 to 13:15 WIB, and session three from 16:00 to 16:15 WIB. The components observed were 2 (two) groups of workers, each consisting of laborers and bricklayers.

Analysis Method

This study seeks to diagnose potential issues within the workforce to optimize labor efficiency. This study will thoroughly analyze labor productivity. The research will utilize a multifaceted approach that evaluates labor productivity against established benchmarks and compares it with on-site performance. This comparative analysis will be conducted by first employing the AHSP Coefficients outlined in Ministerial Regulation PUPR to assess labor productivity. The resulting productivity values will be juxtaposed with the labor productivity data collected from direct observations at the construction site. By conducting this comprehensive evaluation, we can gain valuable insights into the effectiveness of labor utilization and identify potential areas where productivity can be enhanced.

Flowchart of Research Process for Measuring and Comparing Labor Productivity in Red Brick Wall Installation

Figure 1 shows the research process initiated with observation and data collection, followed by a comprehensive data analysis. This analysis is segmented into four key areas: assessing labor productivity on-site, evaluating labor productivity based on PUPR Ministerial Regulation, comparing on-site labor productivity with regulatory standards, and developing simple forecasting models. These segmented analyses provide a detailed understanding of the current productivity levels and regulatory benchmarks. Following the data analysis, the insights gained from each key area are integrated to form the overall conclusion and recommendations. This final step consolidates the findings, offering practical strategies for enhancing labor productivity and aligning on-site practices with regulatory standards. The research thus follows a systematic approach to identify, compare, and forecast productivity, ultimately providing actionable recommendations for improvement.

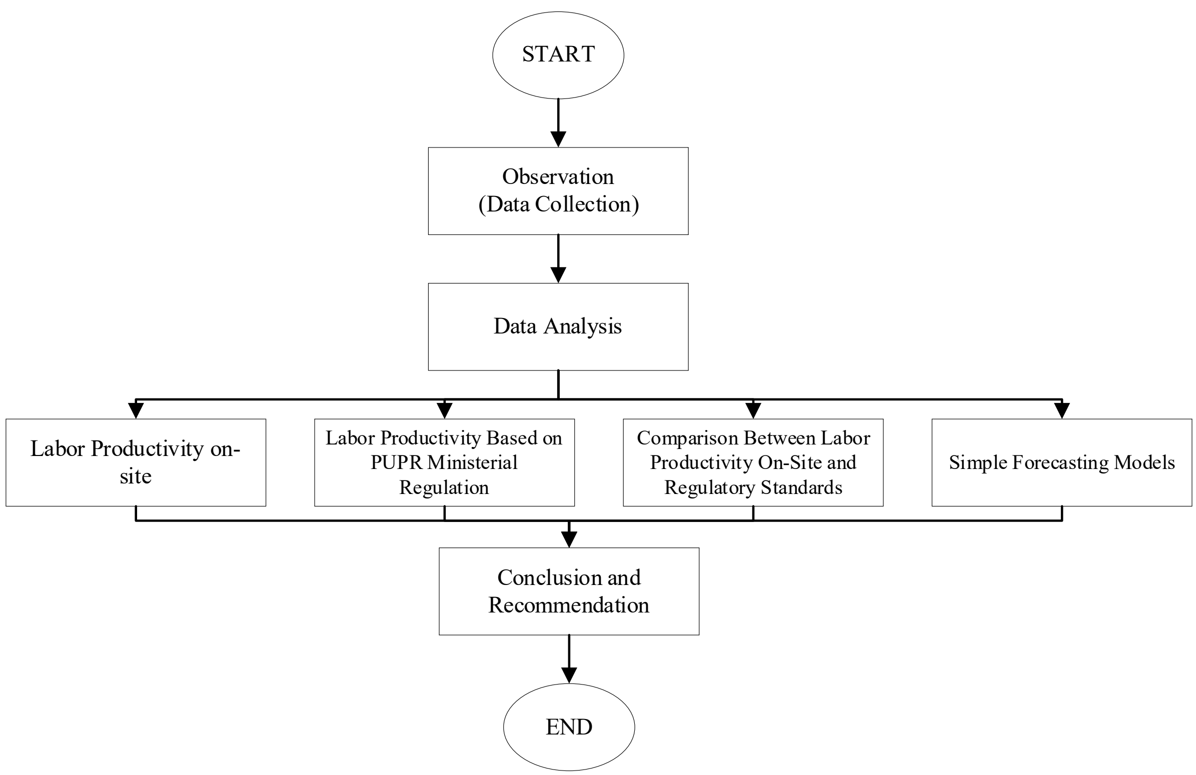

FIGURE 1. Research Process

RESULT AND DISCUSSION

Labor Productivity on-site

The research obtained the labor productivity values in the field from secondary data collected on-site and expressed these values in person/day units. The table below shows the labor productivity figures we observed in the field. Additionally, we calculated labor productivity on-site by measuring the actual volume of work completed and deriving the coefficients from these measurements.

TABLE 2. Volume and labor productivity on-site

Volume and Productivity of Brick Wall Construction			Session 1	Session 2	Session 3	Average/15 Minutes	The number of workers	The number of skilled workers	Worker Productivity	Average Group 1 and 2	Average	Skilled Worker Productivity	Average Group 1 and 2	Average
			m^2	m^2	m^2	m^2			m^2/days		m^2/days	m^2/days		m^2/days
			a	b	c	d=Avg (abc)	e	f	g=d/(e/28)	h=Avg(g)	i=Avg(h)	j=d/(f/28)	k=Avg(j)	l=Avg(k)
Days	1	1	0.300	0.180	0.120	0.200	1	1	5.600		**6.658**	5.600		**6.658**
		2	0.300	0.200	0.200	0.233	1	1	6.533	6.067		6.533	6.067	
	2	1	0.356	0.285	0.165	0.269	1	1	7.525			7.525		
		2	0.292	0.146	0.146	0.195	1	1	5.451	6.488		5.451	6.488	
	3	1	0.356	0.285	0.165	0.269	1	1	7.525			7.525		
		2	0.165	0.165	0.110	0.147	1	1	4.107	5.816		4.107	5.816	
	4	1	0.360	0.240	0.240	0.280	1	1	7.840			7.840		
		2	0.300	0.200	0.100	0.200	1	1	5.600	6.720		5.600	6.720	
	5	1	0.360	0.300	0.120	0.260	1	1	7.280			7.280		
		2	0.200	0.200	0.100	0.167	1	1	4.667	5.973		4.667	5.973	
	6	1	0.360	0.240	0.210	0.270	1	1	7.560			7.560		
		2	0.360	0.240	0.240	0.280	1	1	7.840	7.700		7.840	7.700	
	7	1	0.344	0.295	0.197	0.278	1	1	7.795			7.795		
		2	0.376	0.282	0.188	0.282	1	1	7.896	7.845		7.896	7.845	
Coefficient of Worker				m=e/i	**0.150**									
Coefficient of Skilled Worker				n=f/l	**0.150**									

Figure 2 shows the plot represents the productivity over time for Group 1 and Group 2. The productivity data for two groups over 7 days reveals distinct patterns. Productivity Group 1 maintains higher overall productivity, starting and ending at 7, with peaks at 8 on Days 2 and 4, showing a relatively stable and higher performance trend. In contrast, Productivity Group 2 shows more variability, starting at 6, dropping to a low of 4 on Day 3, and then recovering to 7 by Day 7. The significant dip in Group 2's productivity between Days 2 and 3 suggests potential issues that were later resolved. Both groups end with similar productivity levels, but Group 1 demonstrates more consistent performance throughout the period.

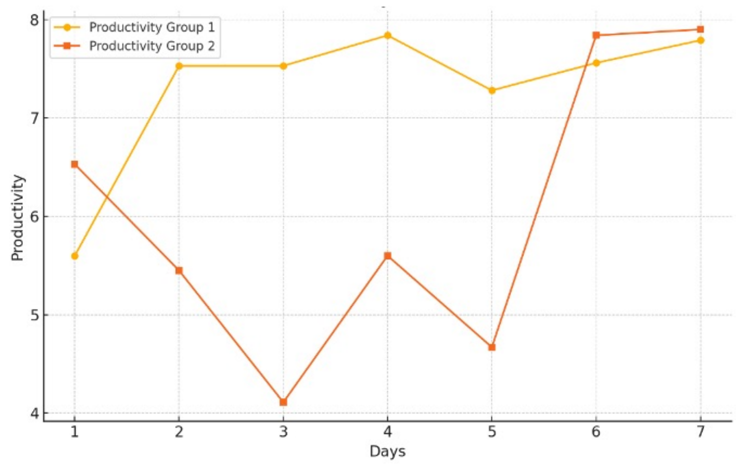

FIGURE 2. The productivity of Group 1 and Group 2

Labor Productivity Based on PUPR Ministerial Regulation

We derive the calculation of labor productivity for brick wall construction from the coefficients provided in various regulations issued by the Ministry of Public Works and Public Housing. Specifically, these regulations include Minister of Public Works and Public Housing Regulation Number 28/PRT/M/2016, which offers guidelines for unit price analysis in public works, Minister of Public Works and Public Housing Regulation Number 28/PRT/M/2018, Minister of Public Works and Public Housing Regulation Number 1 of 2022, and Minister of Public Works and Public Housing Regulation Number 8/PRT/M/2023. These documents outline the standard coefficients that indicate the amount of labor required per unit of work, enabling us to calculate productivity in the field systematically and accurately. By applying these coefficients, we can determine the labor needed and productivity for specific construction tasks, ensuring consistent and efficient project planning and execution.

The Table 3 explains the productivity calculations based on the specified regulations. This table summarizes the labor productivity calculations for brick wall construction based on the coefficients from each regulation. By examining these coefficients and their application to a standard work volume, we can understand the variations in productivity across different regulatory guidelines.

Comparison Between Labor Productivity On-Site and Regulatory Standards

We then compared our field productivity values with the coefficients provided in the Minister of Public Works and Public Housing regulations to assess the accuracy and efficiency of our labor productivity.

By comparing the on-site productivity values with those outlined in the Minister of Public Works and Public Housing regulations, we can evaluate the performance and efficiency of our workforce relative to standardized benchmarks. This comparison helps identify areas for improvement and ensures that our productivity aligns with industry standards. The table below shows the comparison.

The comparison of coefficients reveals that on-site, the coefficient for both skilled and regular workers is 0.150 person-days/m². In contrast, the coefficients from the regulations range from 0.200 to 2.400 person-days/m².The on-site coefficients are significantly lower than the regulatory coefficients, indicating that less labor time is being recorded per unit area of work on-site than the standards set by the regulations.

The comparison of productivity explains that on-site productivity for both skilled and regular workers is 6.658 m²/person-day. In contrast, the productivity values from the regulations range from 0.833 to 5.000 m²/person-day. The significantly higher on-site productivity suggests that the on-site team completes more work per unit than the regulatory standards expect. This indicates a highly efficient workforce, performing above the expected benchmarks set by the regulations.

Figure 3 shows the comparison between the coefficients and productivity of the workforce on-site and the standards set by several regulations of the Minister of Public Works and Public Housing (PUPR).

TABLE 3. PUPR Ministerial Regulation Brick Wall Labor Productivity

PUPR Ministerial Regulation	Unit	Labor	Coefficient	volume	The number of skilled workers	The number of workers	Productivity Skilled worker	Productivity worker
			a	b	d	e	f=d/a	g=e/a
PUPR Ministerial Regulation 28/2016	m^3	Skilled worker	1.200	0.036	1	1	0.833	0.833
		Worker	2.400					
PUPR Ministerial Regulation 28/2018	m^3	Skilled worker	1.200	0.036	1	1	0.833	0.833
		Worker	2.400					
PUPR Ministerial Regulation 01/2022	m^2	Skilled worker	0.200	0.238	1	1	5.000	5.000
		Worker	0.600					
PUPR Ministerial Regulation 08/2023	m^2	Skilled worker	0.200	0.238	1	1	5.000	5.000
		Worker	0.600					

TABLE 4. Comparison of the site and PUPR Ministerial Regulation brick wall labor productivity

Item	Unit	Coefficient		Productivity	
		Skilled Worker	Worker	Skilled Worker	Worker
On-Site	m^2	0.150	0.150	6.658	6.658
PUPR Ministerial Regulation 28/2016	m^3	1.200	2.400	0.833	0.833
PUPR Ministerial Regulation 28/2018	m^3	1.200	2.400	0.833	0.833
PUPR Ministerial Regulation 01/2022	m^2	0.200	0.600	5.000	5.000
PUPR Ministerial Regulation 08/2023	m^2	0.200	0.600	5.000	5.000

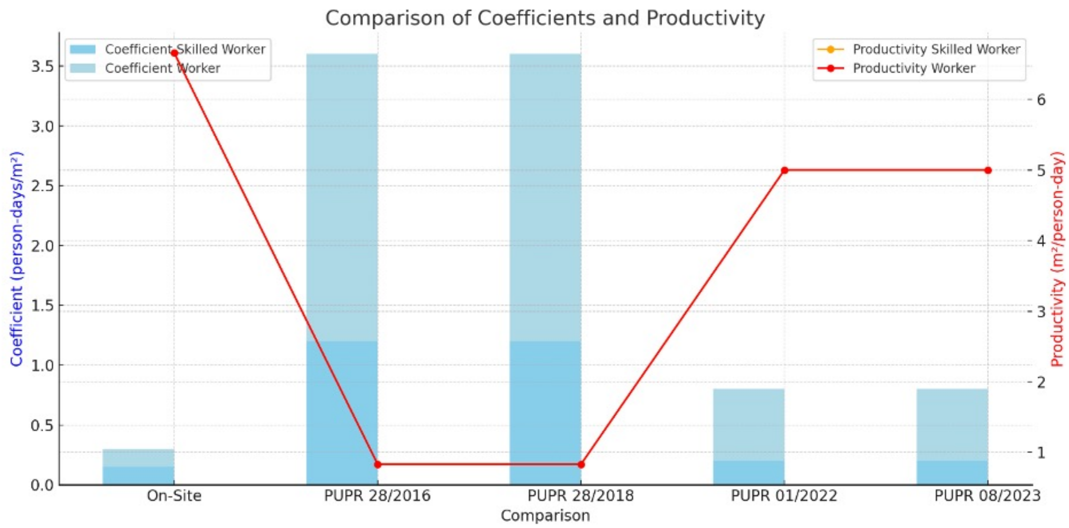

FIGURE 3. Comparison of coefficients and productivity

One of the aims is to provide insight into construction sector policy developments and offer future policy recommendations. Figure 1 illustrates the comparison between on-site workforce coefficients and productivity and the standards set by the Minister of Public Works and Public Housing (PUPR) regulations. By analyzing these comparisons, we can identify current trends and areas for improvement, which will help shape future effective policies for the construction sector.

Current trends in the construction sector reveal higher on-site productivity than the standards set by PUPR regulations, suggesting that the workforce completes more work per unit of time than expected. To shape effective future policies, it is crucial to investigate the factors contributing to this high productivity, such as advanced techniques, efficient project management, and favorable working conditions. Standardizing these practices across more projects could enhance overall sector efficiency. Additionally, the lower recorded labor time on-site compared to regulatory standards indicates a need for accurate reporting and recording of labor time to avoid under-reporting. Aligning on-site practices more closely with regulatory benchmarks is another area for improvement. Encouraging the adoption of advanced technologies sector-wide through incentives and training programs can further improve productivity and quality, leading to more efficient construction processes.

Recommendations for future policy are to formulate policies to standardize best practices observed in high-performing projects, ensuring they are replicated across the sector. Invest in comprehensive training programs focused on advanced construction techniques, efficient project management, and accurate labor reporting. Promote the integration of advanced construction technologies through incentives, grants, and training, making these tools accessible to all industry players. Establish a robust framework for regularly monitoring and evaluating construction projects to ensure compliance with standards and continuous improvement. Encourage data-driven decision-making by improving data collection and analysis methods across all construction sites. Future policies can enhance the construction sector's overall efficiency, productivity, and quality by addressing these areas, ensuring sustainable growth and development.

Simple Forecasting Models for on-site productivity

Based on the combined data from Group 1 and Group 2, we can make a simple forecast for future productivity. We derive the following equation for predicting productivity over time using linear regression analysis.

The provided graph (Figure 4), which shows the productivity of Group 1 and Group 2 over a series of days, indicates an overall positive trend in productivity, as demonstrated by the linear trend line equation $y = 0.2828x + 5.5273$. This equation suggests that productivity increases by approximately 0.2828 units for each additional day, with an intercept of 5.5273 representing the estimated productivity at day 0. While the observed data points display some day-to-day variability, the general upward trend implies that productivity improves over time. The scatter points around the trend line show fluctuations, indicating that some days have higher or lower productivity than the trend line predicts. This variability could be due to various influencing factors, and understanding these factors could help further stabilize and enhance productivity. The increasing trend is encouraging and suggests practical productivity enhancement efforts or a natural improvement over time. The trend line can be used to predict future productivity by extending it beyond the current data points, providing valuable insights for planning and improvement strategies.

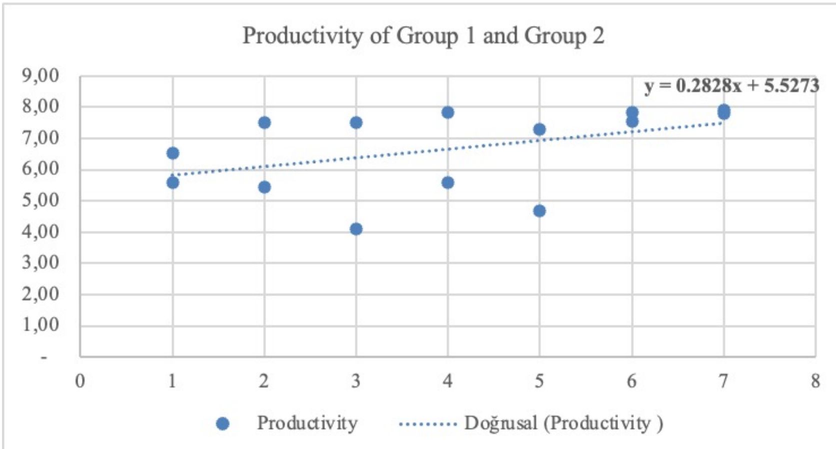

FIGURE 4. The productivity forecasting for Group 1 and Group 2

Figure 5 illustrates the productivity trends for two groups over time, with an additional forecast for future productivity. Group 1 (orange line) shows an initial increase followed by fluctuations, maintaining a productivity range between 7.0 and 8.0 units. Group 2 (green line) experiences a sharp decline to around 4.0 units, then gradually improves to match Group 1's productivity levels by the end of the observed period. The forecasting productivity (blue line) indicates a positive trend, projecting a steady increase to approximately 9.0 units. This analysis suggests that while both groups have experienced variability in productivity, future productivity is expected to rise, indicating potential improvements in efficiency or external factors influencing productivity positively.

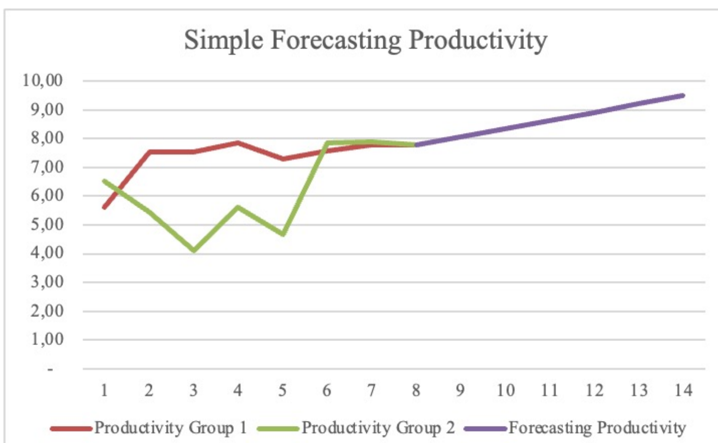

FIGURE 5. Simple forecasting model for on-site productivity

Discussion of the result

Overall, this study underscores the importance of continuous productivity monitoring and alignment with regulatory standards. The positive productivity trend, supported by linear regression analysis, provides a promising outlook for future productivity improvements. Organizations should focus on understanding and leveraging the factors contributing to high on-site productivity to sustain and enhance their efficiency levels in bricklaying and other construction activities.

CONCLUSIONS AND RECOMMENDATION

This research successfully measured the on-site productivity of installing red brick walls and compared it to regulatory benchmarks, revealing a highly efficient workforce. Factors such as better management, advanced techniques, or favorable working conditions may contribute to this enhanced productivity. The study found that the labor time per unit area was lower than the standards, indicating significant efficiency. However, it is crucial to ensure this is not due to under-reporting or overlooking some aspects of the work.

Regular comparisons with regulatory standards were essential in identifying discrepancies and areas for improvement. This practice ensures that workforce performance remains aligned with industry benchmarks and helps in setting realistic targets. Understanding and analyzing the factors contributing to high productivity, such as work processes, tools and techniques, and worker skills, can provide deeper insights and aid in maintaining or further enhancing productivity levels.

Utilizing linear regression analysis, the study derived a predictive model with the equation $y = 0.2828x + 5.5273$, indicating a positive trend in productivity over time. Figure 4 illustrated productivity trends for two groups, showing an initial increase followed by fluctuations. Group 1 maintained a productivity range between 7.0 and 8.0 units, while Group 2 improved from around 4.0 units to match Group 1 by the end of the observed period. The forecasting productivity trend projected a steady increase to approximately 9.0 units, suggesting potential improvements in efficiency or positive external factors.

To further enhance productivity, it is recommended to conduct a detailed analysis of the factors contributing to high on-site efficiency. This should include an evaluation of work processes, tools and techniques, and worker skills. Additionally, maintaining regular comparisons with regulatory standards will help identify areas for improvement and ensure alignment with industry benchmarks. Implementing targeted training programs and adopting advanced techniques could also contribute to sustained productivity growth.

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