LEADER
Civil Engineering and Architecture Journal

Civil Engineering and Architecture Journal Vol.3 No.4 (2025) 3026-622X
10.37253/leader.v3i4.11260

Boosting Rigid Pavement Productivity: Lessons from Experience and Working Hours on the Bengkulu Toll Road Project

Akhmad Mujiburrokhman[1], Danang Purwanto[1], Fadhil Muhammad[2]
[1]Civil Engineering, Faculty of Engineering, Universitas Negeri Yogyakarta
[2]Architecture, Faculty of Engineering, Universitas Negeri Yogyakarta
Correspondence email: akhmadmujiburrokhman@uny.ac.id

ARTICLE INFO

Keywords:

Experience,
Productivity,
Rigid Pavement,
Working Hours

ABSTRACT

Rigid pavement work was a key component in toll road construction that played a strategic role in the speed of project completion. Two important internal factors that affected productivity were experience and working hours. Mismanagement of either of these factors could cause project delays. This study aimed to analyze the significance of the influence of work experience and working hours on the productivity of rigid pavement work in the Trans-Sumatra Toll Road project, Bengkulu–Lubuklinggau Section 3. The research method used was a quantitative approach with multiple linear regression analysis. Primary data were obtained from daily work reports that recorded the area of concrete coverage, working hours, and worker experience. Experience had a significant positive effect on productivity, while working hours had a significant negative effect. The variables of experience and working hours together influenced productivity by 60.8%. The average productivity value was recorded at 91.05 m^2/hour with a high variance (variance = 391.545), which reflected the actual conditions on-site and indicated the significant influence of both external and internal factors. In practical terms, these findings had managerial implications indicating that construction companies needed to prioritize the placement of experienced workers on rigid pavement jobs to increase productivity. Furthermore, project management was required to optimize working hours to prevent fatigue, which could impair performance. The implementation of a workforce rotation system, the provision of proportional rest periods, and the delivery of ongoing training for new workers were considered effective strategies. Consequently, project productivity was sustained without compromising workers' health or the quality of the work.

1. Introduction

One of the road projects that was a priority for the Indonesian government was the construction of the Trans Sumatra Toll Road/Jalan Tol Trans Sumatra (JTTS). This project aimed to improve interregional connectivity, accelerate logistics distribution, encourage investment, and open new economic areas along its corridor. The districts and cities traversed by the JTTS saw an average increase in GRDP (gross regional domestic product) of 1.28%, with a contribution to Sumatra's total GRDP reaching 3.3% [1]. Bengkulu–Lubuklinggau Toll Road was one of the supporting corridors of the JTTS. The total length of this section was 95.8 km. Section 3 (Taba Penanjung–Bengkulu) has been completed and is now operational. Construction of sections 1 (Lubuklinggau–Kepahiang) and 2 (Kepahiang–Taba Penanjung) has not yet begun and is currently still in the planning stage.

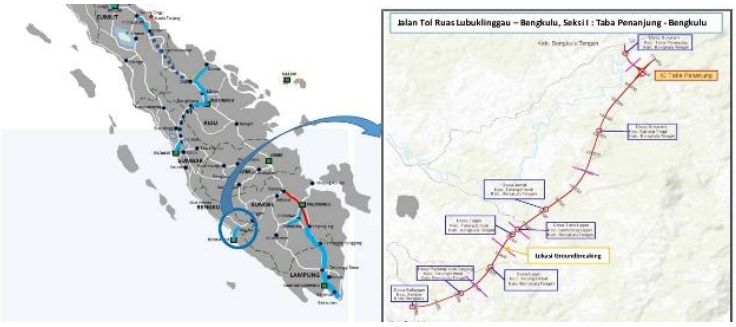

Figure 1. JTTS Taba Penanjung–Bengkulu Project Location
Source: author documentation

In the implementation of toll road projects, one of the main tasks that played a crucial role in determining the project completion speed was rigid pavement work. This rigid pavement structure was widely chosen in toll road projects because it had high resistance to heavy traffic loads and a relatively longer service life compared to flexible pavement [2]. However, rigid pavement construction also presented its own challenges in terms of productivity, as the construction process was susceptible to various disruptions [3], required favourable weather conditions, good performance of heavy equipment, and a smooth supply of concrete materials [4], [5], [6]. A case study on the Cikopo–Palimanan Toll Road showed that rigid pavement could have a service life of more than 20 years, exceeding the service life of asphalt. This reflected the crucial role of rigid pavement for the sustainability of toll roads [7].

High productivity reflected the efficiency of work performance, while a decline in productivity could lead to project delays and increased costs. Two important factors that influenced productivity were experience and working hours [8], [9]. Both factors needed to be considered when drawing up project schedules and calculating resource requirements. Work experience and worker skills had a strong positive correlation with increased productivity [10], the more experienced the workers were, the higher their productivity. Increasing weekly working hours and prolonged project working hours significantly reduced construction worker productivity, excessive overtime hours could potentially reduce efficiency due to physical and mental fatigue. Careless management of one of these factors could cause delays in project completion. Therefore, analysing the impact of experience and working hours on the productivity of rigid pavement work was important for formulating strategies for implementing toll road projects.

In the context of toll road construction in Bengkulu, studies on the influence of experience and working hours on the productivity of rigid pavement work were still limited. The geographical conditions and characteristics of the workforce in this region could have produced different outcomes compared to similar projects in other areas. These limitations of empirical studies underscored the need for more specific research to provide a realistic understanding of the factors that influenced productivity on-site. Accordingly, the findings of this study were expected to serve as a practical basis for the development of project management strategies, particularly in optimizing workforce allocation and work schedule arrangements to enhance the efficiency of toll road construction projects in Bengkulu.

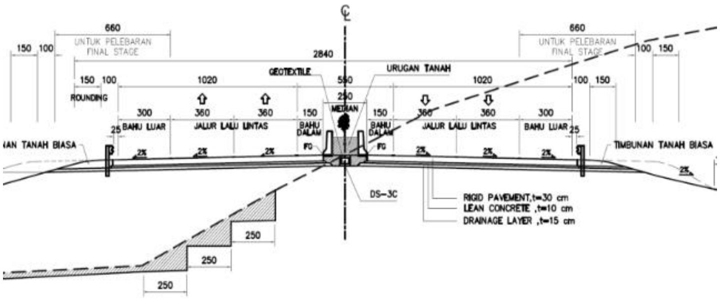

Figure 2. Cross Section Design
Source: author documentation

2. Literature Review

2.1 Productivity

Productivity in construction was defined as the ratio between output (volume of work) and input (resources), such as labour, materials, and equipment used in a given period [11]. Output could be the volume of work completed, for example, square meters of floor work, number of piles, or length of road completed. Input was usually measured in terms of labour hours, number of workers, equipment usage, or costs.

$$\text{Productivity} = \frac{\text{Output (volume of work)}}{\text{Input (labour hours)}} \tag{1}$$

The productivity of rigid pavement construction is typically measured in units of area or volume per unit of working time (e.g., m^2/hour or m^3/hour) and is influenced by a combination of technical, human, logistical, and environmental factors. In the last decade, research has shifted not only to identifying factors, but also to accelerated construction solutions, the adoption of precast and quick-drying mixes, and digital integration (BIM, simulation) for resource optimization. Skilled workers and heavy equipment operators have a significant impact on output. Modern construction productivity studies identify skilled labour and training as one of the dominant factors influencing productivity [12] [13].

Working hours (number of hours worked per day/week and overtime practices) are often used to meet project schedule targets. However, recent literature shows a non-linear relationship between working hours and productivity: increasing working hours may increase daily output but tends to decrease productivity per hour, increase fatigue, and have a negative impact on long-term safety and quality [14]. Studies on construction projects (particularly structural work) report that additional overtime increases daily work volume but productivity per hour decreases as working hours increase. This decline is evident in heavy physical work, such as reinforcement installation and casting [15]. Insufficient recovery time/sleep disturbance worsens performance on subsequent days, so the effects of overtime are cumulative [16]. Work performed while tired often requires rework, reducing the effective productivity of the project [17].

2.2 Rigid Pavement

Rigid pavement was a type of road pavement construction that used Portland Cement concrete as its main material. This pavement was characterized by high rigidity and was typically used on roads with heavy traffic loads and high traffic volumes, such as toll road [18]. Despite these advantages, the construction of rigid pavement was highly labour and equipment-intensive, involving sequential activities such as subgrade preparation, formwork installation, reinforcement placement, concrete mixing and casting, vibration, finishing, and curing [19]. Each stage required strict quality control and coordination, and the speed of execution was directly influenced by the experience, skill, and efficiency of the workforce. Thus, rigid pavement projects often demanded greater attention to workforce productivity compared to flexible pavement projects, where work processes were relatively less complex.

Figure 3. Implementation of Rigid Pavement with Concrete Pavers
Source: author documentation

2.3 Productivity Management in Rigid Pavement Work

Productivity management was conceptualized as a systematic process that ensured organizations operated with maximum efficiency and effectiveness through the optimal utilization of available resources. It emphasized the integration of structured performance measurement systems, such as key performance indicators (KPIs), analytical evaluations, continuous monitoring, and feedback mechanisms, which collectively facilitated the identification of inefficiencies and opportunities for improvement [20].

Within the construction industry, productivity management was not limited to tracking the ratio of output to input but also encompassed strategic approaches to workforce allocation, scheduling, and technological adoption. The incorporation of monitoring tools and continuous improvement practices was particularly critical in adapting to the dynamic and complex nature of construction projects, thereby supporting both short-term operational objectives and long-term organizational performance goals [21].

In the context of rigid pavement construction, productivity management was regarded as a critical component in ensuring the timely and cost-effective completion of infrastructure projects. The process of productivity management not only involved the measurement of output, such as the installed concrete surface area per labour hour, but also the strategic consideration of factors that directly influenced work efficiency, including workforce experience, working hours, and site conditions. Empirical studies demonstrated that skilled and experienced workers significantly improved the rate of pavement installation, whereas extended working hours and excessive overtime often resulted in diminishing returns due to fatigue and reduced accuracy [22].

This indicated that productivity management in rigid pavement projects required a balance between resource allocation, workforce capability, and work schedule arrangements. By applying systematic monitoring and continuous improvement practices, project managers were able to identify inefficiencies, mitigate risks of project delays, and enhance overall performance outcomes.

2.4 Multiple Linear Regression

Multiple linear regression was a statistical analysis method used to model the relationship between one dependent variable (Y) and two or more independent variables ($X_1, X_2, \ldots, X_n$). This method aimed to predict the value of the dependent variable based on a combination of independent variables, as well as to determine the magnitude of the influence of each independent variable on the dependent [23]. In general, multiple linear regression models can be expressed by the equation:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \epsilon \qquad (2)$$

where:
Y = dependent variable
X_i = independent variable i
β_0 = intercept
β_i = regression coefficient of independent variable i
ϵ = error

The application of multiple linear regression required the fulfilment of several classical assumptions [24] [25], including:

1) Linearity, the relationship between the dependent and independent variables was linear.
2) Normality of residuals, the distribution of errors (ϵ) followed a normal distribution.
3) Homoscedasticity, the variance of the residuals was constant for all values of the independent variables.
4) No multicollinearity, there was no high correlation among the independent variables.

The process of multiple linear regression analysis included:

1) Determining the dependent and independent variables.
2) Collecting and processing data.

3) Checking classical assumptions.
4) Testing the significance of the model (F-test) and variables (t-test).
5) Determining R value (correlation coefficient).

The F-test was a statistical test used to test the significance of a model simultaneously, that is, whether all independent variables in the model collectively had a significant effect on the dependent variable. The t-test was a partial statistical test used to determine the individual influence of each independent variable on the dependent variable, assuming that the other independent variables in the model were held constant. The F-test tested whether all variables had a combined effect, while the t-test tested whether a specific variable had a significant effect.

The R value, or Correlation Coefficient (Pearson Correlation Coefficient), measured the strength and direction of the linear relationship between two variables. The R value ranged from -1 to +1. A positive value indicated a direct relationship, a negative value indicated an inverse relationship, and a value of 0 indicated no linear relationship. The closer the value was to -1 or +1, the stronger the relationship.

3. Method

The research location was JTTS Bengkulu-Lubuklinggau Section 3 (Figure 1) at STA 0+000 to STA 6+500. The type of work studied was rigid pavement 30 cm thickness design (Figure 2) and work carried out using a concrete paver (Figure 3). The data collection technique used was a census. The data collected consisted of 64 consecutive daily reports on rigid pavement work carried out over a period of three months.

This study used quantitative methods. The method used to process the data was multiple linear regression. Multiple linear regression was selected as the primary analytical method because it allowed for the simultaneous examination of the influence of more than one independent variable on a single dependent variable. In the context of rigid pavement productivity, workforce experience and working hours represented two distinct but interrelated predictors that required a combined analytical approach to capture their effects on productivity outcomes. Unlike simple regression, which only measured the relationship between one predictor and the outcome, multiple regression provided the advantage of controlling for the influence of one variable while assessing the effect of another, thereby ensuring a more accurate estimation of their respective contributions.

Regression analysis provided information about which variables had the greatest influence on the outcome, through statistically significant regression coefficients (t-test). This method had a clear theoretical foundation and procedures for testing classical assumptions (linearity, normality, homoscedasticity, and no multicollinearity). This ensured that the analysis results were reliable and valid if the assumptions were met.

The dependent variable was Productivity (Y), while the independent variables were Experience (X_1) and Working Hours (X_2). The null hypothesis (H_0) stated that there was no effect of Experience (X_1) and Working Hours (X_2) on Productivity (Y), while the alternative hypotheses were:

- H_1 = There was an effect of Experience (X_1) on Productivity (Y).
- H_2 = There was an effect of Working Hours (X_2) on Productivity (Y).
- H_3 = here was a simultaneous effect of Experience (X_1) and Working Hours (X_2) on Productivity (Y).

with a confidence level of 95%, $\alpha = 0.05$. The data used were primary data obtained from the field in the form of daily reports on the implementation of rigid pavement work, which contained the following information:

- STA location, length, and width of the completed pavement.
- Date, start time, and completion time of the work.
- Source of concrete material.

From the STA location, length, and width data, the pavement area (m^2) was calculated. From the date, start time, and completion time data, the working hours duration (hours) was obtained, and subsequently, the productivity value (m^2/hour) was calculated. SPSS software was used for data processing. In this study, the author conducted descriptive statistical analysis and multiple linear regression modelling. From the descriptive statistical analysis, the mean, variance, and standard deviation of productivity were obtained. The linear regression modelling was able to show whether the data analysis results were reliable and valid through classical assumption tests, followed by obtaining the significance value and the correlation level of the variables.

4. Results and Discussion

Primary data were obtained from daily reports containing the implementation of rigid pavement work. The data were then compiled into tables to calculate the productivity of rigid pavement work (Table 1), then summarized and modelled using multiple linear regression.

Table 1. Daily Report Data Summary

Experience n repetition (X_1)	Working hours (hour) (X_2)	Productivity (m^2/hour) (Y)	Experience n repetition (X_1)	Working hours (hour) (X_2)	Productivity (m^2/hour) (Y)
1	18.567	67.325	33	10.300	82.524
2	8.250	72.727	34	7.483	93.541
3	10.033	72.259	35	4.667	75.000
4	6.800	69.853	36	6.533	80.357
5	7.317	68.337	37	7.850	108.280
6	9.833	71.186	38	3.183	91.099
7	8.467	82.677	39	6.250	81.600
8	11.567	95.101	40	17.333	87.981
9	12.450	84.337	41	10.550	109.005
10	4.000	62.500	42	6.517	107.417
11	1.833	95.455	43	8.067	127.066
12	3.867	116.379	44	10.467	88.376
13	5.283	99.369	45	4.617	113.718
14	4.783	99.303	46	9.600	98.958
15	4.683	101.423	47	5.233	76.433
16	9.083	77.064	48	5.333	103.125
17	6.333	110.526	49	5.517	117.825
18	4.200	83.333	50	5.600	93.750
19	4.133	84.677	51	2.317	161.871
20	4.450	78.652	52	3.733	113.839
21	5.750	60.870	53	5.633	106.509
22	4.833	87.931	54	5.933	101.124
23	7.783	80.300	55	7.183	73.086
24	6.717	96.774	56	3.567	147.196
25	4.900	76.531	57	4.100	115.854
26	3.633	103.211	58	4.400	107.955
27	6.183	88.949	59	5.483	104.863
28	6.450	81.395	60	3.117	136.364
29	8.500	67.647	61	9.217	89.512
30	8.400	80.357	62	4.400	96.591
31	5.783	95.101	63	8.533	108.398
32	5.017	109.635	64	6.833	117.073

Source: primary data

The relationship between working hours and productivity was illustrated in Figure 4, whereas the relationship between experience and productivity was presented in Figure 5.

4.1 Comparison of Working Hours to Productivity

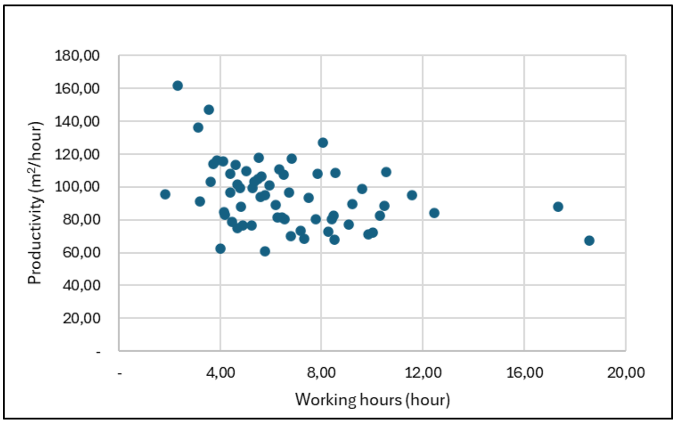

Figure 4. Comparison of Working Hours to Productivity
Source: author analysis

Figure 4 illustrated the relationship between working hours and productivity of rigid pavement work (m^2/hour). The distribution data showed that longer working hours did not necessarily increase productivity. Instead, productivity tended to decline when the working hours were extended.

Within the range of 3 to 8 hours, productivity appeared relatively higher and more stable, varying between approximately 80 and 160 m^2/hour. However, when the working hours exceeded 8 hours, productivity generally decreased, with most data points falling below 100 m^2/hour. This indicated that worker fatigue and decreasing concentration might have negatively affected work efficiency after a certain duration of time.

This phenomenon was consistent with the theory of construction management, which stated that labor productivity was not linear to working hours. Additional working hours often resulted in a diminishing return, where output per hour decreased rather than improved. In other words, there existed an optimal working duration that maximized productivity without leading to excessive fatigue.

Moreover, the wide dispersion of data in the shorter working hours (3–6 hours) suggested that other factors besides duration played a role in determining productivity. These factors possibly included worker experience, weather conditions, material availability, and site coordination. Hence, productivity was influenced by multiple variables, not solely by working hours.

Practically, this finding implied that project management should not rely merely on increasing working hours to achieve progress. Instead, contractors were encouraged to design efficient work schedules that considered the optimal working time, which was around 6–8 hours per day, while simultaneously improving other supporting factors. By doing so, productivity could have been maximized without compromising workers' health and safety.

4.2 Comparison of Experience to Productivity

Figure 5 illustrated the relationship between experience and productivity of rigid pavement work (m^2/hour). The distribution of data showed a positive trend, where an increase in the number of repetitions (experience) was generally associated with higher productivity levels.

At lower levels of experience (less than 10 repetitions), productivity varied widely, ranging approximately between 60 and 120 m^2/hour. This variation indicated that novice workers had not yet reached consistent performance levels, and their productivity was strongly influenced by external factors such as coordination, learning adaptation, and technical skills. As experience increased, productivity gradually improved and became more stable. Workers with higher repetitions (more than 40) consistently achieved productivity values above 100 m^2/hour, with some data points even exceeding 160 m^2/hour. This pattern suggested the presence of a learning curve effect, where repetitive practice and accumulated knowledge enhanced both efficiency and output quality.

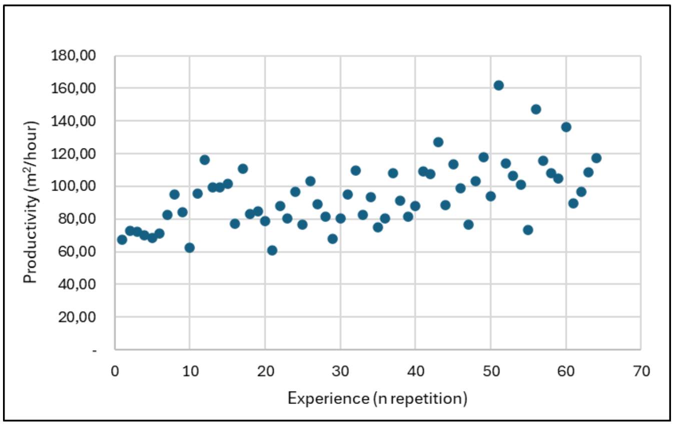

Figure 5. Comparison of Experience to Productivity
Source: author analysis

The findings were consistent with the concept of skill acquisition theory, which emphasized that performance improved through practice and repetition until a plateau was reached. In construction studies [26], who reported that task repetition reduced variability and increased productivity over time. Furthermore, workers' learning curves in construction activities significantly contributed to productivity improvement, particularly in labor intensive tasks [27].

However, despite the upward trend, the scatter of data points in higher experience levels suggested that productivity was still affected by other factors such as site conditions, equipment performance, material supply, and team coordination. Thus, while experience played a crucial role in enhancing productivity, it was not the sole determinant.

From a managerial perspective, these results implied that allocating experienced workers to critical tasks and ensuring knowledge transfer from skilled to less experienced labor could have optimized overall productivity. Moreover, structured training and mentoring programs could have accelerated the learning curve, thereby reducing inefficiencies at the early stages of worker involvement.

4.3 Assumption Test

Assumption testing was performed using SPSS software, yielding the following results:

4.3.1 Normality Test

A regression model was said to be normally distributed if the data plotting (points) representing the actual data followed a diagonal line [28]. The results of the normality test showed that the regression model was normally distributed, as shown in Figure 6.

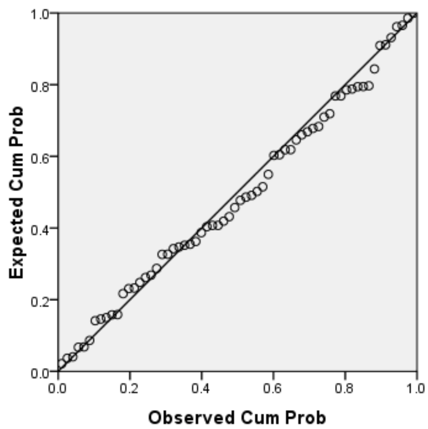

Figure 6. Normal Plot of Regression Standardized Residual
Source: SPSS analysis results

4.3.2 Multicollinearity Test

Multicollinearity did not occur if the Tolerance value was > 0.100 and the VIF value was < 100 [28]. The Tolerance value from SPSS obtained was 0.947 and the VIF value was 1.056 (Table 2), so the results of the multicollinearity test showed no signs of multicollinearity.

Table 2. t-test and Collinearity

Variable	T	Sig.	Collinearity Statistics	
			Tolerance	VIF
Experience (X_1)	4.799	0.000	0.947	1.056
Work hours (X_2)	-2.376	0.021	0.947	1.056

Source: SPSS analysis results

4.3.3 Scatterplot Heteroscedasticity Test

Heteroscedasticity did not occur if there was no clear pattern (wavy, widening, then narrowing) in the scatterplot image, and the points were scattered above and below the number 0 on the Y-axis [28]. From Figure 7, it was concluded that there were no signs of heteroscedasticity.

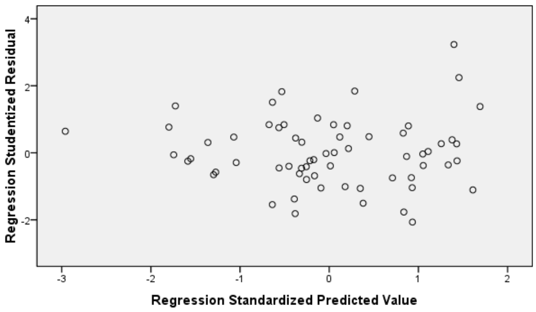

Figure 7. Scatterplot Image
Source: SPSS analysis results

A multiple linear regression model was considered a good model (accurate in estimation and consistent) if it met the assumption of normality and was free from the classical assumptions of multicollinearity and heteroscedasticity. The conclusion of the multiple linear regression model in this study was that it was a good model because it was normally distributed and free from classical assumptions.

4.4 Interpretation

4.4.1 Partial t-test

If the Sig. value was < 0.05, it meant that the independent variable (X) partially influenced the dependent variable (Y) [28]. The results of the SPSS partial t-test were shown in Table 2, where the Sig. value for X_1 was 0.000 and for X_2 was 0.021. It was concluded that Experience (X_1) influenced Productivity (Y), and Working Hours (X_2) influenced Productivity (Y). f the t-calculated value was greater than the t-table value, it meant that the independent variable (X) partially influenced the dependent variable (Y) [29]. The t-calculated value for X_1 was 4.799 and the t-calculated value for X_2 was -2.376 (Table 2). The t-table value obtained was (α/2; n-k-1) = (0.05/2; 64-2-1) = (0.025; 61). Next, using the t-test table, the t-table value was found to be 2.000.

$$\text{t-table} = (\alpha/2;\ n-k-1) \tag{3}$$

where:
α = 0,05
n = number of data samples
k = number of independent variables

Looking at the comparison of the t-value with the curve in Figure 8, the result was that Experience (X_1) had a t-value (4.799) > t-table (2.000), so X_1 had a positive effect on Productivity (Y). Working Hours (X_2) had a calculated t-value (-2.376) < t-table (-2.000), so X_2 had a negative effect on Productivity (Y). It was concluded that in the rigid pavement work studied, more experience increased productivity, and longer working hours decreased productivity.

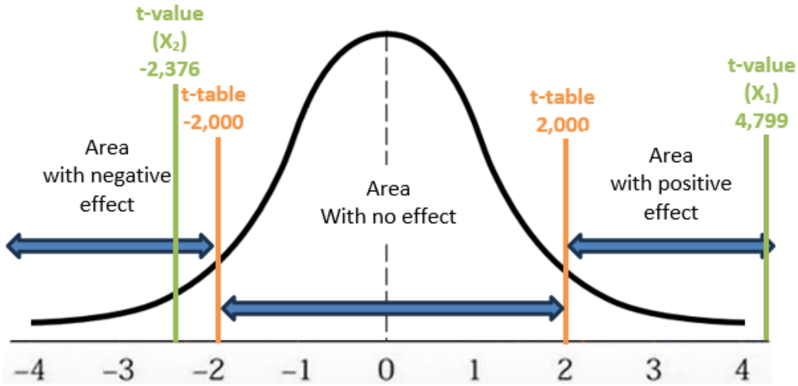

Figure 8. Comparison Between t-calculated and t-table
Source: author analysis

4.4.2 F-test

If the Sig. value was < 0.05, it meant that the independent variable (X) simultaneously affected the dependent variable (Y) [28]. he results of the SPSS F-test had a Sig. value of 0.000, indicating that Experience (X_1) and Working Hours (X_2) simultaneously affected Productivity (Y).

If F-value was greater than F-table, it meant that the independent variable (X) simultaneously affected the dependent variable (Y) [29]. The F-value obtained was 17.911. Next, the F-table value was found using the following steps. Thus, the F-table value was obtained as F-table = (k; n-k) = (2; 64-2) = (2; 62). Next, using the F-test table, the F-table value was found to be 3.15. F-calculated (17.91) > F-table (3.15), so Experience (X_1) and Working Hours (X_2) simultaneously affected Productivity (Y).

$$\text{F-table} = (k; n\text{-}k) \tag{4}$$

where:
n = number of data samples
k = number of independent variables

4.5 Influence (%) of Experience and Working Hours on Productivity

The R value from SPSS was 0.608, meaning that variable X (Experience and Working Hours) had a 60.8% influence on Y (Productivity). The R value of 0.608 indicated a moderate to strong correlation between the independent variables (Experience and Working Hours) and the dependent variable (Productivity). This meant that 60.8% of the variation in productivity could be explained by the combined influence of experience and working hours, while the remaining 39.2% was influenced by other factors not included in the model.

The result suggested that both experience and working hours played a significant role in determining productivity levels in rigid pavement work. In particular, the positive contribution of experience aligned with the expectation that more skilled and knowledgeable workers could perform tasks more efficiently. Conversely, the negative influence of extended working hours reflected the potential decline in efficiency due to fatigue and decreased concentration. These findings were consistent with previous studies in the construction field, which emphasized the importance of optimizing human resource management and scheduling to maintain high productivity levels.

4.6 Average and Variance of Productivity

Table 3. Descriptive Statistics

Variable	Mean	Std. Dev.	Variance
Productivity (Y)	91.050	19.788	391.545

Source: SPSS analysis results

The following presented the results of the calculation of the mean, standard deviation, and variance of productivity (Table 5). The mean productivity in this study was 91.05 m^2/hour. In Table 6, the author compared the average productivity results of this study with those of previous studies. Productivity values varied considerably, from 88.21 m^2/hour to 143.33 m^2/hour. This indicated significant differences in performance between work locations.

The large variance value of 391.545 indicated that the productivity data were highly dispersed. This was consistent with field conditions, where the productivity of rigid pavement was greatly influenced by strong external and internal factors. This study demonstrated that experience and working hours accounted for 60.8% of the variability in productivity values.

4.7 Comparison of Productivity Values with Previous Studies

Figure 9 illustrated the comparison between pavement thickness design and productivity (m^2/hour) across several road projects. The results showed that the design thickness of rigid pavement significantly influenced productivity, where thinner pavement designs generally corresponded to higher productivity levels.

At the Tebing Tinggi–Parapat project [30], where the pavement thickness was designed at 27 cm, productivity reached the highest value of 143.33 m^2/hour. This finding suggested that a thinner pavement design required less concrete volume per unit area, which reduced both material handling and placement time, thereby increasing the speed of installation.

In contrast, projects with thicker designs, such as the Bakauheni–Terbanggi Besar section [31] (30 cm) and the section analysed in this study (30 cm), recorded much lower productivity rates, at 88.21 m^2/hour and 91.05 m^2/hour, respectively. These results indicated that the additional thickness increased workload and slowed down the casting process, which in turn reduced productivity.

Interestingly, the Jalan Lintas Timur Sumatra project [32], which had the thickest design at 30.5 cm, achieved a relatively high productivity of 115.51 m^2/hour. This outcome suggested that factors beyond thickness design also played a role in determining productivity. Such factors might have included construction methods, crew experience, material supply, and site management practices, which could have compensated for the heavier workload associated with thicker pavement.

Overall, the findings supported the notion that design thickness was an important determinant of productivity, but not the sole factor. While thinner pavements facilitated faster work, high productivity could still be achieved in thicker designs if supported by efficient construction management and technology. This aligned with prior research emphasizing that both technical design parameters and operational factors collectively influenced the productivity of rigid pavement construction.

In addition to design parameters, this study also suggested that human factors such as experience and working hours played a significant role in determining productivity levels in rigid pavement work. The positive contribution of experience aligned with the expectation that more skilled and knowledgeable workers could perform tasks more efficiently through the learning curve effect. Conversely, the negative influence of extended working hours reflected the potential decline in efficiency due to fatigue and decreased concentration. These results reinforced the idea that productivity was shaped by the interaction between technical design aspects and human resource factors, rather than by a single determinant. Consistent with previous studies in the construction field, the findings highlighted the importance of integrating technical planning with optimized human resource management and scheduling strategies to ensure consistently high productivity in rigid pavement projects.

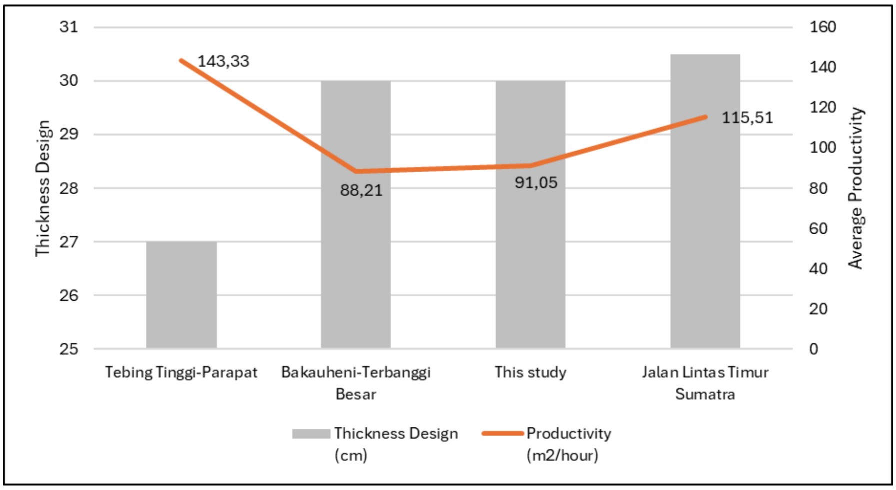

Figure 9. Comparison of Productivity Values with Previous Studies
Source: author analysis

From a practical perspective, these results implied that project planners should consider not only the structural requirements of pavement thickness but also the impact on construction productivity and cost-efficiency. Optimizing both design and operational strategies would have been essential to achieving a balance between structural performance and timely project delivery.

5. Conclusion

This study analysed the productivity of rigid pavement work by examining the influence of experience and working hours using a multiple linear regression model. The model was validated by passing normality, multicollinearity, and heteroscedasticity tests, confirming its accuracy and consistency. The partial t-tests showed that both experience and working hours significantly affected productivity, with experience having a positive effect and working hours having a negative effect. The F-test confirmed that these variables simultaneously influenced productivity. The regression model explained 60.8% of the variability in productivity, indicating a moderate to strong relationship.

Descriptive statistics revealed that productivity values varied widely, consistent with the large variance observed, which reflected the complex influence of various factors in the field. Overall, the results demonstrated that increasing experience improved productivity, while longer working hours decreased it, highlighting the importance of skilled labour and optimal working time management in rigid pavement construction.

From a scientific perspective, this study contributed empirical evidence of the negative effect of excessive working hours on rigid pavement productivity, a phenomenon that has been widely hypothesized but rarely documented in the context of toll road construction projects in Indonesia. By confirming that extended working hours reduced efficiency despite increasing total time input, the findings strengthened the theoretical argument that fatigue, diminished concentration, and reduced physical endurance are critical determinants of labor performance in large scale infrastructure projects.

From a managerial standpoint, the findings underscored the necessity for strategic workforce management. Construction companies were recommended to implement shift scheduling systems to distribute working hours more evenly, thereby preventing worker fatigue. Additionally, providing targeted training and skill development programs for less experienced workers would accelerate their learning curve and help balance workforce capacity. Together, these strategies could maintain steady productivity levels while ensuring both the health of workers and the quality of construction output.

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