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EVALUATION OF LABOUR PRODUCTIVITY IN ROAD CONSTRUCTION PROJECTS: A CASE STUDY IN NEPAL

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Abstract — Labour productivity is the most important and multifaceted parameter in the construction sector, serving as a measure of the efficiency and effectiveness of labour resources in completing projects. Despite its significance, the construction industry lacks universally recognised and standardised indicators for assessing labour productivity. This research focuses on determining labour productivity in road construction projects within the Tanahun district of Nepal. In this study, labour productivity in construction activities such as stonework, gabion box filling, soling, PCC, and plum concrete was analysed across four projects using an activity-orientated model measured as output per work hour. Data was gathered over six consecutive days, totalling 24 measurements per activity, with Department of Road Nepal norms serving as benchmarks. Statistical tests, including one-way ANOVA and t-tests, were applied to assess productivity differences across groups. The obtained labour productivity values for skilled and unskilled labour across various construction activities are as follows: Masonry, PCC (M10), PCC (M15), plum concrete, and unskilled labour for soling were found to be 0.76 m^3/man-day, 0.28 m^3/man-day, 2.39 m^3/man-day, 0.789 m^3/man-day, 7.734 m^3/man-day, 0.858 m^3/man-day, 5.446 m^3/man-day, 0.777 m^3/man-day, 3.875 m^3/man-day, 0.416 m^3/man-day, and 0.518 m^3/man-day respectively. The findings suggest that labour productivity in road construction projects can be improved through timely payment, efficient scheduling, provision of sufficient tools and equipment, effective inventory management, standardised construction techniques, sound financial planning, and provision of adequate breaks. It offers practical strategies to enhance labour productivity in road construction projects and meet productivity standards in the context of developing countries like Nepal.

***Keywords*:** labour productivity, road construction, project

1.0 INTRODUCTION

The construction industry globally serves as a vital economic driver for countries, fostering growth and development [1]. Construction labourers are vital assets in the industry and contribute significantly to project performance and quality, reinforcing their crucial role for construction companies [2]. Construction productivity shapes a country's standard of living, inflation, and global competitiveness [3]. Low productivity in construction projects persists in developing countries, where manual labour predominates, delaying efficient project advancement [4]. Efficient construction management relies on monitoring and measuring productivity against schedules [5]. Factors such as working conditions, management quality, and technology significantly impact labour productivity [6].

Productivity is a key driver of performance for organisations of any size. In construction, it critically impacts time and cost objectives and overall project goals [7]. Measuring labour productivity is essential to identify areas for improvement, optimise performance, and enhance efficiency in achieving project goals [8]. Efficient management of workforce productivity, machinery, and finances is essential for minimising the time and costs of the project [9, 10]. Productivity growth is essential for the survival of construction businesses [11]. To enhance productivity, the construction workforce requires improvement strategies; therefore, understanding the influential factors and practices and measuring their impact on labour productivity is important [12].

Improvement efforts must target both efficiency and effectiveness for increasing work output and sustaining productivity in construction projects [13]. In road projects, poor planning and implementation management are key factors negatively impacting overall project performance in Egypt [14]. Material unavailability, insufficient supervision, skill gaps, inadequate tools, and incomplete specifications are challenges impacting productivity and hindering efficient project execution in construction. Issues related to inadequate training facilities, delayed salary payments, low labour motivation, insufficient wages, and ineffective performance evaluation contribute to labour productivity in the Sri Lankan construction industry [15].

The construction industry in developing countries confronts a significant issue of diminished productivity among skilled workers, impeding overall progress and growth [16]. Labour productivity is influenced by factors such as an inexperienced workforce, material shortages, accidents, tool insufficiency, poor site mismanagement, payment delays, and safety negligence [10]. Labour productivity is essential in budgeting, estimation, and scheduling, acting as a key metric for industry improvements [17]. In today's competitive market, precise and timely project execution is vital for construction organisations. Human resource management, particularly labour productivity, is fundamental to achieving these goals. This research focuses on assessing labour productivity within the construction industry, recognising its vital role in modern society.

Enhancing construction productivity is key to setting realistic objectives and fostering greater efficiency. The study is crucial as it directly impacts the economics of the construction sector, influencing its ability to contribute to societal goals and development in today's dynamic world. In Nepal, where road construction projects are rapidly rising, there is a need to better understand labour productivity. The construction industry, particularly in Nepal, lacks studies to assess labour productivity, hindering project efficiency. This study addresses the need for an evaluation of labour productivity in road construction projects in the Tanahun district. By analysing various construction activities, the research aims to identify productivity levels and factors influencing them, ultimately providing practical strategies to enhance labour productivity and meet industry standards. The past investigation was based mostly on labour productivity in building construction projects, but there were very limited studies on labour productivity in road construction projects in Nepal, so this research is carried out to fill this gap by focusing on measuring labour productivity in road construction projects within the Tanahun district of Nepal.

2.0 MATERIALS AND METHODS

This study was conducted in the Tanahun district of Nepal, located in Gandaki province, with Damauli as its headquarters, covering 1,546 square km. For calculating labour productivity, four under-construction projects, namely the upgrading of Manung-Kilchowk-Ghumti-Harkapur-Bhimad, Barahi Kani Marga, Lochadanda Krishi Paryatan Road, and Kalika Marga (CH:2+600 to 3+940), were selected.

Labour productivity in construction activities, including stonework, stone filling in gabion boxes, soling, PCC, and plum concrete, was measured. Data was collected over six consecutive days across four different projects, resulting in a total of 24 measurements for each activity to evaluate performance and efficiency.

2.1. Labour Productivity Calculation

An activity-oriented model was used for calculating labour productivity. It is expressed in output in amount or per work hour. This model gives a direct relation of output with the time consumed.

2.2. Labour Productivity in Nepal

Several departments of the Nepal government publish norms of their department, which give a standard value of labour productivity to be followed while doing rate analysis. According to the Department of Roads, the following standard values have been provided:

Table 1 Standard Norms of Labour Productivity in Nepal

Activities	TL	Q	NQ	LP
Providing and laying random rubble stone masonry work in cement mortar1:4 in structure	Skilled	5	7	0.71
	Unskilled	5	20	0.25
Providing and laying gabion structure for retaining earth with a diaphragm, including rolling, cutting weaving, placing, laying sides and diaphragms with binding wire and filling boulders, all complete as per drawing and technical specification mesh wire - 10 Swg (0.0615 kg/m), selvage wire 8 Swg (0.1057 kg/m), binding wire 12 Swg (0.0409 kg/m), hexagonal mesh type 100 mm X 120 mm, box size 1.5 X 1 X 1 m	Skilled	6	3	2
	Unskilled	6	8	0.75
Providing and laying of plain cement concrete M 10 (or 1:3:6 for nominal mix) in the foundation complete as per drawing and technical specifications.	Skilled	15	2	7.5
	Unskilled	15	22	0.68
Providing and laying of plain/reinforced cement concrete in the foundation complete as per drawing and technical specifications. PCC Grade M 15	Skilled	15	3	5
	Unskilled	15	30	0.5
Providing and laying hand-pack stone soling with 150 to 200 mm thick stones and packing with smaller stones on the prepared surface as per drawing and technical specification	Unskilled	5	12	0.42
Providing and laying plum concrete (boulder mixed concrete) as per drawing and specifications 60% M 15 Concrete and 40% boulders/stones using mechanical aids (including formworks)	Unskilled	10	30	0.33
	Skilled	10	3	3.33

Note: TL=Type of labour, Q=Quantity, NQ=Number of labour required, LP=Labour productivity

2.3. Statistical Tests

Statistical inference includes two main types: parametric and non-parametric tests. Parametric tests involve defining the probability distribution of variables and making inferences about the distribution's parameters. These techniques assume that the data follow a specific distribution, such as normality. T-tests and ANOVA are examples of parametric methods that can be applied when sample data meet normality conditions. Conversely, non-parametric methods are used when the probability distribution cannot be defined or when data do not satisfy parametric assumptions, making them more flexible for various data types and distributions. Since the samples in our context meet normality conditions, parametric tests like t-tests and ANOVA are employed for data analysis.

2.4. Hypothesis Test

H1: There is a significant difference in the mean productivity of labour for providing and laying random rubble masonry work.

H2: There is a significant difference in the mean productivity of labour for providing and laying a gabion structure for retaining earth.

H3: There is a significant difference in the mean productivity of labour for providing and laying Plain Cement Concrete (PCC).

H4: There is a significant difference in the mean productivity of labour for providing and laying reinforced cement concrete in the foundation (RCC).

H5: There is a significant difference in the mean productivity of labour for providing and laying hand-packed stone soling.

H6: There is a significant difference in the mean productivity of labour for providing and laying plum concrete.

2.5. One-Way ANOVA

One-way analysis of variance (ANOVA) is a statistical test used to determine whether there are any significant differences between the means of three or more independent (unrelated) groups. It is often used when you have multiple groups and you want to test whether there are any statistically significant differences among these groups in terms of a continuous outcome variable.

2.6. T-test

The t-statistic is the ratio of the departure of the estimated value of a parameter from its hypothesised value to its standard error. The t-test is a statistical hypothesis test in which the test statistics follow a student's t-distribution according to the null hypothesis; it includes many types. There is a one-sample t-test, which is used to compare sample means with assumed population values [18].

$$t = (\dot{x} - u_0) / (s / \sqrt{n})$$

where,
$\dot{x}$ = the sample mean
u_0 = the hypothesized population mean
s = the sample standard deviation
n = 4.4 Measurement of labour productivity

3.0 RESULTS AND DISCUSSION

Table 2 presents labour productivity data for various construction activities during the upgrading of Barahi Rani Marga. The activities include stone masonry, gabion structure installation, concrete laying, stone soling, and plum concrete work. Skilled and unskilled labour productivity is measured over six days for each activity in four different projects. The table outlines the productivity values for each day, providing insights into the efficiency of the workforce in executing the specified tasks. Data obtained for labour productivity varies from day to day, as it is not possible to do the same quantities every day. There is different weather, different moods of labour, different sets of labour, and different numbers of supporting unskilled labour from day to day depending on the quantity of work done in each day.

The table provides P values for various construction activities and types of labour involved, indicating the statistical significance of differences in labour productivity. For skilled labour in activities like random rubble stone masonry and gabion structure installation, P values are 0.213 and 0.184, respectively. Unskilled labour, with P values of 0.320 and 0.334 in the same activities, is also assessed. Additionally, P values for activities involving plain cement concrete, hand-packed stone soling, and plum concrete are provided for both skilled and unskilled labour. These values offer insights into the significance of observed variations in labour productivity across different construction tasks. Here, no p-value is less than 0.05, which means the null hypothesis is not rejected, which means there is no significant difference between the mean of four sets of data for any activity.

Table 2 P-Value of Activities for One-Way ANOVA Test

Activities	Type of Labour	P-value
Providing and laying Random Rubble Stone Masonry work in cement mortar1:4 in structure	Skilled	0.213
	Unskilled	0.320
Providing and laying a gabion structure for retaining earth with a diaphragm, including rolling, cutting, weaving, placing, and laying sides and diaphragms with binding wire and filling. Box size 1.5 X 1 X 1 m	Skilled	0.184
	Unskilled	0.334
Providing and laying of Plain Cement Concrete M 10 (or 1:3:6 for nominal mix) in Foundation	Skilled	0.226
	Unskilled	0.216
Providing and laying of plain/reinforced cement concrete in the foundation. PCC Grade M 15	Skilled	0.803
	Unskilled	0.812
Providing and laying hand-packed stone soling with 150 to 200 mm thick stones and packing with smaller stones on the prepared surface	Unskilled	0.538
Providing and laying Plum concrete (boulder-mixed concrete) 60% M15 concrete and 40% boulders/stones using Mechanical Aids (Including Formworks)	Skilled	0.128
	Unskilled	0.799

3.1. One-Sample T-Test

On taking an average of four sets of samples, the following result was found, and then a one-sample t-test was done to confirm whether there was a significant difference between the data obtained and the standard data of the Nepal government.

Table 3 Average Value of labour Productivity

Activities	TL	Labour productivity at				
		R1	R2	R3	R4	Average
Providing and laying Random Rubble Stone Masonry work in cement mortar1:4 in structure	Skilled	0.79	0.76	0.75	0.76	0.76
	Unskilled	0.29	0.28	0.28	0.28	0.28
Providing and laying a gabion structure for retaining earth with a diaphragm, including rolling, cutting, weaving, placing, and laying sides and diaphragms with binding wire and filling boulders. Box size 1.5 X 1 X 1 m.	Skilled	2.41	2.34	2.42	2.40	2.39
	Unskilled	0.80	0.78	0.78	0.80	0.79
Providing and laying of Plain Cement Concrete M 10 (or 1:3:6 for nominal mix) in Foundation	Skilled	7.70	7.80	7.68	7.77	7.73
	Unskilled	0.86	0.87	0.85	0.86	0.86
Providing and laying of plain/reinforced cement concrete in the foundation. PCC Grade M 15	Skilled	5.42	5.47	5.44	5.46	5.45
	Unskilled	0.77	0.78	0.78	0.78	0.78
Providing and laying hand-packed stone soling with 150 to 200 mm thick stones and packing with smaller stones on the prepared surface	Unskilled	0.52	0.53	0.51	0.52	0.52
Providing and laying plum concrete (boulder-mixed concrete) as per drawing and specifications. 60% M15 concrete and 40% boulders/stones using mechanical aids (including formworks)	Skilled	3.88	3.93	3.78	3.91	3.88
	Unskilled	0.42	0.41	0.42	0.42	0.42

Note: *R1= Manung-Kilchowk-Ghumti-Harkapur-Bhimad Road Project, R2= Barahi Kani Marga Road Project, R3=Lochadanda Krishi Paryatan Road Project, R4=Kalika Marga (CH:2+600 to 3+940) Road Project.*

Table 4 presents a comprehensive comparison of the obtained labour productivity values with standard values across various construction activities. The analysis of labour productivity in various construction activities reveals significant disparities between observed values and the DoR norms. For the task of providing and laying random rubble stone masonry in cement mortar 1:4, skilled labour demonstrated observed productivity of 0.76 m^3/man-day, while unskilled labour achieved 0.28 m^3/man-day. In comparison, DoR standards specify 0.714 m^3/man-day for skilled labour and 0.25 m^3/man-day for unskilled labour. Consequently, the observed values exceed the standards by 6.442% and 12% for skilled and unskilled labour, respectively. Similarly, in the case of constructing gabion structures, skilled and unskilled labour exhibited observed productivities of 2.39 m^3/man-day and 0.789 m3/man-day, greater DoR standards by 19.5% and 5.2%, respectively. The results for Plain Cement Concrete M10, Plain/Reinforced Cement Concrete in Foundation, and Plum Concrete also indicate significant discrepancies, with observed values ranging from 3.12% to 55.4% greater than DoR standards. Additionally, stone soling exhibited an observed productivity of 0.518 m3/man-day, surpassing the DoR standard by 24.519%.

Table 5 presents the p-values derived from one-sample t-tests conducted for each activity, confirming that the observed mean values are statistically significantly different from the DoR standards. These findings call for further investigation and potential adjustments in construction practices to align with established productivity norms.

Table 4 Comparison of the Obtained Value of labour Productivity with Standard Value

Activities	TL	P(DoR) (1)	A (2)	D (2)-(1)	% Different ((2)-(1))*100% (1)
Providing and laying Random Rubble Stone Masonry work in cement mortar1:4 in a complete structure	Skilled	0.71	0.76	0.05	6.44
	Unskilled	0.25	0.28	0.03	12
Providing and laying a gabion structure for retaining earth with a diaphragm, including rolling, cutting, weaving, placing, laying sides and diaphragms with binding wire and filling boulders; Box size 1.5 X 1 X 1 m.	Skilled	2	2.39	0.39	19.5
	Unskilled	0.75	0.79	0.04	5.2
Providing and laying of Plain Cement Concrete M 10 (or 1:3:6 for nominal mix) in Foundation	Skilled	7.5	7.73	0.23	3.12
	Unskilled	0.68	0.86	0.18	25.99
Providing and laying of plain/reinforced cement concrete in the foundation. PCC Grade M15.	Skilled	5	5.45	0.45	8.92
	Unskilled	0.5	0.78	0.28	55.4
Providing and laying hand-pack stone soling with 150 to 200 mm thick stones and packing with smaller stones on the prepared surface	Unskilled	0.42	0.52	0.10	24.52
Providing and laying concrete (boulder-mixed concrete) with 60% M15 concrete and 40% boulders/stones using mechanical aids (including formworks).	Skilled	3.33	3.88	0.54	16.37
	Unskilled	0.33	0.42	0.07	26.06

Note: *P(DoR)=labour productivity as per Depart of Road Nepal, A= Observed Average labour productivity, D= difference between A and P(DoR).*

Table 5 P-value of Activities for One Sample T-Test

Works as per drawing and technical specification	Type of labour	P-value
Providing and laying Random Rubble Stone Masonry work in 1:4 c/s mortar	Skilled	4.852E-08
	Unskilled	1.432E-12
Providing and laying a gabion structure for retaining earth with a diaphragm, including rolling, cutting weaving, placing, laying sides and diaphragms with binding wire and filling boulders, all complete, Box size 1.5 X 1 X 1 m	Skilled	3.012E-19
	Unskilled	2.125E-07
Providing and laying Plain Cement Concrete M10 in the foundation	Skilled	6.594E-10
	Unskilled	3.073E-28
Providing and laying plain/reinforced cement concrete in the foundation. PCC Grade M 15	Skilled	6.514E-18
	Unskilled	1.982E-32
Providing and laying hand-packed stone soling with 150 to 200 mm thick stones and packing with smaller stones on the prepared surface.	Unskilled	8.871E-19
Providing and laying plum concrete (boulder-mixed concrete) as per drawing and specifications. 60% M15 concrete and 40% boulders/stones using mechanical aids (including formworks)	Skilled	4.755E-17
	Unskilled	6.229E-22

From the table above, p-values from one-sample t-tests were found to be 4.852E-08, 1.432E-12, 3.012E-19, 2.125E-07, 6.594E-10, 3.073E-28, 6.514E-18, 1.982E-32, 8.871E-19, 4.755E-17, and 6.229E-22 for skilled and unskilled labour for random rubble stone masonry work. Providing and laying a gabion structure for retaining earth with a diaphragm, including rolling, cutting, weaving, placing, and laying sides and diaphragms with binding wire and filling boulders, Plain Cement Concrete M10 (or 1:3:6 for nominal mix), Plain/Reinforced Cement Concrete (PCC grade M15), stone soling, and plum concrete, respectively. Since the level of significance, the α value for the calculation, was taken to be 0.05, and no activity had a p-value greater than 0.05, it means that the null hypothesis is rejected. Hence, there is a significant difference between the mean observed and the standard given by the norms of DoR.

The reason for the above result is that the standard given by the Nepal government was formulated in certain conditions, like average working conditions and average capacity of labour, which were different from the study conditions, such as the skill and experience of labour working on site, the accessibility of the site, and the availability of materials, tools, and equipment at the construction site. The main reasons for greater productivity in the site DoR are that there was proper and regular supervision of work as well as labour and there is good leadership and effective management in all four sites. In the construction industry, labour performance is vital for project success. Insufficient labour productivity is a key factor hampering efficiency. Addressing and improving labour performance is essential for effective project delivery [19].

Given the labour-intensive nature of the construction industry, labour emerges as the key productive resource, and evaluating its productivity becomes essential for gauging overall company performance. Challenges in workforce performance are frequently identified as root causes for suboptimal project outcomes [20]. Acknowledging productivity as central to both industry challenges and national prosperity underscores the need for ongoing improvement within the construction sector [21]. Accurate anticipation of productivity facilitates precise estimation, scheduling, and cost projections for construction operations. A study conducted in Pakistan revealed that addressing key issues like unskilled labour, payment delays, equipment shortages, supervisor-labour communication, and financial constraints can improve labour productivity, ultimately enhancing project performance and achieving better outcomes in construction projects [22]. Key factors affecting labour productivity include lack of experience, material shortages, limited labour skills, accidents, equipment shortages, poor site management, and safety issues. Improving labour productivity in road construction requires a focus on enforcing regulations that promote efficiency and skill development. Establishing a skilled workforce and adhering to high industry standards are vital [10]. Similarly, enhanced project performance and labour productivity also rely on project managers' skills to effectively handle the project activities [23].

4.0 CONCLUSION

For the construction industry to remain profitable, it must always strive for higher productivity. This research aims to calculate labour productivity and compare it with established standard norms. The value of labour productivity of skilled and unskilled labour for stone masonry, PCC (M10), PCC (M15), plum concrete, and unskilled labour for soling was found to be 0.76 m^3/man-day, 0.28 m^3/man-day, 2.39 m^3/man-day, 0.789 m^3/man-day, 7.734 m^3/man-day, 0.858 m^3/man-day, 5.446 m^3/man-day, 0.777 m^3/man-day, 3.875 m^3/man-day, 0.416 m^3/man-day, and 0.518 m^3/man-day respectively. On testing the hypothesis, it is concluded that labour productivity measured in road construction of Tanahun district was found to be significantly greater than that provided by the government norms. The disparity in labour productivity results is attributed to variations in study conditions compared to the standard set by the Nepal government. Factors like skilled labour, site accessibility, material availability, and effective management contribute to enhanced productivity in the study sites. Regular supervision and strong leadership are identified as key contributors. These findings highlight the necessity for further exploration and potential adjustments in construction practices to align with established productivity norms. The study indicates that improving labour productivity in road construction involves factors like competitive payment, efficient resource allocation, scheduling, tool availability, effective inventory management, standardised design, financial planning, and provision of adequate break times.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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