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Analysis of Labour Productivity in Construction Industry Using Analytical Hierarchy Process and Linear Regression Method

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Abstract: ***Construction is a labour-intensive industry. The project focuses on labour productivity in the construction industry. It covers the construction labour productivity aspects, factors affecting it, comparison between the actual labour outcomes. Regression analysis and analytic hierarchy process was used to develop a model to quantify labour productivity. The aim of this study is to identify the key factors that affect the labour productivity in construction industry. Survey is carried out through questionnaire and distributed to respondents who work at various projects in construction industry and the questionnaires are rated by project managers, experienced engineers and labours using their past experiences. The data are collected and analysed. Using this data the factors affecting labour productivity are identified and ranked. Thereafter, necessary suggestions are given to improve the labour productivity.***
Keywords: Regression analysis, Labour productivity, Analytic hierarchy process, Questionnaire survey, Construction industry.

I. INTRODUCTION

Productivity in construction is often broadly defined as output per labour hour. Since labour constitutes a large part of the construction cost and the quantity of labour hours in performing a task in construction is more susceptible to the influence of management than are materials or capital, this productivity measure is often referred to as labour productivity. However, it is important to note that labour productivity is a measure of the overall effectiveness of an operating system in utilizing labour, equipment and capital to convert labour efforts into useful output, and is not a measure of the capabilities of labour alone. For example, by investing in a piece of new equipment to perform certain tasks in construction, output may be increased for the same number of labour hours, thus resulting in higher labour productivity. Here we are using AHP method and linear regression method to analyse the factors affecting labour productivity in construction industry.

A. Scope and Objectives

The aim of the study is to analyse the factors affecting labour productivity in construction industry and necessary recommendations to improve the labour productivity. Thus construction work can be done with less manpower and there by reduce overall labour cost which ultimately can help to get higher profit from the project.
The main objectives of this study is stated below;

- To study and discuss various factors affecting labour productivity in construction industry.
- Analyse and calculate the RII values and rank the factors affecting labour productivity in construction industry.
- To make recommendations to improve labour productivity in construction industry.

II. LITERATURE REVIEW

Xueqing Zhang (2019) Improving Construction Productivity by Integrating the Lean Concept and the Clancey Heuristic Model. The study illustrates the potential power of integrating “lean construction” and the “Clancey heuristic model” to elaborate a lean-Clancey-based decision-making matrix (LCDMM). Shoar and Banaitis (2019) Application of fuzzy fault tree analysis to identify factors influencing construction labor productivity: a high-rise building case study.In a different study the inter-relation between the factors were considered. First, the researchers ranked the factors affecting productivity using RII. Factors having RII>0.7 were shortlisted and then the fuzzy fault tree analysis (FTA) technique was applied to identify the basic events that cause low productivity. Aman Agrawal, Srijeet Halder (2019) Identifying factors affecting construction labour productivity in India and measures to improve productivity.In this study, various factors affecting labour productivity were identified. The data were collected by visiting six different sites and asking 302 construction workmen about their views of what affects their productivity.

Responses were also collected from site management personnel such as site engineers, supervisors and project managers about ways to improve labour productivity. Findings have been reported ranking the factors by their importance. Mohd Rahim, F. A., Mohd Yusof (2016) The challenge of labour shortage for sustainable construction. Identified skilled labour charges as much as 50% higher than unskilled labour. Apart from that, the supply of skilled labour is often found to be short of demand. Labour shortage is one of the major risks in construction projects, which can transform a well-performing project into one with cost- and schedule overrun. Due to this reason, employing skilled labour for all work is not always feasible or fnancially Viable. Madhan A, Gunarani G (2018) Factors Affecting Construction Labour Productivity using Questionnaire Survey. Found that one of the leading factors that affect labour productivity is communication problem between workers and supervisors which ranks third with 57.47%. Improper project coordination among the site personals and labours influence labour productivity in same ratio. Delay in progress payments by owners is another important factor to be considered. Lack of availability of sanitary facilities in or near the construction site especially in small projects like construction of residential sites. Menon, M. A., & Varghese, S. (2018) Labour productivity measurement method using 3D BIM of a commercial project. Labour productivity of a commercial project was assessed by modelling it 3 dimensionally by using a software called BIM. A combined productivity rate was derived from standard productivity rate and past labour usage were used for determining expected work volume and actual work volume. Project progress was monitored by comparing the actual daily productivity and the calculated. The minimum percentage of future productivity was estimated from the productivity analysis graph of the building. Mostafa E. Shehata (2012) Towards improving construction labor productivity and projects' performance. To improve project performance, variability in labor productivity should be reduced with regard to available workload and capacity (work hours). Variation that affects labor productivity and should be reduced is defined as the time difference between what was planned and what occurred in terms of task starting times and duration. Abu Bakar Muzamil (2014) Analysis of Labour Productivity of Road Construction in Pakistan.For the reliability of data cronbach's alpha test was carried out through SPSS software. The cronbach's alpha value received was 0.96 for cumulative responses. The most influential factors identified by the respondents in the country are poor salary, poor execution plan and inefficient equipment respectively. Prachi R. Ghate (2016) Importance of measurement of labour productivity in 6 construction. Found that Skilled labour is a factor which highly affects the labour productivity; since with skilled labour work can be done in less time without compromising quality of work. Changes in site layout affects labour productivity since proper arrangement of material on site can reduce time consumption for completion of work. Mistry and Bhatt (2013) Critical factors affecting labour productivity in construction projects: case study of south Gujarat region of India. Identified 27 different factors that affect labour productivity. The factors were divided into four main categories, which are technology, labour, management and external. They used the Relative Importance Index (RII) and the Analytical Hierarchy Process (AHP) to rank the factors by their importance. Czumanskia and Loddinga (2012) introduce a state-oriented approach providing the possibility to identify and prioritize the different impacts on labour productivity for subsequent process enhancements and evaluate state data of an assembly cell to establish a goal-oriented improvement process.Benviolent and Moyo (2014) stated that unavailability of materials, late payment of salaries and wages, suitability/adequacy of plant and equipment, supervisory incompetence, and lack of manpower skills, are the top five most important factors impinging on labour productivity but they did not say anything about labour strikes and other political factors.

III.METHODOLOGY

Poor labour productivity is a major problem faced in construction industry. This study is to identify the factors affecting labour productivity. The data analysis is done in excel and SPSS software. The flow chart of the study is shown in Fig.1 .

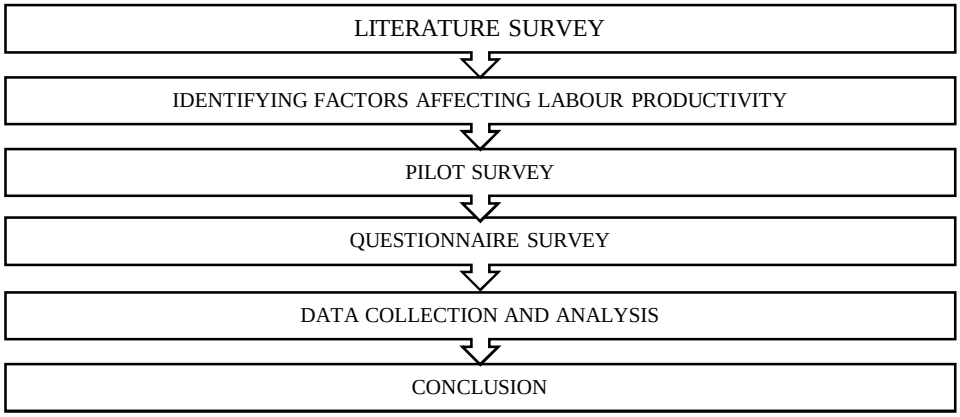

Fig.1 Overview of methodology

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A. Ranking of Factors

Inorder to rank the factors affecting labour productivity basically two methods are used, RII (Relative Importance Index) method and AHP (Analytical Hierarchy Process) method.

B. Preparation of Questionnaire

The questionnaire was distributed and 30 responses are then used for ranking of factors. The respondents were chosen based on their work, designation, experience and their willingness to contribute to construction. Based on the response from the survey the rankings are done.

C. Data Analysis

The following data analysis approaches are used ;

Relative importance index technique-Relative Importance Index method helps to determine the relative importance of the various factors affecting on labour productivity in construction industry. The five-point scale ranging from 1 to 5 is adopted and the equation to find out the relative importance index is;

$$RII=\frac{5(n_5)+4(n_4)+3(n_3)+2(n_2)+1(n_1)}{5(n_1+n_2+n_3+n_4+n_5)}\ X\ 100$$

Where;

Where: n_1, n_2, n_3, n_4, n_5 = the number of respondents who selected 1,2,3,4,5.

1 means no effect;
2 means Less important;
3 means Somewhat important;
4 means important;
5 means very important.

TABLE I
RII COMPARISON SCALE

SCALE	MEANING
1	Does not affect
2	Less important
3	Somewhat important
4	Important
5	Very important

Reliability analysis - Cronbach's coefficient alpha is used primarily as a means of describing the reliability of multi item scales. Alpha can also be applied to raters in a manner analogous to its use with items. Formula for the standardized Cronbach's Alpha is;

$$\alpha = (N.\hat{C})/(\tilde{V}+(N-1).C)$$

Here, N is equal to number of items,

$\hat{C}$ is the average inter-item covariance among the items

$\tilde{V}$ is the average variance.

Analytical hierarchy process (AHP) – AHP is a decision making tool. It assists in structuring complex problems into a system there by capturing both qualitative and quantitative factors. The first step of the AHP consists of building a hierarchy of elements and describing the problem under consideration. The objective or goal from the decision-makers viewpoint is represented at the top level of the hierarchy. This is followed by the intermediate levels that demonstrate the criteria and sub-criteria contributing to the decision. Once the hierarchies have been established, the next step is finding out the weight of each criterion with respect to others within the same level. This is accomplished via pair wise comparisons using a nine-point scale.

TABLE II
AHP PAIRWISE COMPARISON SCALE

VALUE RATING FOR JUDGEMENT	LINGUISTIC JUDGEMENT
1	Elements are equally preferred
3	One is moderately preferred to the other
5	One is strongly preferred to the other
7	One is very strongly preferred to other
9	One is extremely preferred to the other

Linear regression method - Regression analysis is widely used for prediction and forecasting and, is used to understand which among the independent variables are related to the dependent variable, and to explore the forms of these relationships. In some circumstances, regression analysis can be used to infer casual relationships between the independent and dependent variables. In this thesis, regression analysis will be done using the software SPSS.

IV. RESULT AND DISCUSSION

From AHP and RII techniques ranking of factors which affect labour productivity were worked out and the following table gives the ranking.

TABLE III
RANKING OF FACTORS AFFECTING LABOUR PRODUCTIVITY BY AHP AND RII TECHNIQUES

SL.NO.	FACTORS AFFECTING LABOUR PRODUCTIVITY	RII RANK	AHP RANK
1.	TECHNOLOGICAL		
F.1.1	Clarity Of Technical Specification	7	10
F.1.2	The Extent Of Variation/Change Order During Execution	17	16
F.1.3	Coordination Level Among Design Disciplines	16	13
F.1.4	Design Complexity Level	9	14
F.1.5	Rework	6	15
F.1.6	Site Lay Out	10	9
F.1.7	Inspection Delay/Stringent By The Engineer	12	12
F.1.8	Site Restricted Access	8	11
2.	HUMAN/LABOUR		
F.2.1	Motivation of labour	18	4
F.2.2	Skill of labour	1	8
F.2.3	Physical fatigue	26	5
F.2.4	A shortage of experienced labour	4	6
3.A	MANAGEMENT (Type-A)		
F.3.1A	Construction managers lack of leadership	25	21
F.3.2A	Lack Of Labour Supervision	20	27
F.3.3A	Working over time	24	26
F.3.4A	Crew size and composition	11	24
F.3.5A	Unsuitability of storage location	13	25
F.3.6A	Accidents as a result of poor site safety programme	3	22
3.B	MANAGEMENT (Type-B)		
F.3.1B	Proportion of work subcontracted	19	17
F.3.2B	Unrealistic scheduling and expectation of labour performance	22	23
F.3.3B	Shortage of materials	14	19
F.3.4B	Construction method	5	3
F.3.5B	Payment delay	2	1
4.	EXTERNAL		
F.4.1	High/low temperature	23	7
F.4.2	High humidity	27	18
F.4.3	High wind	21	20
F.4.4	Rain	15	2

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Regression Model For Internal Plastering - The linear regression analysis was done based on the data collected from different sites. The number of labours required for each day's work is noted and only 12 mm thick internal plastering in 1:6 cement motar is considered. The summery of data collected is shown in the Table IV

TABLE IV
DATA FOR INTERNAL PLASTERING MODEL

NO. OF LABOURS	**OUTCOME**
4	34.3
5	39.5
6	46.2
7	56.8
8	68
8	62.7

TABLE V
MODEL SUMMARY

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.986	.972	.965	2.50015
a. Predictors: (Constant), NO OF LABOUR				
b. Dependent Variable: OUTCOME				

TABLE VI
COEFFICIENTS OF VARIABLES

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.140	4.455		.031	.976
	No Of Labour	8.070	.685	.986	11.786	.001
a. Dependent Variable: OUTCOME						

Table V provides the R and R^2 values. The R value represents the simple correlation and is 0.986 (the "R" Column), which indicates a high degree of correlation. The R^2 value (the "R Square" column) indicates how much of the total variation in the dependent variable (outcome) depends on the independent variable (no of labours).
The Coefficients table provides us with the necessary information to predict labour outcome from factors considered, as well as determine whether these factors contributes statistically significantly to the model (by checking at the "Sig." column). Furthermore, the values in the "B" column under the "Unstandardized Coefficients" were used to present the regression equation as:

O/C = 0.140 + 8.070 N
O/C: Internal plasteringlabour outcome in m^2

N: Number of labour required

Thus the regression model has a strong correlation coefficient R equal 0.986 and the coefficient of determination R square equal 0.972.

A. Methods To Improve Labour Productivity In Construction Industry

1) *Encourage, Motivate, Reward and Recognize:* The employer must ensure that on his part he always has words of encouragement for his staff. Encouraging and helps them move forward and do even better, and makes the worker feel happy. Innovative ways of motivating them spurs them even more.
2) *Accountability:* Every employee needs to be well aware that he is accountable for his actions and decisions, and he can neither pass the buck nor pass the blame to someone else.
3) *Team work:* Team work always helps in increasing workplace productivity since there is more input in the form of more ideas and minds at work.
4) *On time Payment to the Workers:* The employer should pay the wages to the employees on time.
5) *Proper Supervision:* There should be proper and clear supervision of work and the supervision should be done in time to ensure productivity.
6) *Clearance Of Legal Documents Before Starting Of Work:* All the legal formality should be done before starting the work.
7) *Scheduling:* Scheduling is to organize and allocate the resources of, equipment and labour with the construction project's tasks over a set period of time.
8) *Seasonal Change:* Weather is to some extent unpredictable. When not scheduled adequately, weather can cause delays due to forced changes in the schedule as well as damages causing rework.
9) *Rules and Regulations :* Every employer as well as employee should follow the rules and regulations.
10) *Political Influence:* Stability of government is essential in productivity.
11) *Planning and Coordination:* Contractors and other building industry practitioners to dedicate their efforts to managing those factors that significantly impact on labour productivity. This can be achieved through adequate work planning, coordination and management of the construction process with more emphasis on implementation of efficient systems for procuring materials, tools and equipment; worker motivation; continuous professional development schemesfor workers.

V. CONCLUSIONS

From the present study, total 27 factors were identified which affects labor productivity in construction industry. 30 feedbacks from various sectors were collected to identify critical factors by two techniques : AHP & RII. RII Technique gives first 5 crucial factors as: (1) Skill of Labour, (2) Payment Delay, (3) Accidents as a result of poor site safety programe. (4) Shortage of experienced labour, (5) Construction method. AHP Technique gives first 5 crucial factors as (1) Payment Delay, (2) Rain, (3) Construction methods, (4) Motivation Of Labour, (5) Physical fatigue. Finding from this study reveals that there is a contradiction in critical factors ranking by two techniques. Contractors should act on these factors to improve labour productivity which ultimately can help to get higher profits from the projects. From the Cronbach's Alpha relatiability analysis the observed Cronbach's Alpha value for technical factor, labour related factor, management related factor, safety issues and external factors are 0.977, 0.879, 0.954, 0.919 respectively. Satisfactory result are obtained from the Cronbach's Alpha analysis.

Construction is labour intensive, it can be argued that labour-power is the only productive resource, thus construction productivity is primarily dependent on human effort and performance. The buildability variables explored are quantified, coupled with the method applied to establish the relationship between the various factors investigated and labour productivity, further add to the contribution of this study to the body of buildability knowledge. This can ultimately assist in developing a design support system, which can provide designers with the specific buildability knowledge required to make timely design decisions.

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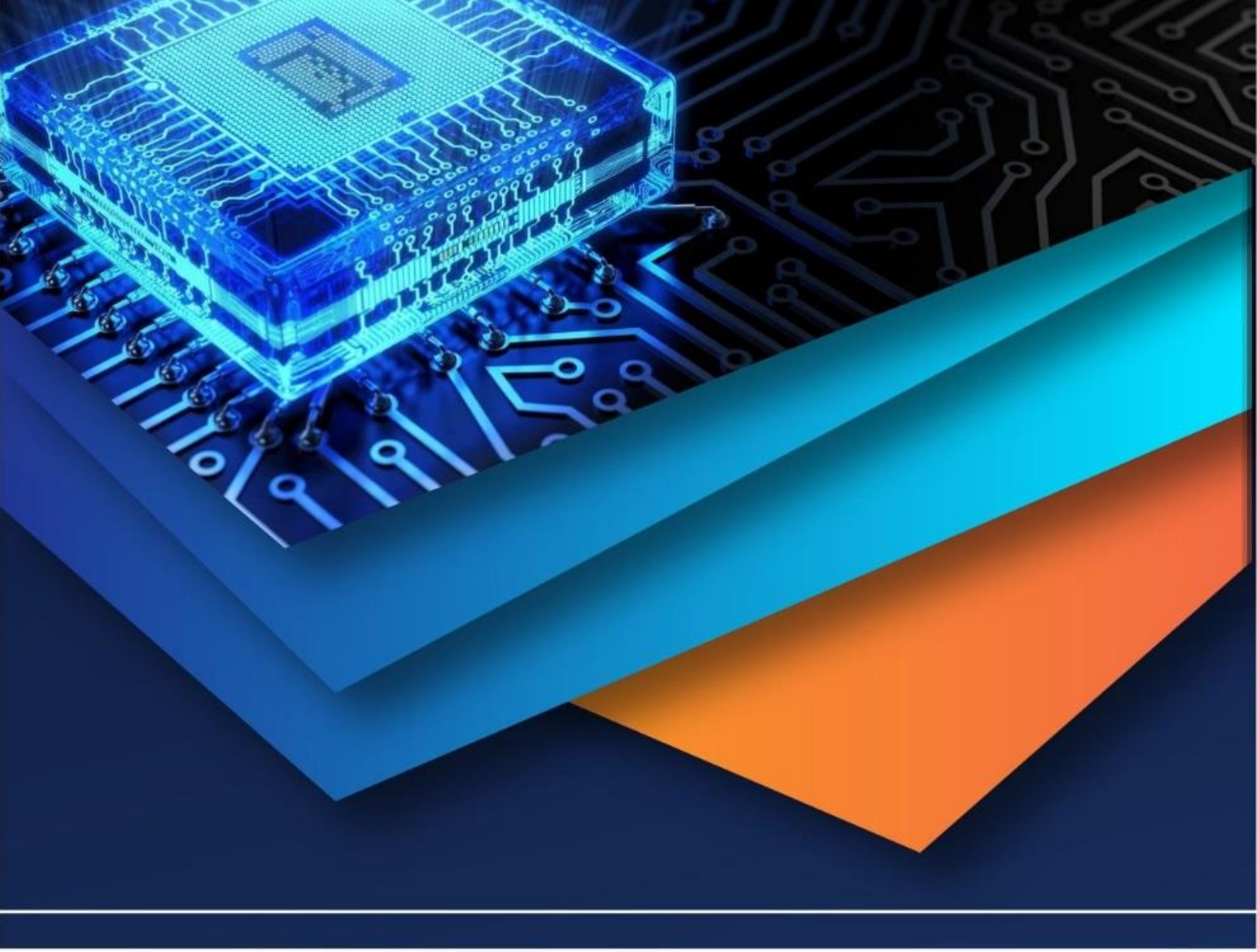

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