

Influential Factors Affecting Labour Productivity in Concreting of Columns

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Abstract - Concreting is one of the expensive elements in construction projects. Labour cost accounts for a major share in the total project cost along with the cost of materials and machineries. Labourers are the most dynamic element in the construction industry and accounts for 30 to 50% of the total construction cost. Therefore, it is imperative to identify the important factors influencing labour productivity and its effects on labour productivity. Data collected from four different construction sites were considered in this study. A multivariate linear regression analysis was used to identify the effects of statistically significant parameters on labour productivity. The study shows that skilled labourers, overmanning, daily payment, complexity of design and age group between 30 - 50 increases the productivity of machine mixing - man transfer concreting technique of columns. Similarly labour productivity was found to decrease with female worker, higher floor number, native speaker, communication problem and afternoon work hours.

Key words: Labour productivity, Multivariate linear regression, Machine mixing, Man transfer, Concreting

I. INTRODUCTION

Construction is the world's largest and most challenging industry. The Construction projects uses huge amount of resources on and off the field in various forms of resources viz., materials, construction plants, equipment and human resources along with money, time and space. Optimizing material, equipment and labour use is a key factor in maximizing the productivity and minimizing cost of construction projects. Most of the construction agencies focus on material and equipment management to reduce cost and increase efficiency. However, the construction labourers are the most dynamic element in the construction industry and their cost represents 30 to 50% of the overall construction cost. Hence, labour productivity plays an equal role in the success of a project especially in today's world of high labour expenses. Time and cost overruns of construction projects are widely attributed to poor productivity of construction labour force. Labor productivity is defined as the amount of goods and services produced by one hour of labor.

Productivity is considered as the main value-adding function within the construction sector. Productivity is generally defined as the average direct labour hours required to install a unit of material. Labour is one of the basic requirements in the construction industry. Labour productivity can be measured for a firm, a process, an industry, or a country. It is often referred to as workforce productivity. Labour productivity usually relates manpower in terms of labour cost to the quantity of outputs produced (Borcherding and Liou, 1986).

In today's world, the construction industry is rated as one of the key industry. It helps in developing and achieving the goal of society. Study and knowledge of construction productivity are very important because it can be a decisive factor for profit or loss to the governing agencies. Knowledge of labour productivity during construction can save money and time. That is, making maximum out of every rupee being spent on labour cost is essential for keeping the cost to minimum.

This study focuses on identifying the effect of different influential factors on labour productivity of machine mixing-man transfer technique for concreting of columns, which will help construction agencies in labour allocation to different projects.

The next section focuses on the relevant literature published on labor productivity. It is followed by data collection and methodology. The paper concludes with a discussion on the results obtained in the study.

II. LITERATURE SURVEY

Productivity in construction industry is defined in terms of the units of production output per personal hour input (Neil and Knack [1984] and Thomas [2000]). A review of the relevant literature published on labour productivity is given below.

Craftsman questionnaire surveys have been used in several studies to analyze the factors influencing the productivity in construction industry. (Hanna et al., 2005; Rivas et al., 2011; Jarkas and Bitar, 2012; El-Batreek et al., 2013). Previous studies were conducted on labour productivity evaluation to examine the effects of delivery method and weather on structural steel erection projects (Thomas et al., 1999), the effect of floor numbers for a multi-storey building in Vietnam (Nguyen, and Nguyen, 2012), and the impact of extended overtime (Thomas, 1992; Hanna et al., 2005). In another study, Jarkas and Bitar (2012) focused on factors perceived by contractors to identify the major factors influencing the labour productivity in Kuwait. And also studies were conducted on factors affecting masonry labour productivity (Sanders and Thomas., 1991), buildability factors influencing concreting labour productivity (Jarkas, 2012), impact of change orders on small labour intensive projects (Hanna and Gundus, 2004).

Very few studies are reported on the labour productivity of concreting of columns. One of the studies that focused on labour productivity of concreting is Jarkas(2012), in which he made an investigation to determine and quantify the effects and relative influence of skipped and pumped concrete placement methods on labour productivity. The study reported that the influence of concrete workability, reinforcement congestion, volume placed and height above ground level is found to be significant on the labour productivity of both pumped and skipped concreting methods.

To the best of author's knowledge no studies have been conducted on assessing labour productivity of machine mixing-man transfer technique in concreting of columns. Therefore, an attempt is made to identify the important factors affecting labor productivity for machine mixing- man transfer concreting in columns and its effect.

III. DATA COLLECTION

The data required for the study are - work done in terms of volume, time taken to finish the task, details of laborers involved, overtime, delay in material and equipment supply, floor number, labor rates, environmental factors at the time of construction etc. The data sources for this study include direct field observation, questionnaire survey, labor office etc.

Daily visit method was employed to collect data from the sites. As a part of data collection questionnaire survey was carried out and relevant other information such as work done in m³, no. of labourers, no. of hours worked, data regarding the dimensions of columns etc were collected from four commercial building construction project sites located in the state of Kerala in India.

The various factors which were used as input to the regression model are given in Table 1:

Table 1- Factors used for regression

| Factors | Type of data |
|--------------------------|--------------|
| Skilled/Unskilled labour | Categorical |
| Gender | Categorical |

| | |
|------------------------------|-------------|
| Floor number | Categorical |
| Availability of working crew | Categorical |
| Availability of materials | Categorical |
| Overtime days | Categorical |
| No. of hours | Continuous |
| Native speaker or not | Categorical |
| Communication problem | Categorical |
| Method for Concreting | Categorical |
| Method for transfer | Categorical |
| Overmanning | Categorical |
| Effect of complex design | Categorical |
| Preferred time | Categorical |
| Mode of payment | Categorical |

IV. METHODOLOGY

The labour productivity for this study is estimated using work done in m³, no. of hours worked and no. of labourers using equation (I) :

$$\text{Labour productivity} = \frac{WD}{L \times H} \quad (I)$$

Where, WD = Work done in m³

L = No. of labourers

H = No. of hours worked

In this study labour productivity was modeled using multiple linear regression as shown in equation (II). The analysis was carried out using Ordinary Least Square (OLS) method. The assumptions of linear regression includes:

- Expected value of Y is a linear function of X.
- The error term is homoscedastic i.e., uniform variance
- Error is normally distributed
- Error terms are random

The relationship between dependent and independent variable can be modeled in a multiple regression analysis using the following equation:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n + \varepsilon \quad (II)$$

Where,

y = Dependent variable

x₁, x₂ x_n = Independent variable

n = No. of predictors

$\beta_1, \beta_2, \dots, \beta_n$ = Estimated coefficients

$$\beta_0 = \sum (y - \hat{y}) \quad (\text{III})$$

$$\beta_i = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{(x_i - \bar{x})^2} \quad (\text{IV})$$

$i = 1, 2, 3, \dots, n$

y = Observed value of dependent variable

x = Observed value of independent variable

\hat{y} = Estimated Value of dependent variable

\bar{x} = Mean of independent variables

\bar{y} = Mean of dependent variables

β 's are estimated using Ordinary Least Square method. In this method the focus is on minimizing squared prediction error within the sample.

Goodness of fit of the model is estimated using coefficient of regression (R^2). R^2 shows variance of "y" explained by the model.

$$R^2 = 1 - \frac{SSE}{SST} \quad (\text{V})$$

Where,

$$SSE = \text{Error sum of squares} = \sum (y - \hat{y}) \quad (\text{VI})$$

$$SST = \text{Total sum of squares} = \sum (y - \bar{y})^2 \quad (\text{VII})$$

y = Observed value of dependent variable

\bar{y} = Average y value of dependent variable

$R^2 = 1$ is a perfect score, obtained only if the data points happen to lie exactly along a straight line; $R^2 = 0$ is perfectly lousy score, indicating that 'x' is absolutely useless as a predictor for 'y'.

A t-value in a linear regression model is computed by dividing the slope by the standard error:

$$t = \frac{\beta_i}{se(\beta_i)} \quad (\text{VIII})$$

Where,

β_i = Estimated coefficient

$$se(\beta_i) = \sqrt{\frac{\sum (y - \hat{y})^2}{n - 2}} \quad = \quad \sqrt{\frac{SSE}{SS[x]}} \quad (IX)$$

This equation provides the standard error formula for the slope in a simple linear regression model only. As the sum of squares of x gets larger, the standard error becomes relatively smaller. As the SSE becomes larger, the standard error also becomes larger.

Each *t*-value is associated with a *p*-value that depends on the sample size. The *p*-value is used as the basis for determining the significance of different predictors in the model.

V. RESULT AND DISCUSSION

The data is analyzed using "Stata 11" software. A multivariate linear regression analysis was performed to identify the influence of different factors on labour productivity of concreting for columns using machine mixing-man transfer method.

A total of 15 variables were considered for the analysis. But out of that only 11 variables were found to be significant at $\alpha = 0.1$. The sample size for machine mixing - man transfer concreting analysis was 160 and the regression model developed has an R^2 value of 0.46. The corresponding F statistics was 11.44, P value <0.001 ensuring overall fit to the regression value. The coefficient of the regression model along with the associated statistics are shown in Table 2.

Table 2- Coefficients of associated statistics of linear regression model for machine mixing-man transfer type of concreting

| Labour productivity | Coefficient | Standard error | T | Significance |
|--------------------------|-------------|----------------|-------|--------------|
| Skilled/Unskilled | 0.010 | 0.004 | 2.57 | 0.011 |
| Gender | -0.015 | 0.005 | -2.7 | 0.008 |
| Floor No. | -0.041 | 0.006 | -7.39 | <0.001 |
| Native speaker | -0.034 | 0.006 | -5.85 | <0.001 |
| Communication problem | -0.022 | 0.006 | -3.44 | 0.001 |
| Overmanning | 0.012 | 0.004 | 3.07 | 0.003 |
| Effect of complex design | 0.011 | 0.003 | 3.88 | <0.001 |
| Preferred time | -0.013 | 0.005 | -2.58 | 0.011 |
| Mode of payment | 0.021 | 0.003 | 6.41 | <0.001 |
| No. of hours | -0.015 | 0.003 | -5.28 | <0.001 |
| Age: 30-50 | 0.006 | 0.003 | 1.67 | 0.098 |
| Constant | 0.134 | 0.017 | 7.96 | <0.001 |

The variables that were found to be statistically significant include number of hours worked, indicator for skilled labours, gender of the workers, floor number, native speaker, overmanning, communication problem, effect of design complexity, preferred working time, mode of pay and age group. The analysis suggest that skilled labourers, overmanning, daily payment, complexity of design and age group between 30 - 50 increases the productivity of machine mixing - man transfer concreting of columns. The factors that negatively influence labour productivity of machine mixing - man transfer concreting of columns includes female worker, floor number, native speaker, communication problem and afternoon work. It was also noticed that the labour productivity decreases with the number of hours of labour.

From this analysis, it can be concluded that, labour productivity of machine mixing-man transfer technique can be increased by providing skilled labourers, by ensuring proper communication and understanding of the work and design by labourers, by avoiding afternoon work, not requiring long work days etc. It is also advised to keep the payment method on daily basis. The findings of the present study were limited to the data collected from four construction sites. It is recommended that further studies, involving data collected from more number of construction sites are carried out to study the impact of various factors on labour productivity for column concreting using machine mixing-man transfer technique.

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