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MICRO AND MACRO LEVEL ANALYSIS OF LABOR PRODUCTIVITY

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ABSTRACT

In this paper a study has been made using a simple productivity measurement system used to measure the productivity of the major activities in a construction project. In this measurement system productivity data is collected for the activities such as formwork, rebar, concreting, masonry, plastering and painting activities. The micro level study of the activities is performed by Time - Motion study. Later X bar control chart was used to analyze the deviation in the daily labor productivity of the repetitive construction process, so as to arrive at the actual productivity values of the construction activities which serve as a basis to forecast the progress of work. This paper analyzes the labor productivity data of external painting activity only. The objective of the study was to study the variation in the daily productivity values to arrive at the actual productivity value by eliminating the values which fall out of the control limits.

Key words: Labor productivity, Micro level study, Time-motion study, X bar control chart, External painting.

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1. INTRODUCTION

Construction is one of the biggest and the oldest business in the industrial sector contributing a substantial amount towards the economy of the world. The construction field is one of the labor intensive fields, with the intensive use of human labor comes the question of productivity of labor. The productivity of labor has been a topic of interest for researchers for many decades, as a result, numerous literatures have been published on the measurement, effectiveness and improvement of labor productivity. In this research an attempt has been made on the analysis of labor productivity using X bar control chart.

Productivity has been defined in numerous ways, one of the simplest form of defining productivity is as the ratio of output to input (Park, Thomas and Tucker 2005) [1]. In context to labor productivity, the productivity of labor is defined as the ratio of labor output in units of work to the input of time consumed by the labor to perform that work measured in units of time (Shehata and El-Gohary 2012) [2]

$$\text{Productivity}= \frac{\text{Output}}{\text{Input}}$$

$$\text{Labor Productivity}= \frac{\text{Output in Units of Work}}{\text{Work-hours}}$$

The labor productivity is an important factor which can indicate the present performance and also effectively predict the future state of the project. A simple, effective and economically feasible model is needed to monitor the labor productivity of a project. The productivity data's of only formwork, rebar and concreting activities alone may not be responsible for the hindrance of project progress. From the literature survey we can see that micro level productivity data is an accurate indicator of the labor productivity.

1.1. Productivity Data Collection

There are many productivity measurement techniques that exist which can be utilized for measuring construction labor productivity. In this study Time- motion study has been used to collect the micro level labor productivity data on the construction activities and also to measure the interruptions associated with the activities

1.2. Active Time

The active time corresponds to that amount of time where a mason or a worker is engaged in performing activities in lieu of work.

1.3. Inactive Time

The inactive time corresponds to that amount of time where a mason or a worker is not engaged in performing activities in lieu of work i.e. the worker may be resting due to fatigue, speaking to a co-worker and waiting for materials etc.

1.4. Productivity and Performance Indicators

The average productivity values obtained from the activities which indicates the labor performance and the deviations causing the values to out of control is depicted using indexes such as Disruption Index (DI) and Performance Ratio (PR).

1.5. Disruption Index

It is the ratio of the number of disrupted workdays divided by the total number of observed workdays.

$$\text{Disruption Index (DI)} = \frac{\text{Number of abnormal (disrupted) work days}}{\text{Total no of work days}}$$

1.6. Performance Ratio

It is defined as the ratio of the actual cumulative productivity divided by the expected baseline productivity.

$$\text{Performance Ratio (PR)} = \frac{\text{Cumulative Productivity}}{\text{Expected Baseline Productivity}}$$

1.7. Cumulative Productivity

Cumulative productivity is defined as total quantities installed to date divided by compilation of all of the work hours charged to an activity.

The primary use of cumulative productivity calculations is to evaluate how the work is progressing as a whole and to predict the final productivity rate upon completion of the activity

$$\text{Cumulative Productivity} = \frac{\text{Total quantities installed}}{\text{Total work hours charged to a task}}$$

1.8. Baseline Productivity

Baseline Productivity is defined as the best productivity that occurs when there are few or no distractions. This best productivity is called the baseline productivity.

The baseline productivity is calculated in the following way:

- Consider the number of workdays that constitute 10% of the total workdays.
- Round this number to the next highest odd number; this number should not be less than 5. This number (n) defines the number of days in the baseline subset.
- The contents of the baseline subset are the n workdays that have the highest daily production.
- List the daily productivity values for these days.
- The baseline productivity is the mean of the daily productivity values in the baseline subset.

1.9. Time - Motion Study

Time motion study is defined as systematic observation, analysis and measurement of the separate steps in the performance of a specific job for the purpose of establishing a standard time for each performance, improving procedures and increasing productivity.

2. LITERATURE REVIEW

The authors Song and Abourizk (2008) [3] demonstrated an approach to measuring productivity, collecting, historical data, and developing productivity models using historical information. The authors discovered that based on the productivity measurement decision, a data acquisition system must be carried out to maintain a track of task input, work output, and productivity-influencing factors from past and current projects using appropriate information-collection techniques, which are influenced by the features of the data in terms of data source and the degree of detail needed. Xhaferi (2013) [4] reviewed the methodologies used in productivity measurement and concluded that the definition of variables used in the model and the estimation methodology are crucial for the results obtained and also suggested that micro- panel dataset will be more helpful in solving estimation and comparison models in productivity studies Sweis et al. (2009) [5] suggested a methodology to model the variability of masonry labor productivity. The authors analysis indicated that when daily productivity values fall between the control limits, loss of productivity is within normal variation while daily productivity values falling above the upper control limit imply a loss of productivity that is imputable to the work environment factors as within the normal variation, and in particular to certain significant influential factors that can be cited during the project.The author Ault (2013) [6] studied the role of individual control charts to help the productivity improvement of repetitive construction processes. The author used control charts, as the first step in the improvement process. Process measurement translated into control charts will specifically identify points in the construction process where variation is occurring.Proper management of resources in construction projects can yield substantial savings in time and cost. Therefore, it is important for contractors and construction managers be familiar with the methods leading to evaluate the productivity of the equipment's and the laborers in different crafts. As construction is a labor-intensive industry. The authors Shehata and El-Gohary (2012) [2] have provided a guide for necessary steps required to improve construction labor productivity and consequently, the project performance. It can help to improve the overall performance of construction projects through the implementation of the concept of benchmarks. Also the authors have conducted two major case studies to show construction labor productivity rates, factors affecting construction labor productivity and depicting the performance using varies entities like Disruption Index (DI), Performance Ratio (PR) and Project Management Index (PMI). Pekuri, Haapasalo and Herrala (2011) [7] clarified the meanings of different terms related to productivity and analyzed the state of productivity in the Finnish construction industry at the macro level. They proposed to make an understanding of prevailing habits and shortcomings in productivity and carrying out measurement. Their study of the performance measure in the construction industry indicated that productivity is an ambiguous concept. The authors Prakash Rao, Ambika Sreenivasan and Prasad Babu (2015) [8]studied about the daily labor productivity and the factors attributing to the same. In the construction industry, productivity is an important aspect that can be used as an index for measuring the efficiency of production. In some instances it also assists in examining the economic development of a society

3. METHODOLOGY

The required productivity values for the various activities is determined by the quantity estimation from GFC drawings and the baseline schedule.

The determined macro level productivity values is taken as the required net baseline productivity values or as the target productivity value to be achieved.

Then the micro level data of the activities in the scope of study is collected using Time Motion Study.

The daily productivity values is analysed using X bar control chart to arrive at the true productivity.

The interruptions caused during the execution of the activities is identified and quantified.

The actual baseline productivity is determined by using the daily productivity values.

The variation in the productivity values in each month is depicted using indices such as Disruption Index (DI) and Performance Ratio (PR).

3.1. Data Collection

The case study construction project from which the observation is made was an industrial construction. In this research the time motion study technique is used to collect the labor productivity data at four quadrants every day, each quadrant is divided based on the time table fixed as per time keeping regulation existed at the project site.

The time consumed by the labor for a particular work was recorded in minutes and the least count or least recorded time was 1 min, any activity or an interruption to work falls below 1 min was unrecorded.

In order to standardize the process of data collection, a list of sub activities which is included and excluded for the time study have been devised for each of the activities considered under the scope of study and are shown in Table 1

Table 1 List of inclusion and exclusion of sub-activities considered for time-motion study

List of Inclusion and Exclusion of sub activities for External Painting	
Inclusion	Exclusion
Surface Preparation	Emulsion Preparation
Base Coat, Second Coat and Final Coat	Scaffolding Erection for Painting

3.2. Control Chart

Control charts are a statistical tool used in quality control to

- Analyze and understand process variables
- Determine process capabilities
- Monitor effects of the variables on the difference between target and actual performance.

Control charts indicate upper and lower control limits, and often include a central (average) line, to help detect trend of plotted values. If all data points are within the control limits, variations in the values may be due to a common cause and process is said to be "in control". If the data points fall outside the control limits, variations may be due to a special cause and the process is said to be out of control (Mann, 2010).

3.3. X bar Control Chart

The X bar control chart uses control limits to optimize the process by eliminating the values which are out of control limits. The X bar chart uses Upper Control Limit (UCL) and Lower Control Limit (LCL) to establish the control limits along with central average line. In this study 1σ limits are used to optimize the process

3.4. Sample Size Calculation

The sample size or minimum number of observations per activity is determined by taking the absolute limit of inaccuracy, L as +5% at 95% confidence level. (Shehata and El-Gohary 2012) [2]

The minimum number of observations required is calculated using the formula

$$N = \frac{Z^2 * P * (1 - P)}{L^2}$$

Where,

Z = number of standard deviations defining the confidence intervals, its value depends on the level of confidence required, (Z= 2 when 95% confidence is required).

L = absolute limit of inaccuracy (sampling error) expressed as a decimal equivalent

P = the estimated probability of observing a worker doing a certain activity. P is taken as 0.3 (Shehata and El-Gohary 2012). Hence

$$N = \frac{2^2 * 0.3 * (1 - 0.3)}{0.05^2} = 336$$

The minimum number of observations was calculated and found to be 336 observations. In a day if a 5 member labor team was observed, then for 4 quadrants, 4 x 5 = 30 observations are made per day.

4. RESULTS

The micro level factors are the factors responsible for the hindrance of productivity of a labor or a team of labors at the activity level. The reasons for interruption of the activity out of which some are common for projects irrespective of location or scale and there may be additional reasons which are not present or too minimal to be accounted in this project. Table 2 summarizes the labor productivity analysis of external painting while Table 3 summarizes the interruptions for external painting activity. Labor productivity indices of external painting are shown in Table 4. Figure 1 shows the X bar chart for external painting activity for the month of January while Figure 2 shows the X bar chart for February. Monthly variation of Disruption Index and Performance Ratio are shown in Figure 3

Table 2 Labor productivity analysis of external painting

Month	Required Productivity per mason per day (Sq.-m)	Actual Productivity per mason per day (before using control chart) (Sq.-m)	Actual Productivity per mason per day (after using control chart) (Sq.-m)	Baseline Productivity per mason per day (Sq.-m)	Cumulative Productivity per mason per day (Sq.-m)
January	124.922	99.688	112.500	110.35	98.100
February	108.570	95.381	99.200		95.650

Table 3 Interruptions for external painting activity

Interruptions (%)							
Month	Resting	Talking	Waiting for Materials	Waiting for Instructions	Using Mobile Phone	Using Restroom	Client Site Visit
January	2.18%	2.20%	1.74%	0.69%	1.55%	0.00%	0.51%
February	2.86%	1.83%	2.75%	0.00%	1.59%	0.26%	0.00%

Table 4 Labor productivity indices of external painting

Month	Disruption Index (DI)	Performance Ratio (PR)
January	13%	79%
February	29%	88%

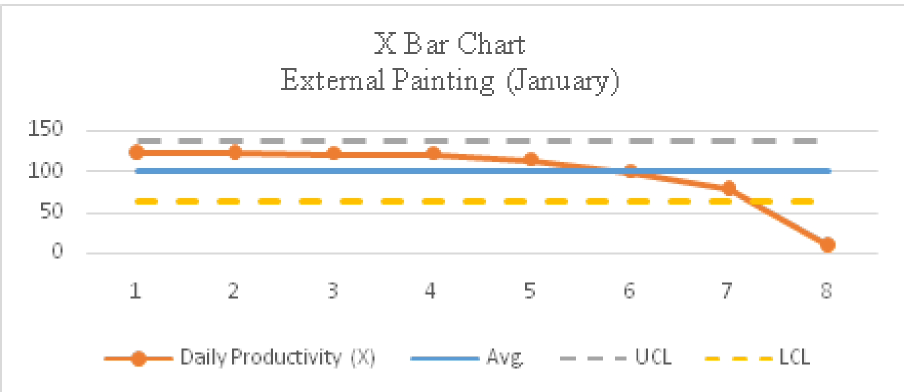

Figure 1 X bar chart for external painting (January)

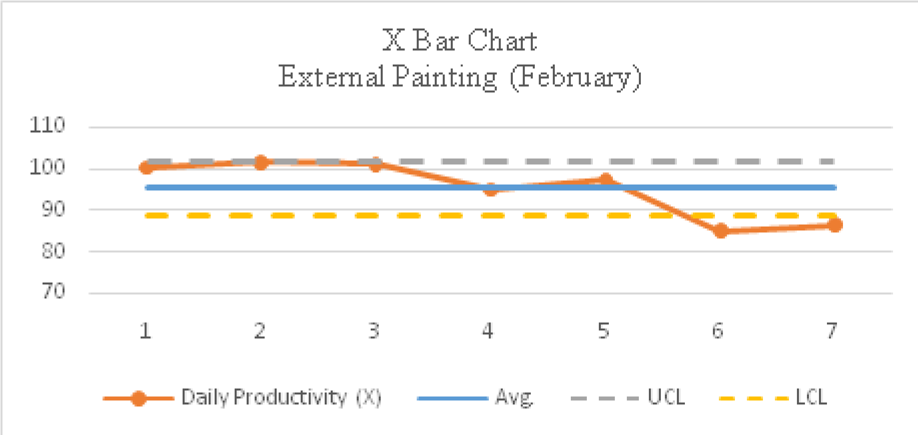

Figure 2 X bar chart for external painting (February)

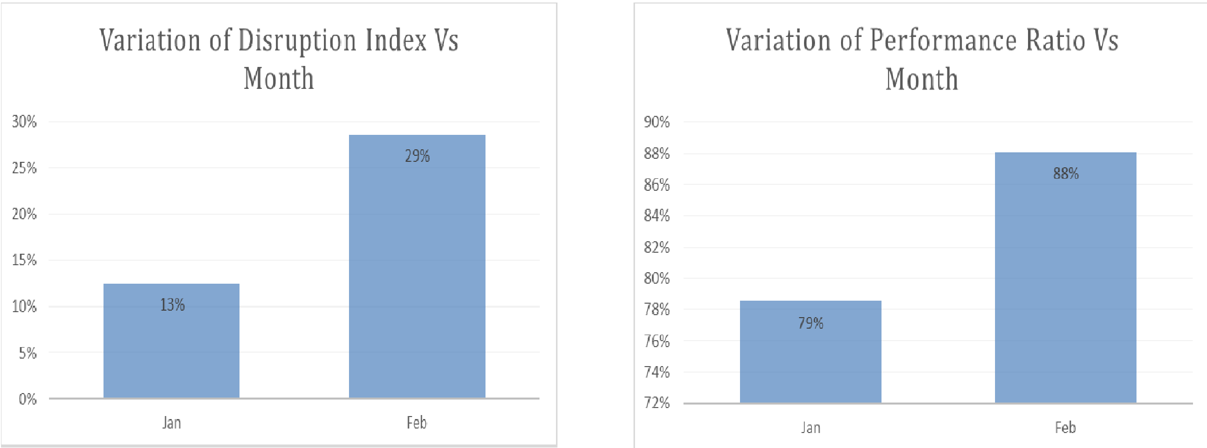

Figure 3 Monthly variation of Disruption Index and Performance Ratio

4.1. Interpretation

The micro level analysis of external painting activity gives a greater insight into the productivity of the external painting labor team. The interpretation of the analysis is listed below.

- The required productivity or the expected productivity was greater than the actual productivity for the months January and February as shown in Table 1.
- The Table 3 shows the time spent by the labors being idle mainly due to "resting" followed by talking to co-workers and waiting for materials etc. Which could have been minimized to get the required productivity.
- The Figure 3 shows the variation of disruption index. February month shows disruption index of 29% due to lack of clearance for the carrying out the activity. However the performance ratio during the month of February (88%) is higher than January.

5. CONCLUSIONS

- The daily measurement and recording of labor productivity is essential for the benchmarking of productivity of that labor with respect to that location and the prevailing condition project.
- The known values of labor productivity will give the exact idea of the number of labors to be employed to achieve the scheduled quantity of work.

- The use of X bar control chart gives more accurate productivity value of the labor than the conventional average method by eliminating the productivity values which are out of control limits due to the disruption.

6. LIMITATION AND FUTURE SCOPE

- The use of control chart for arriving at the average productivity value will be effective when productivity of an activity is measured for similar type of work i.e. productivity values of similar tasks.
- In this research for setting the control limits $\mu \pm 1\sigma$ was used for UCL and LCL. In the future research a comparative study can be made by comparing the use of 2σ and 3σ against 1σ.
- In the present research X bar control chart is used for arriving at the average productivity. In the future research a comparative study can be made by using other control charts such p-chart and s-chart against the X bar chart.

REFERENCES

[1] Park, H. Thomas, S. R. and Tucker, R. L. (2005), “Benchmarking of Construction Productivity”, Journal of Construction Engineering and Management, Vol. 131, No. 7, Jul 2005, ASCE.

[2] Shehata, M. E. and El-Gohary, K. M. (2012), “Towards Improving Construction Labor Productivity And Projects’ Performance”, Alexandria Engineering Journal, Vol. 50, pp. 321–330, Mar 2012, Elsevier.

[3] Song, L. and Abourizk, S. M. (2008), “Measuring and Modeling Labor Productivity Using Historical Data”, Journal of Construction Engineering and Management, Vol. 134, No. 10, Oct 2008, ASCE.

[4] Xhaferi, B. (2013), “Measuring Productivity”, European Scientific Journal, Vol. 8, No.12, Jun 2013

[5] Sweis, et. al. (2009), “Modeling the Variability of Labor Productivity in Masonry Construction”, Jordan Journal of Civil Engineering, Vol. 3, No. 3, Jul 2009.

[6] Ault, J. (2013), “Control Charts as a Productivity Improvement Tool in Construction” [M.Sc. thesis], Purdue University, West Lafayette, Indiana, May 2013.

[7] Pekuri, A., Haapasalo, H. and Herrala, M. (2011), “Productivity and Performance Management – Managerial Practices in the Construction Industry”, International Journal of Performance Measurement, Vol. 1, pp. 39-58, 2011.

[8] B.PrakashRao , B. R., Ambika, S. and Prasad, B. (2015), “Labor Productivity - Analysis and Ranking”, International Research Journal of Engineering and Technology, Vol. 2, Issue 3, pp. 151 – 155, Jun 2015.

[9] Dr. Hemant J. Katole, A Study of Contract Labour at A Real Estate and Construction Company. International Journal of Management (IJM). Volume 7, Issue 3, March-April 2016, pp. 128–135

[10] Dr. V.S. Dhekale and Dr. B.T. Bandgar, Labour Absenteeism in a Textile Unit at Kolhapur. International Journal of Management, 7(7), 2016, pp. 162–171.