Improving Labor Productivity on Building Construction Projects

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ABSTRACT   *In order for businesses to succeed, management must keep a close eye on the bottom line. One of the many factors that directly affect a firm's profitability is worker productivity. The purpose of this research is to measure and study variability of construction labor productivity in building construction project and to demonstrate the conceptual benchmarking principles for construction labor productivity, by the use of indices and measures of benchmarking in labor productivity. Indices such as the disruption index (DI), performance ratio (PR), project management index (PMI) are calculated. The data were collected from two building projects in Thane, Mumbai, India sharing similar exogenous conditions and being similar in scope, size of components, specifications, quality requirements and design features. Literature review was conducted through referred researches and journals to show different findings and theories related to the productivity rates and the methods of improvement. The study shows that the productivity rates of the construction workers vary from one project to another, taking into consideration the type of the activity to be carried out and the surrounding work environment.*

I. INTRODUCTION

Construction projects largely entail labor-intensive activities, thus enhancing the labor productivity of construction activities would immensely be advantageous for the economy of any country in micro and macro levels. This is because higher level of productivity facilitates utilizing the available resources more efficiently. Apart from the national level, higher labor productivity in a construction company makes the company more competitive in the market. The attempts have involved conducting studies focused on comparing labor productivity in one organization to that of others particularly leading corporations. The foregoing strategy titled as Benchmarking is a logical and systematic tool extensively deployed to measure, compare and eventually increase the level of productivity in the construction industry in project, corporate and activity levels. As a developing country, Indian construction industry has always suffered from poor levels of productivity ending up in frequent delays and budget overruns.

Labor productivity estimates are often performed by individuals using combinations of analytical techniques and personal judgment namely, the worker hour estimates are usually obtained through direct interaction with a scheduler, the site manager or related sub-contractors who are knowledgeable enough to reflect the actual conditions of a project and its constituent activities. These individuals often have a library of basic productivity rates which are adjusted and recalculated for each project and always modify their productivity rates for each specific estimate. On the other hand, differences in these productivity rates are always likely and normal.

Many articles have described, in general terms, the variation in labor productivity and the evidence of complex variability in construction labor productivity, the decline in construction labor productivity, trends in construction lost productivity claims, benchmarking of construction productivity and explaining labor productivity differentials. However, few articles discussed quantitative issues relating the loss of productivity.

The primary objective of this paper is to measure labor productivity and to study variability of construction labor productivity. This will be done by analyzing a database collected from 2 construction sites, utilizing benchmarking methods for enhancing labor productivity would bring about many advantages for the Indian constructionindustry.

II. OBJECTIVES OF STUDY

In order to achieve the research aim, specific objectives were required:
1. To identify the most effective method to measure the productivity of the construction workers (Two categories of workers were selected: Gypsum plaster Mason, plaster mason).
2. To demonstrate the conceptual benchmarking principles for construction labor productivity, by the use of indices and measures of benchmarking in labor productivity. Indices such as the disruption index (DI), performance ratio (PR), project management index (PMI).

III. DATA COLLECTION AND PROCESSING

The data used in this study were collected from a residential building at thane that has been completed and delivered to its owner, a private sector company, "Hiranandani Developers". Project are sharing similar exogenous conditions and being similar in scope, size of components, specifications, quality requirements and design features, which make the results of the surveys, more comparable which can be used to obtain reasonable benchmarks.

1. Productivity Measurement:
Based on the literature conducted the measurement of the construction worker productivity can be measured according to the general formula of productivity measurement:
Productivity = Output Quantity / Input Quantity.
In this study the Input and the Output will be measured as follow:
1) The Input for labor productivity will be the total Man-Hours, in other words; the total hours consumed by the construction workers in order to achieve the Output.
2) The Output depends on the trade of the worker and the type of the tasks carried out by him, accordingly the

Output measurement in this research will be:

Sr. No.	Worker trade	Major Activities	Output	Input	Unit
1.	Gypsum plaster mason	Gypsum plaster 12mm on block work	Total area plastered	Hours	m²/ hr
2.	Plaster Mason	3. External Plastering. 4. Internal Plastering.	Total area plastered	Hours	m²/ hr

Table.1.The proposed output and input for each construction worker trade.

Data collection focused on quantity of work done by mason, time required to complete that particular work and also document factors that may affect the work of each crew in daily productivity sheet. Measurements of amount of work done on particular day were made once daily at the end of the workday.

5. Project Performance Parameters (Benchmarks):

In order to have common basis for making comparison, all the productivity data need to be prepared and calculated using standard procedure. The data were collected from 2 residential buildings at thane. The goal is to measure labor productivity data for block mason and plaster mason. The design and construction method complexity of all of the projects were the same. The methods for material handling were also similar. In addition, the financial strategies towards suppliers and workers labor rates in charge of the activities in question were alike which assured the similarity between the skills of deployed workers in all the projects

The definitions of the elements of the benchmarking labor productivity are considered as the following:

9. Total work hours: sum of daily working hours in each project.

10. Total quantities: sum of the quantities of completed activities daily in each project.

11. Cumulative productivity: the measure of the inclusive effort necessary to install the work calculated as: Cumulative productivity (m²/hr) = Total quantities completed (m²) / Total work hrs (hrs)

12. Baseline productivity: the highest performance rate a contractor can achieve for a specific design under the certain circumstances.

Disruptions are associated with lower productivity; however, the baseline is unaffected by disruptions. The baseline productivity for each project was calculated by determining the range of random variability in daily productivity values when a project is satisfactorily managed. The boundaries for this range are the Upper Control Limit (UCL) and the Lower Control Limit (LCL). The UCL and LCL can be calculated by applying the following steps:

5.   For both projects, calculate the average for the daily productivity values. Call this average X.

6.   Calculate standard deviation (σ).

7.   5% Deviation allowed from mean. Therefore,

8.   UCL: X + σ.
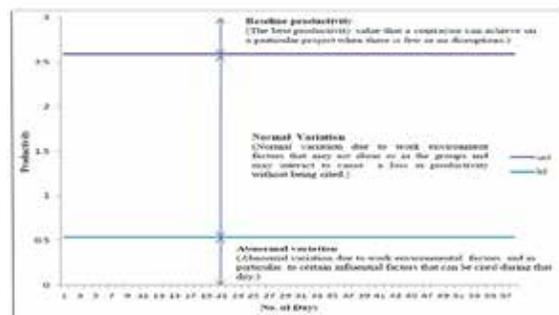
LCL: X – σ.

Figure.1.Conceptual representation of loss of productivity

13. Number of abnormal workdays: Based on the above criteria, an abnormal workday is defined as any workday where the daily productivity statistic value below LCL; thus, abnormal workdays refer to days with significantly below average/ cumulative productivity.

14. **Disruption index (DI):** One metric for benchmarking labor productivity is the disruption index (DI).

DI = Number of abnormal (Disrupted) workdays / Total number of work days.

15. Performance ratio (PR): The performance ratio (PR) is calculated by dividing the actual cumulative productivity by the baseline productivity.

PR = cumulative productivity (W-hr/unit) / Expected baseline productivity (W-hr/unit).

Or

PR = Expected baseline productivity (unit/W-hr) / cumulative productivity (Unit/W-hr).

16. Project management index (PMI): This concept is a parameter (dimensionless) which reflects the project management contribution to the cumulative labor performance of the project. Logically, lower PMI values imply better project management's influence on overall performance.

$$PMI = \frac{Baseline\ productivity\ (W\text{-}hr/unit) - cumulative\ Productivity\ (W\text{-}hr/unit)}{Expected\ Baseline\ productivity\ (W\text{-}hr/unit)}$$

Or

$$PMI = \frac{(Cumulative\ Productivity - Baseline\ productivity)}{Cumulative\ Productivity * Baseline\ productivity} * Expected\ Baseline\ Productivity$$

Data collected from one of the projects (External Plastering activity from project #1)

(1) Work Days (No.)	(2) Total quantity of work done (m²)	(3) Work hours (Hrs.)	(4) Daily Productivity (m²/Hr)	(7) Baseline subset *
1.	89	64	1.39	
2.	122	72	1.69	
3.	50	88	0.57	
4.	127	64	1.984	*
5.	64	72	0.88	
6.	60.1	56	1.073	
7.	46	56	0.821	
8.	61	80	0.763	
9.	88	56	1.571	
10.	46	48	0.96	
11.	112.5	56	2.00	*
12.	124	56	2.214	*
13.	119	48	2.48	*
14.	124	64	1.93	
15.	61	48	1.27	
16.	67	48	1.40	
17.	61	48	1.27	
18.	67	56	1.2	
19.	30	32	0.94	
20.	149	64	2.32	*
Baseline			2.21	

* Bold faces indicate baseline subset numbers

Table.2.External plastering data of project #1

IV.   RESULT AND DISCUSSIONS

Daily productivity rates were calculated. The highest value of production rates were used to determine the baseline subset. Likewise, the median of foregoing values represented the baseline productivity in the project. As an example for Project #1(External plastering), the values of labor daily productivity corresponding to the maximum output are as 2.48, 2.32, 2.214, 2.00 and 1.984. Thus, the baseline productivity of the aforementioned project as the median of mentioned 5 numbers is 2.21, as shown in Table.2. and figure.2.
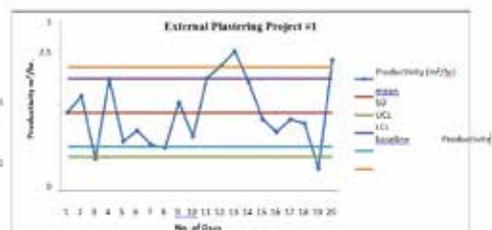
Figure.2.Variability in daily cumulative productivity rates of external plastering (Project #1)

The average baseline productivity (Expected baseline productivity calculated by taking average of baseline productivities for both projects) for the two projects for external plastering by plaster mason under investigation was calculated and equaled 1.90 m²/hr.

Project No.	Worker Trade	Activities	No. of work days	Total work hours	Total quantities	Cumulative productivity (m²/ hr)	Baseline Productivity (m²/ hr)
1.	Gypsum Mason	Gypsum plastering	38	1192	1794.5	1.505	2.15
	Plaster mason	External plastering	16	1176	1667.6	1.42	2.21
		Internal plastering	45	2096	2105.2	1.00	2.00
2.	Gypsum Mason	Gypsum plastering	37	1760	2800	1.59	2.30
	Plaster mason	External plastering	20	664	872	1.31	1.56
		Internal plastering	43	1912	3881	2.03	2.85

Table.3.Project attribute for studied projects

Project No.	Worker Trade	Activities	No. of work days	No. of abnormal days	DI
1.	Gypsum Mason	Gypsum plastering	38	06	0.16
	Plaster mason (m²/ hr)	External plastering	20	03	0.15
		Internal plastering	45	07	0.16
2.	Gypsum Mason	Gypsum plastering	37	05	0.14
	Plaster mason (m²/ hr)	External plastering	16	02	0.13
		Internal plastering	43	05	0.12

Table.4.DI for studied projects

The values of DI range from 0 to 1.00. The higher the DI, the more the project experienced abnormal work days. For each work trade in both the project experienced almost similar DI values. Presumably, the project #1 (for both worker trades) had experienced slightly more disruptions. Table.5 illustrates the performance ratios of both project and for each selected workers trade, lower the PR the better the project performance. It could be noticed that for both the project and for each selected trade performance ratios are greater than 1.00. These PR values represent the best overall performance of the projects in the data set. The project #1 experiences high values of DI and PR (Expect for External plastering which shows slightly low PR for Project #1 than Project #2) than that of Project #2 for each worker trade (Gypsum mason, Plaster mason). Therefore, it can be concluded that this project had poor performance.

Project No.	Worker Trade	Activities	Cumulative productivity (m²/ hr)	Expected Baseline Productivity (m²/ hr)	Performance Ratio (PR)
1.	Gypsum Mason	Gypsum plastering	1.505	2.23	1.48
	Plaster mason	External plastering	1.42	1.90	1.34
		Internal plastering	1.00	2.43	2.43
2.	Gypsum Mason	Gypsum plastering	1.59	2.23	1.40
	Plaster mason	External plastering	1.31	1.90	1.45
		Internal plastering	2.02	2.43	1.20

Table.5.PR for studied projects

PMI concept represents the contribution of the project management to the cumulative labor performance. Higher values of PMI show that project management's influence on the overall performance has been greater. PMI values for the both project and for each selected workers trade are presented in Table.6. It could be concluded from Table.6 that Projects 1 for External plastering activity with PMI values 0.5 had performed poorly than Project #2 for same trade because of their PMIs greater than Project #2.

Project No.	Worker Trade	Activities	Cumulative productivity	Baseline productivity	Expected Baseline productivity	PMI
1.	Gypsum Mason	Gypsum plastering	1.505	2.15	2.23	0.45
	Plaster mason (m²/ hr)	External plastering	1.42	2.21	1.90	0.48
		Internal plastering	1.00	2.00	2.43	1.21
2.	Gypsum Mason	Gypsum plastering	1.59	2.3	2.23	0.43
	Plaster mason (m²/ hr)	External plastering	1.31	1.56	1.90	0.23
		Internal plastering	2.02	2.85	2.43	0.35

Table.6.PMI for studied projects

The results obtained for PMI and DI show the existing correlation between these two indices. More number of abnormal days in a project could be the symptom of a poorly managed project and low levels of labor productivity. Higher values of DI and PMI show unacceptable labor performance and poor management.

V. CONCLUSION

The paper examined benchmarking as lean construction principle and consequently in project performance. Using labor productivity data from two residential building projects in Thane, Mumbai, India, and the benchmarks of labor productivity were calculated. The benchmarks are the disruption index (DI) performance ratio (PR) and project management index (PMI). They are used to identify the performance of projects. The values of DI range from 0.00 to 0.16. The higher the DI, the more the project experienced abnormal work days. This can be attributed to the number of abnormal days during the study period that cause the construction work to fall behind schedule.

These projects (For both selected trade) have large values of PMI that reflects lesser project management influence on overall project management performance. The results showed that this technique of benchmarking is an important tool for project and construction management. Findings of this research can

be used not only for the assessment but for the control of construction projects. Construction managers may use the above measures for controlling the projects as a useful information for correcting the projects' performance which the innovation of t his research.

On top of that, developing countries such as India suffer from the ineffectiveness and absence of documentation in construction projects. Establishing frameworks integrating benchmarking with effective documentation systems seems a necessity in the context of developing countries. Likewise, benchmarking technique could be the source of identifying the main reason behind low level of productivity, delays, and cost and budget overruns in construction projects building upon the documents and lessons learnt from previous projects or meta-analysis studies.

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