Tools for Measuring Construction Material Management Practices and Predicting Labor Productivity in Multi-Storey Building Projects for Akola City

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Abstract— Materials management is a process that consists of the people, organizations, technology, and procedures used to effectively identify, acquire, expedite, inspect, transport, receive and preserve the materials, equipment, and Data across the life cycle of the project. The goal is to achieve a correct quality and quantity of materials and equipment procured in an effective manner, available at a reasonable cost, and availability of them when needed. This paper describes a study in which we developed a tool for scoring materials management practices for building projects and, on that basis building a tool for predicting productivity of labor. The research was carried out in two phases. During Phase I, in-depth interviews were conducted with 10 experts (civil professionals) and specific materials management practices were identified. During Phase II, questionnaires were used to collect quantitative data from 10 contractors. Based on the analysis, tools for measuring and planning the materials management practices and probability-based regression models were developed. This research contributes to the body of knowledge by developing construction materials management practices measuring, planning, monitoring, and evaluating tools in the context of building projects.

Keywords: Regression Models, Materials Management, Management Practices, Labor Productivity

I. INTRODUCTION

Materials management is a critical component of the construction industry. As such, organizations need to understand the effects of proper materials management techniques on the effectiveness of project execution. Extensive literature and reports deplore the lack of efficiency and productivity in the construction industry. Two of ten, construction projects suffer from delays, budget overruns, and claims. A properly implemented materials management program can achieve the timely flow of materials and equipment to the job-site, and thus facilitate improved work face planning, increased labor productivity, better schedules, and lower project costs.

Construction is one of the country's biggest ventures of the world and has been assuming a critical part in financial improvement, and additionally in lessening unemployment. Profitability is one of the essential viewpoints for the organizations in the development business. Change in the efficiency of the development business is accordingly of basic significance thinking about its huge commitment to the GDP (Gross Domestic Product).

The construction company with the most efficient operations has a greater chance to make more money and deliver faster construction project to the project owner. Improving labor productivity can alleviate the shortage of skilled craft-workers, enhance the working conditions, and enhance the overall quality of a product. For every project, productivity, cost, quality and time have been the main concern.

Construction performance & productivity improvement are enter centre regions in development industry for any country. Indian construction industry frames a necessary piece of economy. Constructions constitutes 40% to half of India's capital consumption on ventures in different areas, for example, roadways, streets, railroads, vitality, airplane terminals, water system, and so forth and is the second biggest industry in India after farming. It represents around 11% of India's GDP. Improving productivity is significant worry for any benefit arranged association. When all is said in done terms productivity is named as ratio between input & output. Appropriate administration of accessible resource can help in enhancing productivity. Labor is the most imperative resource for a construction company.30% to half of aggregate cost of venture is spent on labors. Nature of the development to a great extent relies on the nature of work done by labor. Labor productivity specifically influences development efficiency; it is essential to know the factors influencing work efficiency.

II. METHODOLOGY

This research adopted exploratory sequential mixed-methods research design, which involves the collection and analysis of the quantitative and qualitative data in two phases (Creswell 2013). Therefore, this study was carried out, first, by collecting and analysing qualitative data which were obtained from interviews during Phase I. On the basis of the qualitative data, appropriate materials management practices were identified, and their levels of implementations were refined to suit the building construction projects. To investigate the relationship between productivity and the practices, assign the weights to the materials management practices, validate the materials management practices' scoring tool for building projects, and develop as well as validate the productivity predicting tools, the quantitative data were collected and analysed during Phase II. During Phase I, the participants interviewed were 10 professionals having work experience in the construction of multistorey buildings in the Akola city, Maharashtra, India. The expert's have 2-10 years experience. Their positions include construction manager, general manager, project manager, project engineer, project coordinator, site engineer, architect and contract administrator. These experts were chosen on the basis of their experience in working for sub-contractors as well as principal contractors that have been delivering multistorey building projects in Akola city.

The employees who were responsible for the construction of multistorey building projects by these companies were then contacted. Site managers, project managers, and project coordinators were the respondents. The questionnaire consists of three parts. In the first part, the respondents were asked to provide information on a specific building project which they have completed within the last 5 years. The information includes project cost and project time among other things. In the second part of the questionnaire, the respondents were requested to rate the relative importance of the materials management practices which were identified during the first phase of the research. A scale of 1–5 is recommended to get better validity and reliability (Lozano et al. 2008; Jamieson 2004). Accordingly, to rate the practices, this research used a scale of 1 for not important; 2 for slightly important, 3 for somewhat important, 4 for very important, and 5 for extremely important. On that basis, a new instrument (un-weighted scoring tool) was developed and validated through interviews with local experts during Phase I of the study. The clarity, language, format, and the contents of the levels of the practices have been discussed during the validation process of the questionnaire.

Shows the procedures used in preparing the un-weighted and weighted scoring tools. First, the qualitative data were analysed, and materials management practices which are suitable to enhance productivity in building projects were identified. Then the levels of implementation for the identified practices were prepared based on the existing tools developed by the Construction Industry Institute for industrial and infrastructure projects. Thus, the practice and its levels of implementation were excluded. Consequently, the un-weighted scoring tools were prepared and validated by conducting interviews with local experts during Phase I of the study. The validated and un-weighted scoring tool (third part of a questionnaire) was used to collect the data regarding the implementation levels of the identified practices. During Stage I of the quantitative data analysis, the weight computed for each practice was used in the preparation of the weighted scoring tool. The weights were computed using the relative importance index (RII) technique. According to Lam et al. (2007), the mean value and the RII could be used for ranking variables. However, the RII technique is suitable for deriving relative indices between 0 and 1. Thus, it would be easy to compare various variables. Hence, the following RII equation is adopted (El-Gohary and Aziz 2014)

$$\mathrm{RII} = \frac{5(n5) + 4(n4) + 3(n3) + 2(n2) + n1}{5(n1 + n2 + n3 + n4 + n5)} \qquad (1)$$

Where n1 = number of respondents who selected not important;
n2 = number of respondents who selected slightly important;
n3 = number of respondents who selected somewhat important;
n4 = number of respondents who selected very important;
And n5 = number of respondents who selected extremely important.

The weights obtained using this equation was proportionally distributed among the five levels of the practices, and the weighted scoring tool was developed. During Stage II of the quantitative data analysis, the data collected from the building construction projects were transformed into equivalent scores using the weighted scoring tools, and projects scores were computed. The analysis was then conducted to validate the weighted scoring tools.

Thus by calculating Productivity factor (PF), RII and weighted scoring tool for all the management practices we can conclude for the labour productivity depending upon the weights we get using the below formula.

$$\mathrm{Level}\,(N+1) = \mathrm{Level}\,N + \mathrm{RII}/5$$

Construction materials Management practices	Summary of the interview responses	Conclusion
Procurement plans for materials	Materials procurement plan is right on the front end. The potential suppliers are identified; the required materials are estimated upfront; the tracking sheets and charts are prepared; different stages of the procurement are represented using different colours on the chart; and any changes made during the procurement process are tracked.	Suitable
Long-lead materials identification	Usually the long lead items are façade materials, tiles and services such as lifts, generators, and boilers. All these key primary elements have long lead time. These items are identified earlier and tabulated. The approximate lead times for these materials are also estimated; for example, item = tiles, duration = 2-4 weeks. Most items imported from outside city are categorized as long lead items.	Suitable
Materials status database	The contractor's project manager get information regarding the work progress from supervisors or subcontractors and prepare the material status report which comprises the percentage of the materials utilized and the estimates of the quantities of materials required to complete the remaining works. The supervisors then monitor the work on a regular basis; they identify the remaining items and request the procurement of these materials if any.	Suitable
Materials delivery schedule	The materials delivery schedule is prepared based on the construction work program; the principal contractor's supervisors discuss the materials delivery dates with respective subcontractors/ suppliers and prepare the schedule. The schedules are	Suitable

	written on a whiteboard, and the materials delivery is tracked every day. Some materials such as façade are tracked during the manufacturing process; when they are on-site; and after their installation.	
Material inspection Process	The inspection is made up front, the consultants are engaged in the inspection, and sometimes materials are inspected during the manufacturing stage. Inspection is made for various items such as reinforcement, formwork, glass, and concrete. The materials should be inspected before being installed. The subcontractors or suppliers provide the quality assurance documents for all items they bring to a site and the principal contractor's project management team conducts quality assurance checks.	Suitable
Materials inspection Team	The project coordinators and specialist consultants are involved in the inspection process. For instance, façade expert and project coordinator or manager inspect the façade, and structural engineers take part in the inspection of reinforcement bars. Other consultants are also involved depending on the type of the materials or works.	Suitable

Table 1: Summary of the interview results of construction materials management practices

A. *Productivity Factor of the Projects:*

Part one of the questionnaire was analyzed to compute the productivity factors (PFs) of the 10 building projects nominated by the 10 participating contractors. The productivity of construction projects can be measured in the relative or absolute term (Nasir 2013). In the case of the absolute term, the units of measurement of both the output and the input are indicated when presenting productivity value. PF, which is the relative measure, is the ratio of the actual productivity to the planned productivity. In this research, the actual productivity was calculated using a building project value as output and the actual project completion time as input, and the planned productivity was calculated using a building project value as output and planned project completion time as input (Gurmu et al. 2016).

For instance, the project start date for one of the projects was Jan 1, 2016; its planned completion date was June 1, 2017; its actual completion date was Dec 31, 2017; and project cost was 80 lakhs INR. Thus, the planned duration (input) = (Jan 1, 2016) – (June 1, 2017) = 517 days; actual input = (Jan 1, 2016) − (Dec 31, 2017) = 730 days; actual productivity = (8000000 INR)/(730 days) =10958.90 Rs/day; planned productivity = (8000000 INR)/(517 days) = 15473.88 Rs/day; and PF = 10958.90/15473.88 = 0.70. The PFs of the other projects were computed using a similar procedure. According to Alby (1994), PF is a suitable measure for comparing the productivity of various projects. Nasir (2013) concluded that the use of PF as a metric to measure productivity is more beneficial than adopting the absolute measure. According to the study, the weighted average project productivities can be computed because PF is independent of the units of measurement. Caldas et al. (2014) validated the use of PF to measure productivity in industrial projects. In this research, PF is used as it is suitable to compare productivities of various building projects. The mean PF of the projects is 0.84, the minimum PF is 0.65, and the maximum PF is 0.94.

A value of Productivity factor's for all the building projects as data received in the survey is given in the table no. 2 below:

Sr. No.	No. Of Building Project	Productivity Factor
1	1	0.73
2	2	0.86
3	3	0.89
4	4	0.91
5	5	0.89
6	6	0.84
7	7	0.94
8	8	0.81
9	9	0.86
10	10	0.65

Table 2: PF'S of building project's

B. *Weighted Scoring Tool of the Materials Management Practices:*

To prepare the weighted scoring tools, the weight of each practice is proportionally distributed among the five levels of implementation of a particular practice. The following formula is developed to compute the weight proportions of the practices.

$$\text{Level}\ (N+1) = \text{Level}\ N + \text{RII}/5$$

Where N ranges from 0 to 4; Level 0 = 0; and RII denotes the weight of a practice.

As an example, for the practice procurement plan for materials,

RII=0.78;

Level 0 = 0;

N=0, Level 1 = 0 + 0.78/5 = 0.16;

N=1, Level 2= Level 1 + 0.16 = 0.32;

N=2, Level 3 = Level 2 + 0.16 = 0.48;

N=3, Level 4 = Level 3 + 0.16 = 0.63;

N=4, Level 5 = Level 4 + 0.16 = 0.78.

Similarly the weight proportions of all the construction materials management practices were computed and the results are provided in Table 3.

Level	Description	Score
	1. Procurement plan for materials	
0	A procurement plan for materials and equipment is not applicable.	0.00
1	There is no documented procurement plan for materials.	0.16

2	A procurement plan and schedule exist only for large materials and costly items.	0.32
3	Continuation of Level 2, plus plan includes all materials and consumables. Also, there is an established protocol for identifying reputation of potential vendors.	0.48
4	Continuation of Level 3, plus plan identifies necessary equipment and on-site resources to support delivery.	0.63
5	Continuation of Level 4, plus the procurement schedule is integrated with a project information system that automatically updates the procurement schedule as the construction schedule changes.	0.78
	2. Long-lead materials identification	
0	A separate procurement plan for long-lead materials is not applicable.	0.00
1	There is no documented procurement plan for long-lead materials.	0.14
2	A procurement plan and schedule exists for long-lead materials.	0.28
3	Continuation of Level 2, plus there is an established protocol for identifying reputation of potential vendors.	0.42
4	Continuation of Level 3, plus plan identifies necessary equipment and on-site resources to support delivery.	0.56
5	Continuation of Level 4, plus the procurement schedule is integrated with a project information system that automatically updates the procurement schedule as the construction schedule changes.	0.70
	3. Materials status database	
0	Material status database is not applicable.	0.00
1	There is no formal paper-based system used to track materials status.	0.14
2	There is a formal paper-based system to track materials status.	0.28
3	A proprietary internal materials status software tool is used, but it is not integrated with your company's project control systems or used by other contractors.	0.42
4	An available software tool is used but it is only integrated internally with your company's project control systems.	0.54
5	An available software tool is used by all stakeholders that are integrated with your supply chain and other project control systems.	0.68
	4. Materials delivery schedule	
0	Materials delivery schedule is not applicable.	0.00
1	There is no documented materials delivery schedule.	0.15
2	Materials delivery is planned early in the project and is integrated with a project schedule.	0.30
3	Continuation of Level 2, plus the schedule is automatically updated on receipt of new information as procurement proceeds.	0.45
4	Continuation of Level 3, plus the schedule is automatically linked with procurement, materials management, and overall project scheduling systems.	0.60
5	Continuation of Level 4, plus materials delivery planning and management is completely integrated with other automated project processes including automated materials tracking throughout the supply chain.	0.75
	5. Materials inspection process	
0	A material inspection process is not applicable.	0.00
1	There is no materials inspection process.	0.16
2	A materials inspection process is only utilized for large items or costly items on a project.	0.32
3	A materials inspection process is utilized that includes all items delivered to the site. There is a lack of organization of the process and materials are not separated into stages of the receipt process nor does it record the location of the materials and mark the materials for tracking.	0.48
4	A materials inspection process is used at the supplier and on-site, and organizes materials receipt inspections immediately upon delivery of materials, verifies that materials conform to standards, and organizes materials for tracking.	0.63
5	Continuation of Level 4, plus the process includes separation of material into categorical stages of the receipt process (e.g., awaiting inspection, storage area restocking, scrap, and/or awaiting for shipment, verification if the materials conform to specifications, standards, drawings, etc., record of the location of materials and marked materials for tracking, and prioritization for quality).	0.78
	6. Materials inspection team	
0	Materials inspection team is not applicable.	0.00

1	There is no materials inspection team.	0.11
2	There is a designated materials inspection team, but no training and qualifications of the individual's skill level is specified.	0.22
3	Continuations of Level 2, plus inspections are performed by project managers or workers rather than the team.	0.33
4	Continuation of Level 3, plus the inspection team can adequately inspect materials and understand the material specifications.	0.44
5	Continuation of Level 4, plus the members of the inspection team are experts at inspection processes and procedures, and know how to inspect materials and understand the material specifications.	0.54

Table 3: Weighted scoring tools for construction materials

III. RESULTS AND DISCUSSIONS

By using the values which we have got in table no.3 we have plotted the bar chart which shows the values of all the material management practices score in single chart and thus from that chart we came up for the conclusion of the work. Chart is given below:

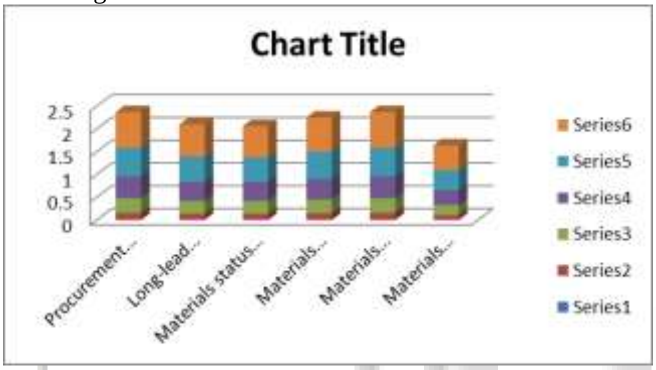

Fig. 1: Bar chart showing result of the weighted scores

IV. DISCUSSION

– As we can see in the above chart that there are 6 series i.e levels for each practices and thus each level is shown in different colour.
– This chart is prepared by taking the values of the weighted scores of all the practices and thus by inserting those values in the table we get this ready chart.
– Bigger the bar for specific practice more effective practice the practice is and more will be the required productivity for such practice.
– Thus by getting the values of the weighted scores and studying this chart we can predict effectiveness of material management practice and thus we can predict labor productivity of the same.
– Overall material inspection process has the highest ratings in all the practices whereas material inspection team has the lowest rating in all practices. Job knowledge proves to be the most important among all other practices.

V. CONCLUSION

From the above study it is concluded that:

– From the above study we came to conclusion that from all the 6 material management practices the best practice or highly accepted practice that is adopted is material inspection process.
– So once we came to conclusion of the best practice we can comment for labor productivity in that term.
– As the practice is best of all practices adopted there must be appointment of the labor having high productivity.
– As it is important practice there must be good inspection on such practice and high wattage is given to that practice.
– Likewise material inspection team is given less wattage of all the practices adopted and thus we can comment that no special team is made on the sites for inspection and thus productivity required there is much less as compared to other practices adopted in this study.
– Other than this adaptability, Job Knowledge, Judgment, Motivation, Productivity are the labor productivity factors derived from the study. Job Knowledge is highly rated by all classes and proves to be the most important factor which firms consider in labor productivity among all other factors.

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