Onsite Material Management for Construction Projects

Performance Measures

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***Abstract*—Effective construction resources management process is a key to success of a construction project. Nowadays, successful material management of construction has to be based on and updated information and processed utilizing a well-designed material management system.The aim of the thesis is to explore the local practice in construction material management and develop a material management system to facilitate the management of construction material mainly in the building construction. Construction management related literature was generally reviewed; meanwhile some material management techniques have been reviewed also. A survey questionnaire supported by interviews was used to explore the local practice in material management.The thesis considers the management of materials in building construction projects. In this study, construction material management can be viewed as three categories which are measures for effective material management in building sites, factors that increase waste in building sites and problems related with material management. The principal tool used for collection of data is questionnaires for field survey. Data for the study are obtained through a structured questionnaire administered to respondents in number of 43. The respondents involve project engineers, site engineers and contractors. The data are analysed by the use of Relative Importance Index (RII). The overall results of this study indicate that the current practices of material management in local construction projects need systematic and effective control. Based on the findings of agreement analysis, it is found that the perceptions of three respondents (project engineers, site engineers and contractors) are identical in all three cases; measures for effective material management, factors increasing waste in building construction projects and problems related with material management. Hence, it is said that all of project engineers, site engineers and contractors are mainly concerned with material management and their roles and decisions are essential to improve effective material management. Moreover, all the results of this study are undoubtedly accepted to be important because of identical perceptions of three respondents.**

***Keywords*: Material Management**

I. INTRODUCTION

Construction sector is very essential and an integral part of infrastructure development which gives tremendous boost to India's economy. At the same time, this sector consumes more resources for its tremendous development. The most important resource which occupies a major portion of this industry is materials. Broadly, the term materials denotes all purchased items utilized at the project site including construction materials, supporting plant and equipment, and administrative facilities and stores. Construction materials cover all types of materials used in construction including electrical and mechanical fittings, fixtures, devices and instruments that are incorporated during the construction of permanent works and supporting works at site.

Materials management is a process for planning, to insure the availability of construction materials at their point of use when needed and to insure that the right quality and quantity of materials are appropriately selected, purchased, delivered, and handled onsite in a timely manner and at a reasonable cost. If materials are purchased too early, interest charges incurred on the excess inventory of materials and Materials may deteriorate during storage.

A construction project depends upon having the right people with right skills and equipment that are able to deliver the project on time and on budget. Having the right material sin the right place at the right time is equally important, and having the cash flow and capital to procure the labour and materials is also important.The materials on a project can represent anything from 30% to 70% of the cost of the work, yet materials management and performance measures hasnotreceivedalotofattentionfromresearchers.

In this dissertation, the existing construction materials management practices of Kolhapur & Sangli region contracting companies are investigated and an attempt to improve it this project is conducted. The proposed improvements are formulated in development of a materials management system and performance measures. In thischapter,theintroduction,researchobjectives, definitionsandoutlineoftheresearchareexplained.This study is about the performance measures affecting the materials management system in industrial construction industry in Kolhapur, Sangli region from contractor's point of view.

Material Management

Material management can be defined as a process that coordinates planning, assessing the requirement, sourcing, purchasing, transporting, storing and controlling of materials, minimizing the wastage and optimizing the profitability by reducing cost of material.Thus, efficient management of materials can result in substantial savings in project cost and time. For effectively managing and controlling materials, the performance of materials management should be measured.

Performance Measure

A performance measure is used to calculate the effective working of a function .These performance measures may differ from system to system. The measures divide the materials management system into parts and make the working of the system more

efficient. When joined, the measures make the complete materials management system. Research has been done in the past by Plemmon's and Al-Darweesh about the effectiveness of performance measures in materials management. Plemmon's developed a list of performance measures for use in industrial construction projects and proposed a model for benchmarking the materials management process in industrial construction. The Plemmon's performance lists are to be used in this study to assess its importance, and practicality of implementation in residential construction projects.

Ouranalysisofprojectcostforcivilengineeringprojectsshowedthematerialsandplantcomponentcanbeupto70%oftheprojectcostdependentuponthetypeofprojecthoweverininterviewswithestimatorsthefindingswerevalidatedbyprofessionaljudgments.Agoodmanagementsystemformaterialsmanagementwillleadtobenefitsforconstruction.

II. OBJECTIVES OF STUDY

1. To study the performance measures used in past and currently in use for material management in construction project.
2. To study the importance of the performance measures in assessing the effectiveness of material management process.
3. Determine the practicality of implementation of performance measures in construction projects.
4. To give suggestive recommendations in order to improve productivity of project.

III. MATERIAL MANAGEMENT

1. Introduction

Materials management is an important element in project planning and control. Materials represent a major expense in construction, so minimizing procurement or purchase costs presents important opportunities for reducing costs. Poor materials management can also result in large and unavoidable costs during construction. First, if materials are purchased early, capital may be tied up and interest charges incurred on the excess inventory of materials. Even worse, materials may deteriorate during storage or be stolen unless special care is taken. For example, electrical equipment often must be stored in waterproof locations. Second, delays and extra expenses may be incurred if materials required for particular activities are not available. Accordingly, insuring a timely flow of material is an important concern of project managers. Materials management is not just a concern during the monitoring stage in which construction is taking place. Decisions about material procurement may also be required during the initial planning and scheduling stages. For example, activities can be inserted in the project schedule to represent purchasing of major items such as elevators for buildings.

The availability of materials may greatly influence the schedule in projects with a fast track or very tight time schedule. Sufficient time for obtaining the necessary materials must be allowed. In some cases, more expensive suppliers or shippers may be employed to save time. Materials management is also a problem at the organization level if central purchasing and inventory control is used for standard items. In this case, the various projects undertaken by the organization would present requests to the central purchasing group. In turn, this group would maintain inventories of standard items to reduce the delay in providing material or to obtain lower costs due to bulk purchasing.

This organizational materials management problem is analogous to inventory control in any organization facing continuing demand for particular items. Materials ordering problems lend themselves particularly well to computer based systems to insure the consistency and completeness of the purchasing process. In the manufacturing realm, the use of automated materials requirements planning systems is common. In these systems, the master production schedule, inventory records and product component lists are merged to determine what items must be ordered, when they should be ordered, and how much of each item should be ordered in each time period. The heart of these calculations is simple arithmetic: the projected demand for each material item in each period is subtracted from the available inventory.

The typical tasks associated with a material management system are:

- Procurement and purchasing
- Expediting
- Materials planning
- Materials handling
- Distribution
- Cost control
- Inventory management / Receiving / Warehousing
- Transportation

2. Material Management Functions

Material management covers starting from material planning up to consumption of the material.

- ***Material Planning***

Material plan is a plan which describes the quantity and type of material which used for the construction and when it will be used. The quantity of the required material identified from the bill of quantity and the drawing. Based on the material plan the engineering staff passes the requisition to the store team then the store team check the availability of the material in the store if available it will be delivered as per the plan if not it will be passed to purchasing team in order to be purchased.

Material management planning is the back bone of material management because every successor activities depend on it which means in order to have good material management the material planning should be good.

- ***Purchasing***

Purchasing is a process of buying material or service based on the request of other team of the company. Profitability of the construction company mainly depends on the efficiency of the purchasing system since the construction material covers most of the cost of the project around 60 percent of the whole project cost. If we able to minimize the material purchasing cost by applying

efficient material purchasing system without compromising the quality of the material and on time delivery of the material, we can maximize the profit highly since material cost covers the major cost of the project.

- ***Receiving***

Material receiving is a process of getting the purchased materials which are previously requested. During the material receiving process the professional who receive the material should check the following things.

Whether the material is the requested one or not

The quality of the material

The quantity of the material

The material handling information, if available

- ***Storing***

As described earlier one of the objective of material management is to deliver the right quality of material with the right quantity at the right time .In order to fulfill this objective we need storage to deliver material when needed. The purchased material should be stored before some duration before needed for the work to keep the continuity of the work. We should keep balance between the storage cost and stock out cost. If we purchase too much material and stock it, in addition to capital tie up or cash flow disturbance there will be storage, protection, obsolescence and some other risk costs. On other way if we keep the inventory level low or null, there will be idle and delay cost because the labor and equipment stop work since they get shortage of material to do the work.

While we store material proper attention should be given according to the type of material .For example first in material should be first out by proper space area arrangement, cement should not be placed directly on the floor to escape the moisture from the floor, Rebar should be placed moisture free area to keep from corrosion, Some material like water heater need to be placed by keeping the up side up, thin material like glass, ceramic, terrazzo etc. should be place vertically to keep from easy breakage

- ***Transporting***

Material transportation is the process of moving material from one place to other place through different transportation mechanism like vehicle, ship, plane, etc. The construction material should be transferred to the construction site as per the planned time safely with a reasonable cost. In order to transport the material safely we should follow the material handling information because if the delivered material is broken or rotten it is similar to material undelivered because the progress of the work stopped due to shortage of material.

3. Advantages of Construction Material Management

- Reduce Excessive Surplus Material
- Reduce Manpower on Material Management
- Labor Productivity Improved
- Improve Cash Flow System
- Reduce the Overall Cost of Material
- Good Material Handling
- Reduce Duplicated Order
- Improve the Accomplishment of the Project Plan
- Quality of Material Improved
- Relationship with Supplier Improved

4. Techniques in Materials Management

There is different industrial engineering techniques (methods) used in materials management. They are used to facilitate in managing materials in all industries including construction industry. Some of these techniques are:

- ***ABC Analysis***

ABC Codes

"A class" inventory will typically contain items that account for 80% of total value, or 20% of total items.

"B class" inventory will have around 15% of total value, or 30% of total items.

"C class" inventory will account for the remaining 5%, or 50% of total items.

This classification enables selective control on the inventory of high value items by planning and ordering more frequently than others and stock outs prevented for ‘B’ and ‘C’ items, by maintaining a higher inventory. It is easier to control lesser number of high value items closely than many low value items which enables reduced investment and control on stock outs

- ***Economic Order Quantity***

Economic order quantity is the level of inventory that minimizes the total inventory holding costs and ordering costs. It is one of the oldest classical production scheduling models

Though EOQ is generally recommended in operations where demand is relatively steady, items with demand variability such as seasonality can still use the model by going to shorter time periods for the EOQ calculation. Just make sure their usage and carrying costs are based on the same time period. The EOQ refers to the order size that will result in the lowest total of ordering and carrying costs for an item of inventory. If a firm place unnecessary orders it will incur unneeded order costs. If a firm places too few order, it must maintain large stocks of goods and will have excessive carrying cost.

Economic Order Quantity (EOQ): This seeks to balance quantity of purchase at a time (Q), annual requirement/demand quantity of an item (A), fixed cost per purchase order (S), and annual holding cost per unit (I).

$$Q = \sqrt{\frac{2 \times A \times S}{I}}$$

- ***High, Medium and Low Classification***

The High, medium and Low (HML) classification follows the same procedure as is adopted in ABC classification. Only difference is that in HML, the classification unit value is the criterion and not the annual consumption value. The items of inventory should be listed in the descending order of unit value and it is up to the management to fix limits for three categories. The HML analysis is useful for keeping control over consumption at departmental levels, for deciding the frequency of physical verification, and for controlling purchases.

- ***VED Classification***

While in ABC, classification inventories are classified on the basis of their consumption value and in HML analysis the unit value is the basis, criticality of inventories is the basis for vital, essential and desirable categorization. The VED analysis is done to determine the criticality of an item and its effect on production and other services. It is specially used for classification of spare parts.

- ***SDE Classification***

The SDE analysis is based upon the availability of items and is very useful in the context of scarcity of supply. In this analysis, items, generally imported, and those which are in short supply. It refers to difficult items which are available indigenously but are difficult items to procure. Items which have to come from distant places or for which reliable suppliers are difficult to come by fall into category. It also refers to items which are easy to acquire and which are available in the local markets.

- ***FSN Classification***

FSN stands for fast moving slow moving and non-moving. Here, classification is based on the pattern of issues from stores and is useful in controlling obsolescence. To carry out an FSN analysis, the date of receipt or the last date of issue, whichever is later, is taken to determine the number of months, which have lapsed since the last transaction. The items are usually grouped in periods of 12 months. FSN analysis is helpful in identifying active items which need to be reviewed regularly and surplus items which have to be examined further. Non-moving items may be examined further and their disposal can be considered.

- ***SOS Analysis***

'S' stands for Seasonal items and 'OS' stands for off-seasonal items. It may be advantageous to buy seasonal items at low prices and keep inventory or buy at high price during off seasons. Based on the fluctuation in prices and availability, suitable decision has to be taken regarding how much to purchase and at what prices.

- ***Just-In-Time***

It is an operating management philosophy of continuous improvement in which non-value-adding activities (or wastes) are identified and removed for the purposes of reducing cost.

IV. PERFORMANCE MEASURES

A performance measure is a measure that calculates the effective working of a function. These performance measures may differ from system to system. The measures divide the materials management system in parts and make the working of the system more efficient. When joined, the measures make the complete materials management system. Plemmon's (1995) research identifies the key effectiveness measures for the materials management process and proposes a mechanism for benchmarking these measures.

- ***Material Management Performance with Attributes***

Plemmon's (1995) identified six performance attributes of the materials management process. These attributes are:

a) Accuracy: It reduces uncertainty and supports the decision making process.
b) Quality: It is related to suitability and cost, rather than to intrinsic excellence.
c) Quantity: It is to quantify the volume of transactions of the materials management process.
d) Timeliness: It is defined as the measurable interval between two events or the period during which some activity occurs.
e) Cost: The focus is on the efficient use of labour, the introduction of labour-saving technology, and the avoidance of "unreasonable" or unnecessary expenses.
f) Availability: It characterizes the ability of the materials management process to fill requests for materials at the agreed time and place.

Table 1: Plemmon's Measures

No.	Performance Measures/ Respondents	Attributes				
		Accuracy	Quantity	Timeliness	Cost	Availability
1	Materials receipt problems	√				
2	Warehouse inventory accuracy	√				
3	Head office requisition percentage		√			
4	Head office purchase order percentage		√			
5	Sole source purchase		√			
6	Minority suppliers		√			
7	Procurement lead –time			√		
8	Bid evaluate commit lead time			√		
9	Purchase order to material receipt duration			√		
10	Material receiving processing time			√		
11	Commodity vendor timeliness			√		
12	Commodity timeliness			√		
13	Materials withdrawal request lead time			√		
14	Materials withdrawal request processing time			√		
15	Average man hour per purchase order				√	
16	Freight cost percent				√	
17	Construction time lost				√	
18	Min/Max release activity				√	
19	Warehouse safety incident rate				√	
20	Total surplus				√	
21	Material availability					√
22	Backorders					√
23	Material wastage				√	
24	Discount from bulk purchase				√	
25	Budget availability					√

V. DATA COLLECTION AND RESULT ANALYSIS

To fulfill the objective of the study the data collected from different professional on different building construction site in Kolhapur, Sangli in the form of interview based on the developed questionnaire. The collected data from the interview were analyzed and tabulated according to their ranking on relative index, bar charts presented from their rating scale.

1. Questionnaire Design

The questionnaire have three sections: section 1 company and respondent profile, section 2 basic information about construction material management and section 3 questioners of performance measures. The answer of the questionnaire data on section 1 and section 2 filled by me during the interview by writing on the space provided and ticking the box. The answers of the questionnaire data on section 3 are designed based on scale of five ordinal measures of agreement towards each statement (from 1 to 5).

2. Data Collection and Analysis

The questionnaire contains a set of simple and straight forward questions whose purpose is to collect particular data and information. This provides the basis to identify the critical factors in MM. In this study, the questionnaire of this study is designed to get the factual information about local practices of contractors in managing construction resource in building projects as well as the opinions of contractors about these practices.

In this research, few methods of data collection were used including observation, documentations, interviews and questionnaire and documentary analysis. The good design of the questionnaire is a key to obtain good results and warranting a high rate of return.

The collected data were analyzed using the Relative Index methods. Based on the frequency analysis the relative index was then calculated to determine the ranking of each performance measures importance and practicability.

The relative index analysis for variable is calculated by using the formula below:

$$\text{Relative Importance Index} = \frac{\sum W}{A \times N}$$

Where:
$0 \leq RII \leq 1$

W= Score given to each factor by respondent ranges from 1 to 5 where 1 not Important/ Practical and 5 extremely Important/ Practical preferred.

A= Highest Score i.e. 5 in this case

N= Total No. of respondent

3. Questionnaire Response Rate

43 professionals whose works related to material management contacted 6 of them refused for the interview, 7 of them the interviews are Incomplete and 30 of them successfully interviewed. Response rate is 69.77 %

4. Importance of the Performance Measures

The interviewed professionals gave their response about the importance of the performance measures by using 5 scales starting from 1 assigned to not important up to 5 assigned to extremely important

The collected data were analyzed using the Relative Index methods in a similar way as calculated for the Performance Measure Usage.

Not Important :the assigned weight of 1
Somewhat Important :the assigned weight of 2
Important :the assigned weight of 3
Very Important :the assigned weight of 4
Extremely Important ;the assigned weight of 5

Table 2: Importance of Proposed Performance Measure

No	Measure Description	RII of Importance
1	Materials receipt problems	0.8333
2	Warehouse inventory accuracy	0.6800
3	Head office requisition percentage	0.6867
4	Head office purchase order percentage	0.6667
5	Sole source purchase	0.3067
6	Minority suppliers	0.3200
7	Procurement lead –time	0.8600
8	Bid evaluate commit lead time	0.6533
9	Purchase order to material receipt duration	0.6400
10	Material receiving processing time	0.5200
11	Commodity vendor timeliness	0.5200
12	Commodity timeliness	0.5400
13	Materials withdrawal request lead time	0.5067
14	Materials withdrawal request processing time	0.5200
15	Average man hour per purchase order	0.5467
16	Freight cost percent	0.4667
17	Construction time lost	0.8933
18	Min/Max release activity	0.5667
19	Warehouse safety incident rate	0.5667
20	Total surplus	0.7000
21	Material availability	0.9467
22	Backorders	0.3067
23	Material wastage	0.9133
24	Discount from bulk purchase	0.6933
25	Budget availability	0.6867

Based on the scored rate of each of the performance measures, they were categorized into four different groups as follows:

Extremely Important : 85-100
Very Important : 65-84
Moderately Important: 45-64
Somewhat Important : 25-44

The measures which get a rate extremely important are: material availability, material wastage, and construction time lost, procurement lead –time.

The measures which get a rate very important are : materials receipt problems, bid evaluate commit lead time, budget availability, total surplus, discount from bulk purchase, head office requisition percentage, head office purchase order percentage, and warehouse inventory accuracy.

The measures which get a rate moderately important are: min/max release activity, warehouse safety incident rate, materials withdrawal request processing time, materials withdrawal request lead time, material receiving processing time, commodity vendor timeliness, commodity timeliness, purchase order to material receipt duration, average man hour per purchase order, and freight cost percent.

Finally, the measures which get a rate somewhat important are: minority suppliers, sole source purchase and backorders.

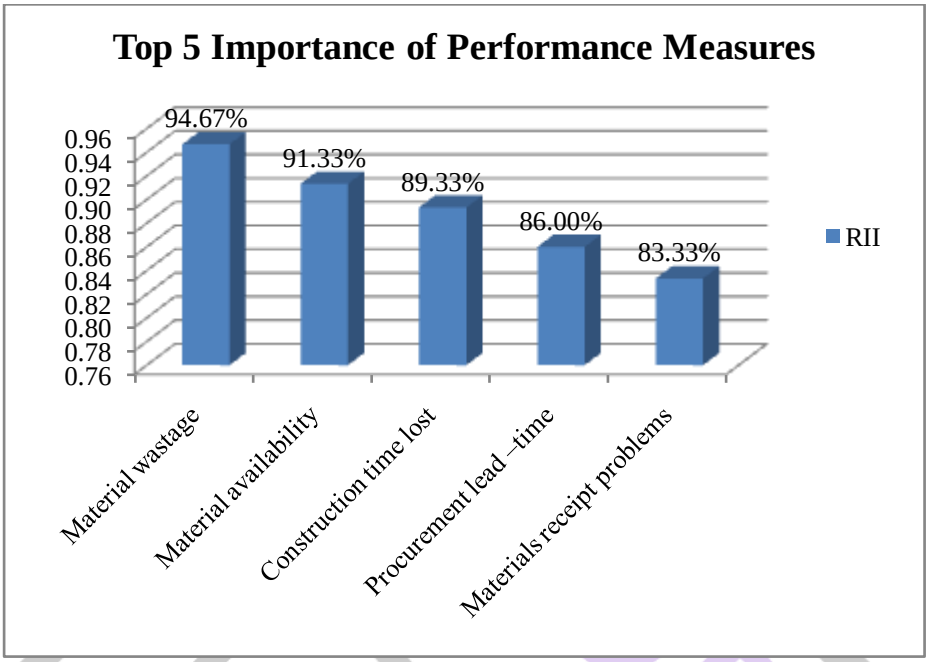

Figure 1: Top 5 Important Performance Measures

5. *Practicality of the Performance Measures*

The collected data were analyzed using the Relative Index methods in a similar way as calculated for the importance of performance measure.

Not Practical	:the assigned weight of 1
Somewhat Practical	:the assigned weight of 2
Practical	:the assigned weight of 3
Very Practical	:the assigned weight of 4
Extremely Practical	:the assigned weight of 5

Table 3: Practicality of Proposed Performance Measure

No	Measure Description	RII of Practicality
1	Materials receipt problems	0.8933
2	Warehouse inventory accuracy	0.5600
3	Head office requisition percentage	0.5400
4	Head office purchase order percentage	0.5600
5	Sole source purchase	0.8667
6	Minority suppliers	0.5533
7	Procurement lead –time	0.8267
8	Bid evaluate commit lead time	0.7133
9	Purchase order to material receipt duration	0.5533
10	Material receiving processing time	0.3733
11	Commodity vendor timeliness	0.3267
12	Commodity timeliness	0.7133
13	Materials withdrawal request lead time	0.3600
14	Materials withdrawal request processing time	0.4000

15	Average man hour per purchase order	0.3667
16	Freight cost percent	0.7400
17	Construction time lost	0.3533
18	Min/Max release activity	0.5533
19	Warehouse safety incident rate	0.3933
20	Total surplus	0.9067
21	Material availability	0.7200
22	Backorders	0.8733
23	Material wastage	0.9333
24	Discount from bulk purchase	0.7267
25	Budget availability	0.5533

Based on the scored rate of each of the performance measures, they were categorized into four different groups as follows:

Extremely Practical : 85-100
Very Practical : 65-84
Moderately Practical : 45-64
Somewhat Practical : 25-44

The measures which get a rate extremely practical are: total surplus, sole source purchase, and material wastage and materials receipt problems.

The measures which get a rate very practical are: procurement lead –time, bid evaluate commit lead time, backorders, freight cost percent, material availability, and discount from bulk purchase.

The measures which get a rate moderately practical are: min/max release activity, budget availability, warehouse inventory accuracy, warehouse safety incident rate, head office purchase order percentage, head office requisition percentage, minority suppliers, purchase order to material receipt duration, and materials withdrawal request lead time.

Finally, the measures which get a rate somewhat practical are: material receiving processing time, materials withdrawal request processing time, construction time lost, commodity timeliness, commodity vendor timeliness and average man hour per purchase order.

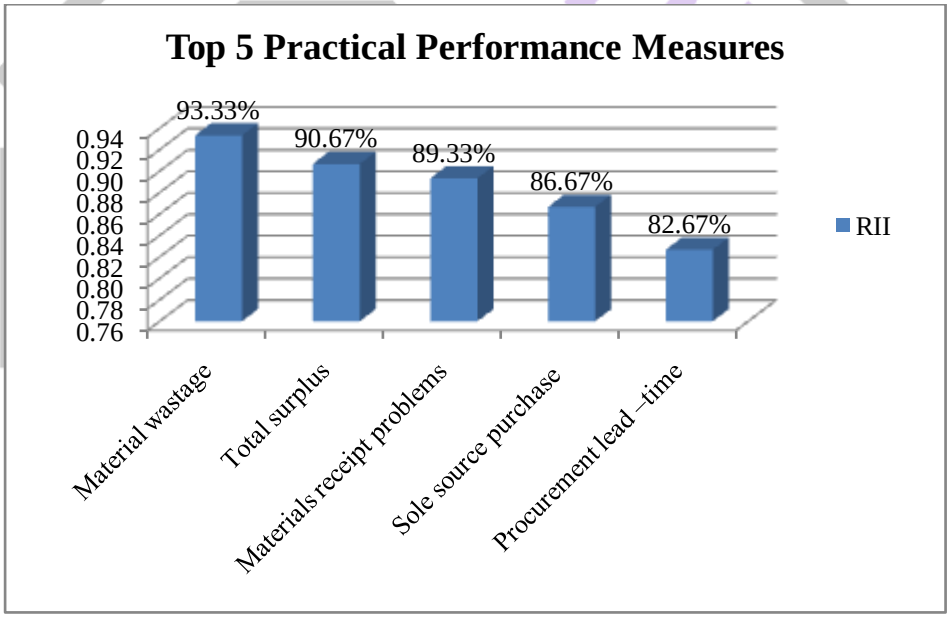

Figure 2: Top 5 Practical Performance Measure

VI. CONCLUSIONS

Construction material management performance measures used rarely in Kolhapur, Sangli building projects. From the selected 25 performance measures only 3 performance measures used on building projects in Kolhapur, Sangli. Construction material management performance measures are very important to measure the effectiveness of the material management process in Kolhapur, Sangli building projects.

The measures which get a rate very important are : materials receipt problems, bid evaluate commit lead time, budget availability, total surplus, discount from bulk purchase, head office requisition percentage, head office purchase order percentage, and warehouse inventory accuracy.

Most of the construction material management performance measures identified in this study are practicable in Kolhapur, Sangli building projects. Four performance measures; total surplus, sole source purchase, material wastage and materials receipt problems have been identified as being somewhat practical to implement. Most of the professionals who work on material management related area in Kolhapur, Sangli building projects have lack of knowledge about construction material management performance measures. The finding of this study helps to improve productivity for effective construction material management process for building projects in Kolhapur, Sangli.

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