



**Evaluation of performance measure for material  
management process in industrial construction projects**

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# EVALUATION OF PERFORMANCE MEASURES FOR MATERIALS MANAGEMENT PROCESS IN INDUSTRIAL CONSTRUCTION PROJECTS

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**Abstract:** Studies have indicated that materials constitute about 60% of the total project cost, and control 80% of the project schedule. Effective management represents improving productivity of work and also controlling cost. This research revealed the Usability, Importance and Practicality of 35 Performance Measures for Materials management process in industrial construction projects in Saudi Arabia.

## 1 INTRODUCTION

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.

This study is about the performance measures affecting the materials management system in industrial construction industry in Saudi Arabia from contractors' point of view.

### 1.1 Research Objectives

The objectives of this study are:

1. Determine the performance measures for Materials in construction projects in the Eastern Province.
2. Determine the importance of the performance measures.
3. Determine the practicality of implementation of performance measures.

### 1.2 Research Methodology

Review was done to find the past and currently used performance measures. The next step was to develop the questionnaire. The third to conduct interviews with the contractors in SABIC and Saudi ARAMCO to determine the performance measures used or currently being used in Saudi Arabia.

### 1.3 Scope and Limitations

Industrial construction involves large amount of materials and complexities managing it. This research is mainly responsible for the materials supply and management and to find the impact of performance measures of materials.

## 2 LITERATURE REVIEW

The goal of any industrial activity is the development and manufacture of products that can be marketed and sold at a profit.

Failure to fulfill any of the responsibilities concerning materials adds to project costs and decreases project profit. The areas reviewed include industrial construction materials management processes, materials management functions, performance categories, effectiveness measure, supply chain management in construction, project management, and re-engineering materials management system.

The Planning Engineer is responsible for development and implementation of the materials execution plan.

Several areas that should be covered by a materials management system which are as follows:

1. Materials identification and control
2. Materials procurement phases
3. Materials tracking
4. Client approval procedures
5. Contractor procedures
6. Contractor, designer, client reporting and communications.

The lack of effectively managing is evident when:

1. Management is complicated.
2. Personnel are not trained.
3. Integration of materials management is lacking.
4. Systems used are not effectively meshed with management system.
5. Information is poorly used.

## **2.1 Problems in Materials Management:**

Materials management is concerned with the flow of materials from suppliers to production and the subsequent flow of products through distribution centers to the customer. This includes the planning, acquisition, storage, movement, and control of materials and final products.

Although owners and contractors may have different perceptions on project management for construction, they have a common interest in creating an environment leading to successful projects.

Problems related to Owners may accrue due to Outdated management, Inefficient planning, Or Improper selection of design-construct and construction contractor.

Owners should consider the need for modern systems, establishing specific scheduling prior to requesting bids, proper selection of design-contract, and the use of incentives.

The problems may happened due between the owner and the contracture due to no standards of performance, untrained personnel. absence of automatic data processing, or inefficient job site inventory.

Owners and Contractors should develop standards, select personnel carefully, use automatic data processing more extensively, expedite placement of purchase orders by techniques, improve job site inventory control by broader use of coding systems and of re-order points for commonly stocked materials.

## **2.2 Materials Management in Construction Industry**

Problems may arise unless special care is taken in the following areas:

1. Planning deliveries
2. Ordering
3. Checking deliveries on site
4. Placing materials onsite
5. Processing delivery tickets and invoices
6. Controlling use of materials
7. Producing costing analysis
8. Paying for materials
9. Feedback on performance

The materials management is “a process that enables the organization to become the low cost/high quality provider of services in the marketplace and maintaining that position in this environment of constant change”.

The orders for the supply of building materials are placed by the contractor. Improper warehousing results in decrease in space utilization, inaccurate retrievable data,

increase in manpower, inferior customer services. Improper warehousing increases the waste. Improper takeoff will result in lack of materials when required.

It is essential to provide an end product that meets the client's needs and is cost effective.

## **2.3 Materials Management in Industrial construction**

The owners are usually deeply involved in project, such that the total time for the completion can be shortened. For large scale projects, the owner may initiate the procurement procedure even before the selection of a contractor in order to avoid shortages and delays. Under ordinary circumstances, the contractor handles the procurement.

### **2.3.1 Materials Management Organization and Personnel**

An overall organizational approach is required for successful material management. They came up with a list of problems as follows:

1. Early receiving.
2. Unavailability
3. Incorrect material takeoff.
4. Subsequent design changes;
5. Damage/loss of items.
6. Failure on installation.
7. Selection of type of contract for specific materials procurement to prevent loss.
8. Vendor evaluation criteria.
9. Piling up of inventory.
10. Management of surplus materials.

On larger projects, materials functions may be consolidated into one unit. On smaller jobs, it could be assigned to individuals who have other responsibilities.

Large projects, will require a full staff of skilled professionals with a direct reporting line to project management. Computer is important as the benefits of materials

management automation become practical for ever smaller jobs”.

Some training for the particular requirements of each project will be required. Personnel must be able to operate in the project environment, to anticipate the requirements of other organizations.

A construction industry cost effectiveness project report point out the following as organizational responsibilities:

1. Must be fully defined.
2. Detailed written procedures should be published.
3. Standards should be used to establish staffing levels.

If the materials coordinator is successful, other functional managers and coordinators will routinely coordinate planning, engineering, changes, and field requirements with the materials coordinator.

### **2.3.2 Improvement in Materials Management System**

A study made on improving the plant life cycle through materials management and computer aided engineering (based on a company named Lummus). Materials management system (MMS) had been designed as an integrated, on-line real time system. The system makes use of data base technology and a telecommunication protocol permitting terminals situated in diverse areas. The implementation of MMS resulted in:

1. Reduce material lost.
2. Reduce subcontractor charges for idle manpower.
3. Material personnel will be able to identify potential material shortfalls.
4. Planners can establish construction areas in MMS and identify material availability for these areas.

### **2.3.3 Models Developed in Materials Management**

A numbers of models have been developed to improve the materials management from organization, finance, scheduling, and time point of view.

System is developed supporting materials, beginning with the identification and requisitioning of the materials and ending with the accounting function.

The main advantages of this system were:

1. Reducing the costs.
2. Improving the reliability of operating units.
3. Increasing the efficiency of materials.

#### **2.3.4 Cost Effectiveness through Materials Management**

The costs and benefits of materials management systems vary depending on the type and magnitude of the project. The importance of proper management is that they account for cost and time.

#### **2.3.5 Productivity and Materials Management**

A study made on the impact of materials management on productivity. The research provided a quantitative estimate of the work-hour losses resulting from ineffective material management practices.

#### **2.3.6 Computerized Materials Management**

Computerized materials management has proved to be more efficient and reliable compared to the traditional materials management system.

It focuses on the item to be tracked or status. The key elements of the CMMS are as follows:

1. The ability to track every item.
2. Report "expected" delivery dates.
3. Prioritize materials.

The attribute included automatic commodity code generation, automatic takeoff execution, intelligent purchase order generation, and components of design and schedule integration.

#### **2.3.7 Implementation of Materials Management**

The implementation of the new materials management system consisted of four phases, requirement definition, software search, system design, and installation.

It will lead to have:

1. Manage the materials
2. Prove necessary interface
3. Administer inventory levels

## **2.4 Techniques in Materials Management**

There are 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:

1-Economic Order Quantity: Determines the amount of orders that minimizes total variable costs required to order and hold inventory.

2-Materials Requirement Planning: It is used to determine the quantity and timing requirements of materials used in the manufacturing operation.

3- 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.

## **2.5 Materials Management Functions**

Materials management consists of seven integrated functions as applicable to a typical industrial construction project. These functions are:

1-Project Planning: It is arrangement of the activities involved in the project to assist smooth flow of the project.

2-Materials Take-off: It is identifying what materials are needed and how much.

3-Vendor enquiry: In the selection of a vendor, the cost of the material is not the only criteria but quality and service.

4-Purchasing: The terms “purchasing” and “procurement” are used interchangeably in many organizations.

5-Material Control: It is the process through which the various materials management attributes, such as cost, quality, quantity, timeliness and availability are monitored.

6-Warehousing: stores management is being pressed for continuing improvements in the warehousing and physical supply operation.

7-Expediting and Shipping: It influences the attribute timeliness as in materials withdrawal request processing time, and commodity vendor timeliness.

## **2.6 Material Management Performance Attributes**

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

1-Accuracy: It reduces uncertainty and supports the decision-making process.

2-Quality: It is related to suitability and cost, rather than to intrinsic excellence.

3-Quantity: It is to quantify the volume of transactions of the materials management process.

4-Timeliness: It is defined as the measurable interval between two events or the period during which some activity occurs.

5-Cost: The focus is on the efficient use of labor, the introduction of labor-saving technology, and the avoidance of “unreasonable” or unnecessary expenses.

6- Availability: It characterizes the ability of the materials management process to fill requests for materials at the agreed time and place.

## **3 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.

Plemmons (1995) research identifies the key effectiveness measures for the materials management process and proposes a mechanism for benchmarking these measures. A total of 35

measures were developed from the construction industry to measure the effectiveness of the materials management process. The table 1 shows the Plemmons measures.

## **4 DATA COLLECTION**

The data was collected by two ways. The first way was, interviews with the individuals representing fifteen industrial construction organizations. Where the second way was survey questionnaire to solicit the opinions from 15 materials management professionals selected from construction related organizations

The author developed a list of 42 potential respondents working in materials management. Then this was short listed to 15 respondents that were suitable for the interview. Only those respondents were selected that had experience in industrial construction. The data obtained for this research was primarily obtained through interviews.

### **4.1 Content of Questionnaire**

The materials management performance measures were arranged in a questionnaire format with 3 questions to be answered for each of the 35 measures used in the questionnaire.

The interviewees were first asked verbally to answer the question about the usability of a measure in past or currently in industrial construction, and were given an option of “yes” or “no”. If the response for the first question was “yes” then the interviewees were further questioned about the importance and practicality of that measure.

### **4.2 Interviews**

The result of the interviews, a general understanding of the materials management control procedures was obtained and a discussion on the measures associated with materials related performance was approved. The interviews reflected a good level of understanding of the measures by the materials management professionals interviewed.

The Lpemmons measures

S.No	The Measures	Location	Attribute
1	Materials receipt problems	Vendor and Warehouses	Accuracy
2	Material receipt problems-internal	Vendor and Warehouses	Accuracy
3	Warehouse inventory accuracy	Warehouses	Accuracy
4	Piping spool rework	Construction with the field	Quality
5	Jobsite rejections of tagged equipment	Construction with the field	Quality
6	Home office requisition ratio	Purchasing with Vendor	Quality
7	Home office Purchase Order ratio	Purchasing with Vendor	Quality
8	Average number of line items per release	Purchasing with Vendor	Quality
9	Commitment-home office	Purchasing with Vendor	Quality
10	Commitment-Field	Purchasing with Vendor	Quality
11	Electronic Data Interchange purchases	Purchasing with Vendor	Quality
12	Sole source purchases	Purchasing with Vendor	Quality
13	Minority suppliers	Purchasing with Vendor	Quality
14	Procurement lead time	Vendor and Purchasing	Timeliness
15	Bid-Evaluate-Commit lead time	Vendor and Purchasing	Timeliness
16	Purchase Order to material receipt duration	Purchasing with Vendor	Timeliness
17	Material receiving processing time	Warehouses with Field	Timeliness
18	Commodity vendor timeliness	Vendor with Warehouse	Timeliness
19	Commodity timeliness	Vendor with Warehouse	Timeliness
20	Materials withdrawal request	Construction with Warehouse	Timeliness
21	Materials withdrawal request (MWR) processing time	Field with Warehouse	Timeliness
22	Average manhour per Material Take-Off	Material takeoff with design interface	Cost
23	Average man-hour per Purchase Order	Purchasing	Cost
24	Freight cost percent	Expediting and Transportation	Cost
25	Express deliveries percent	Vendor and Warehouse	Cost
26	Construction time lost	Construction and Field	Cost
27	Payment discounts	Purchasing	Cost
28	Electronic funds transfer payments	Purchasing	Cost
29	Release value breakdown	Purchasing	Cost
30	Min/Max release activity	Warehouse	Cost
31	Warehouse safety incident rate	Warehouse	Cost
32	Total surplus	Warehouse and Construction	Cost
33	Material availability	Warehouse and Construction	Cost
34	Stock out analysis	Warehouse	Availability
35	Backorders	Purchasing	Availability

Table1

## 5 RESULTS AND DISCUSSIONS

### 5.1 Overview

The data collected from the 15 respondents formed the basis for the analysis of the study. The three objectives of the study i.e. determining the performance measures used, the importance and practicality of the measures in Saudi Arabia were to be analyzed based on the data collected from the interviews.

### 5.2 Performance measures

The first section in the questionnaire contained the respondent profile. The information to be provided by the respondents consisted of their current position, the grade of the firm, length of experience in industrial construction, length of experience in materials management, areas of experience in materials management, and the type of projects they worked on. The profile of the respondents showed that 6 out of the 15 respondents had an experience in the range of 10-15 years, with the rest having an experience of less than 10 years in industrial construction materials management system. See Fig.1

Respondents Areas of Experties

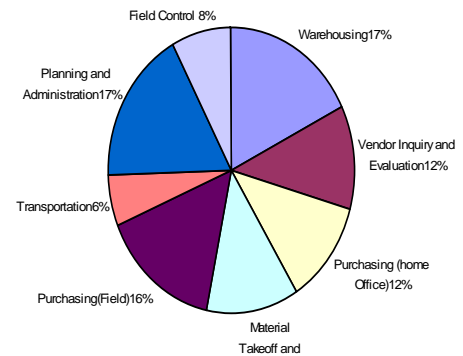


Fig.1

### 5.3 Performance measures

Table 2 shows the response received for each of the measure included in the questionnaire. The purpose of the assessment is to present auxiliary information regarding the identification of the key performance measures for the industrial construction materials management process. The auxiliary information deals with three areas: utilization of the measure in past or present, importance, and practicality to implement



## 5.4 Past and Presently used Measures

The first objective of the study was to determine the performance measures used in the past or currently being used in Saudi Arabia. Fig.2 shows percent response for the past or present use of the measure. Also it shows that all the 35 measures were used or are currently in use in Saudi Arabia. Based on the response score for each of the measures, the measures were

### Response to the performance measures

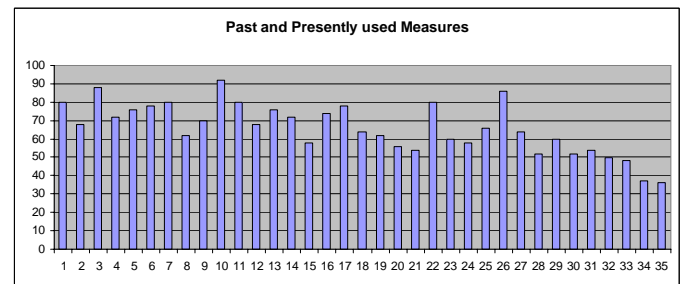
S.No.	Measure	Number of Responses	Past or Current use (%) response
1	Materials Receipt Problems	15	80
2	Materials Receipt Problems-internal	13	80
3	Warehouse inventory accuracy	14	76
4	Piping Spool Rework	8	36
5	Jobsite rejection of tagged equipment	14	72
6	Home office requisition ratio	12	52
7	Home office PO ratio	11	50
8	Average line items per release	14	58
9	Commitment home office	13	60
10	Commitment field	13	58
11	EDI purchase	15	68
12	Sole source purchase	12	60
13	Minority Suppliers	10	37
14	Procurement lead-time	15	88
15	BEC lead-time	14	74
16	PO to materials receipt duration	14	78
17	Material receiving processing time	15	72
18	Commodity vendor timeliness	15	76
19	Commodity timeliness	13	66
20	Materials withdrawal request	14	64
21	Materials withdrawal request (MWR) processing time	14	62
22	Average man hour per MTO	12	52
23	Average man hour per PO	12	54
24	Freight cost percent	15	78
25	Express deliveries percent	15	80
26	Construction time lost	13	86
27	Payment discounts	13	64
28	Electronic funds transfer payments	14	56

S.No.	Measure	Number of Responses	Past or Current use (%) response
29	Release Value Breakdown	11	48
30	Min/Max release activity	14	54
31	Warehouse safety incident rate	15	62
32	Total surplus	15	70
33	Material availability	15	92
34	Stock out analysis	15	80
35	Backorders	15	68

**Table 2**

categorized in 4 different groups with a range of 25% for each category. The ranges were divided as follows:

1. Rare use: 0 – 25%
2. Low use: 26 – 50%
3. Moderate use: 51 – 75%
4. High use: 76 – 100 %



**Fig.2**

None of the measures fell under the category of rare use. Only 3 of the 35 measures came under the category of low use. 20 performance measures in the moderate category and Eleven of the 35 measures fell under high use category.

## 5.5 Importance of the Performance Measures

The importance levels of the performance measures were distributed in five categories, assigning 5 to the extremely important and the not important was given the weight of 1. The values assigned to the importance levels were as follows:

Extremely important: the assigned weight of 5

Very important: the assigned weight of 4

Important: the assigned weight of 3

Somewhat important: the assigned weight of 2

Not important: the assigned weight of 1

The following is the calculation of the index values obtained for the importance of the performance measures:

$$\text{Importance index of a measure} = (X_1 * 5 + X_2 * 4 + X_3 * 3 + X_4 * 2 + X_5 * 1) / N$$

Where X1, X2 ....represents the frequency of responses in a particular rating and

5,4,3,2,1...represents the numerical score of the respective rating. N is the number of

responses. For example, the index for materials availability was developed as:

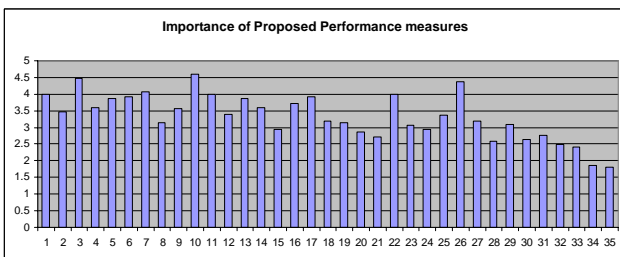
$$(10 * 5 + 4 * 4 + 1 * 3 + 0 * 2 + 0 * 1) / 15 = 4.60$$

Fig.3 shows the results of the importance indices of all performance measures.

Based on the index score for each of the measures, the measures were categorized in 4 different groups with a range of

1. The range was as follows:

1. Extremely important: 4.25 – 5.00
2. Important: 3.25 – 4.24
3. Moderately important: 2.25 – 3.24
4. Somewhat Important: 1.25 – 2.24



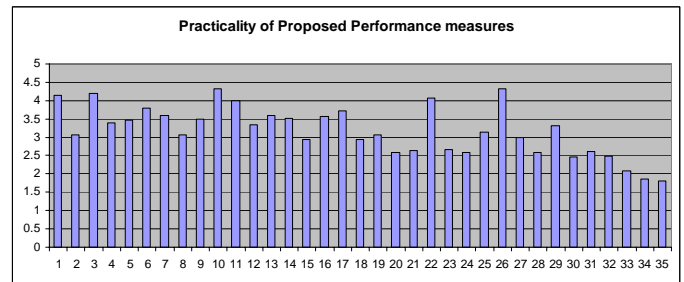
**Fig.3**

Only 3 measures came under the category of extremely important. Fifteen of the performance measures fell under the category of important. The performance measures that came under the moderately important category also summed up to 15. The measures that fell under the category of somewhat important were two.

## 5.6 Practicality of the Performance Measures

Fig.4 shows the results of the practicality indices of all performance measures. Based on the index score for each of the measures, the measures were categorized in 4 different groups with a range of 1. The range was as follows:

1. Extremely practical: 4.25 – 5.00
2. Practical: 3.25 – 4.24
3. Moderately practical: 2.25 – 3.24
4. Somewhat practical: 1.25 – 2.24



**Fig.4**

It can be seen that only 2 measures came under the category of extremely practical. Fifteen of the performance measures fell under the category of practical. The performance measures that came under the moderately practical category also summed up to 15. None of the measures in the practical category can be linked with accuracy, quality and availability. The measures that fell under the category of somewhat practical were minority suppliers and piping spool rework.

## Relationship between Practicality and Importance Measures

A relationship between practicality and importance was studied. This relationship was assessed by the use of Pearson's correlation coefficient. The coefficient will help in finding the correlation between the two categories of importance and practicality. SPSS statistical software was used to calculate the correlation coefficient.

$$\text{Using the formula of Pearson's correlation coefficient, } r = \frac{\sum(X - \bar{X})(Y - \bar{Y})}{\sqrt{\sum(X - \bar{X})^2 \sum(Y - \bar{Y})^2}}$$

Where X and Y are the sample means average (Importance) and average (Practicality), the resulting correlation coefficient  $r = 0.9714$

The above value of the Pearson's correlation coefficient indicates a strong positive correlation between the

two sets of ranks under importance and practicality criteria. The very strong positive correlation between the importance and practicality of the performance measures suggests that there is a wider use of those performance measures which are considered highly important. It can be observed that the top five performance measures Materials availability, Procurement lead time, Construction time lost, and Materials receipt problems – internal maintained their positions in both the categories. These measures represent the attributes accuracy, timeliness, availability, and cost.

## 6 CONCLUSIONS AND RECOMMENDATIONS

### 6.1 Conclusion

The objective of the research was to identify and assess the usability, importance and practicality of measures in the materials management process in the industrial construction sector in Saudi Arabia. The following can be concluded based on the results of this research:

1- It was found that all of the measures were used or are presently in use in Saudi Arabia. The measures were categorized in 4 different groups:

A- *Rare use*: none

B- *Low use*: Piping Spool rework, Minority suppliers, and Release value breakdown.

C- *Moderate use*: Jobsite rejection of tagged equipment, Home office PO ratio, Home office requisition ratio, Average line items per release, Commitment home office, Commitment field, EDI purchase, Sole source purchase, BEC lead-time, Material receiving processing time, Commodity timeliness, Materials withdrawal request, Materials withdrawal request (MWR) processing time, Average man hour per MTO, Average man hour per PO, Payment discounts, Electronic funds transfer payments, Min/Max release activity, Warehouse safety incident rate, Total surplus and Backorders.

D- *High use*: Materials Receipt Problems, Materials Receipt Problems-internal, Warehouse inventory accuracy, Procurement lead-time, PO to materials receipt duration, Commodity vendor timeliness, Freight cost percent, Express deliveries percent,

Construction time lost, Material availability and Stock out analysis.

2- The Importance of the performance measures were categorized in 4 different groups:

A-*Extremely important*: Material availability, Procurement lead-time, Construction time lost.

B-*Important*: Express deliveries percent, Materials Receipt Problems, Materials Receipt Problems-internal, and Stock out analysis, PO to materials receipt duration, Freight cost percent, Warehouse inventory accuracy, Commodity vendor timeliness, BEC lead-time, jobsite rejection of tagged equipment, Material receiving processing time, Total surplus, EDI purchase, Backorders, Commodity timeliness.

C- *Moderately Important*: Materials withdrawal request, Materials withdrawal request (MWR) processing time, Payment discounts, Warehouse safety incident rate, Sole source purchase and commitment home office, Average line items per release, Commitment field, Electronic funds transfer payments, Average man hour per PO, Min/Max release activity, Average man-hour per MTO, Home office requisition ratio, home office PO ratio and release value breakdown.

D-*Somewhat Important*: Minority suppliers and Piping spool rework.

3- The practicality of the performance measures were categorized in 4 different groups:

A-*Extremely Practical*: Material availability and Construction time lost.

B-*Practical*: Procurement lead-time, Materials Receipt Problems, Materials Receipt Problems-internal, and Stock out analysis, PO to materials receipt duration, Freight cost percent, Warehouse inventory accuracy, Express deliveries percent, Commodity vendor timeliness, BEC lead-time, Jobsite rejection of tagged equipment, Material receiving processing time, Total surplus, Backorders, and Sole source purchase.

C-*Moderately Practical*: Materials withdrawal request (MWR) processing time, Payment discounts, EDI purchase, Commodity

timeliness, Warehouse safety incident rate, Average line items per release, Materials withdrawal request, commitment home office, Commitment field, Electronic funds transfer payments, Average man hour per PO, Min/Max release activity, Average man hour per MTO, Home office requisition ratio, and home office PO ratio.

D-Somewhat Practical: Release value breakdown, Minority suppliers and Piping spool rework.

4. Relationship between Importance and Practicality: The correlation coefficient was found to be 0.9714 indicating a very strong positive correlation between the two sets of ranks under the importance and practicality criteria.

## 6.2 Recommendations for Further Studies

Based on the research carried out, the author recommends the following:

1. A study can be carried out to determine the barriers in the implementation of materials management performance measures in the other types of construction like building construction.
2. A study of the use of computerized materials management system currently in use in Saudi construction industry.
3. A similar study can be carried out for other types of constructions, like building construction.
4. A study of the application of materials management models, such as EOQ, MRP, JIT in construction can be done.

## 6.3 Recommendations for Industry

1. To use the materials management performance measures and benchmark their projects with the performance measures.
2. To educate and train on the use Materials management performance measures and their influence on the projects.

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