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COLLEGE OF CONSTRUCTION ENGINEERING AND MANAGEMENT

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Measuring the Effectiveness of Materials Management for Industrial Construction Projects in Saudi Arabia.

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Abstract

This paper investigate the material management practices that are being used in construction projects based on some literature review and measure the use of them in industrial project in Saudi Arabia. This shall create a benchmark model for construction projects in Saudi Arabia which is the first of its kind (to the best of the authors knowledge).

The author choose to use 12 key effective measures of material management of those identified by Plemmons (1995). Plemmons set an equation for each of those measures to give a percentage value of practicing each one.

The measures are classified into two groups. Group A which are best when they are low and include procurement lead time, bid/evaluate/ commit lead time, PO to materials receipt duration, material receiving processing time, material withdrawal request time, construction time lost and total surplus. Group B which are the measures that are best when they are high and include material receipt problem, warehouse inventory accuracy, material availability, commodity vendor timeliness and commodity timeliness.

The study approaches several industrial construction projects managers in the eastern region of Saudi Arabia to assess the use of those measures in a competitive way to rank the projects against each of those measures. 17 project where considered in this study and the data of each was kept confidential by giving a code for each project in data collection and analysis.

After collecting the data, it was input to an Excel spread sheet designed to be the model for analysis and results sorting.

The output of the model represent each project score in each of the quality measures and rank them accordingly to have a sort of benchmark within the small population of the projects under evaluation. It also represent the average value for each measure and represent the highest and lowest limits. This shall give a benchmarking model for material management in industrial construction project in Saudi Arabia.

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1.0 Introduction

Material management is the planning and controlling of all necessary effort to ensure that the correct quality and quantity of material and installed equipment are appropriately specified in a timely manner, are abstained at a reasonable cost and available when needed. (The Business Roundtable BRT 1982).

Since the material constitute to 60% of the project cost (BRT 1983), it represent an are of improvement and saving. According to an experienced project manager (Kerridge 1987), material control accounts for 80% of project schedule. Since the profit is 5.5% of total project cost (BRT 1983), a 2% cut in cost of material will increase profit by 21% (Otaibi 1995). The management of material inventory and issues like inventory stock out, surplus and carry cost are so important in the construction industry as well as other type of industries in order not to suffer the cost of material shortage or material surplus.

From the above facts, the need for an effective material management system in construction is highly considerable. It is for the benefit of the project investment to maintain a good system that shall minimize the surplus, promote craft labor productivity and minimize work-hour overrun.

2.0 Material Management

The project material management should be thought of as a process rather than an organization. Its process cross all organizational lines of the project and it is the responsibility of the owner and engineer. (CII Project Management Planning Guide 1987).

Material management is a system that includes all the functions of acquiring and distributing the material and equipment to support the construction. The objective of this system include:

- Obtaining the best value.
- Assuring supplies are on hand when and where required.
- Reducing inventory.
- Assuring quality requirement.
- Providing efficient, low cost transport, security and storage of material at the construction site. (CII Handbook 1987)

3.0 Effectiveness Measures

Plemmons (1995) identified 35 effectiveness measures for martial management system that either have been used in the past or being used currently. He then sent a survey to functional experts to identify which measures best communicate the effectiveness of the industrial construction material management process. Plemmons then identified 12 key effectiveness measures that have 25% or above response rate as to best communicate the effectiveness of material management process for fixed price contracts. Also, 11 key measures were identified for cost reimbursable contracts. Due to the low response received for unit price and guaranteed max price, no evaluation concerning the measures were identified. The results are shown in table 3.1 below.

Table 3.1 Key Effectiveness Measures

S/n	Fixed price contracts	Response rate	Cost reimbursable contracts	Res rat
1	Materials availability (AV1)	67%	Construction time lost (C5)	75 %
2	Materials receipt problems (AC1)	33%	Materials availability (AV1)	67 %
3	Jobsite rejections of tagged equipment (02)	33%	Procurement lead time (T1)	42 %
4	Materials receiving processing time (T4)	33%	Commodity vendor timeliness (T5)	42 %
5	Commodity vendor timeliness (TS)	33%	Materials receipt problems (AC1)	33 %
6	Construction time lost (C5)	33%	PO to materials receipt duration (T3)	33 %
7	Warehouse inventory accuracy (AC3)	25%	Warehouse inventory accuracy (AC3)	25 %
8	Procurement lead time (T1)	25%	Piping spool rework (01)	25 %
9	Bid/evaluate/commit lead time (T2)	25%	Jobsite rejections of tagged equipment (Q2)	25 %
10	PO to material receipt duration (T3)	25%	Commodity timeliness (T6)	25 %
11	Materials withdrawal request (MWR) lead time (T7)	25%	Total surplus (C11)	25 %
12	Total surplus (C11)	25%		

4.0 Benchmarking for material management

No mater what type is the benchmarking, it consists of four primary steps:

- Planning what to benchmark and what process to be identified and worked out.
- Collecting data about the internal process and the external benchmark.
- Analysis of the data in a comparative way to assess the performance gaps.
- Improve the process in view of the best practice to exceed the performance gaps by committing the necessary resources and keep monitoring the progress.

For the construction industry, there is no benchmark standards except for the effort of Houston Roundtable (HRT).

5.0 Material management computer systems (MMS)

The availability of computers in the project site and office support the material management with no doubt. However any MMS to be effective must include the following:

- Full integration of all functions.
- Line time reporting of purchase order PO and acquisition.
- Flexibility to respond to any contractual arrangement.
- Online capability.
- Menu driven screens format.
- Hardware portability.
- Compatibility with other systems of engineering, accounting and cost estimating.

Tow inventory systems are common MRP (material requirement planning) JIT (Just In Time). The MRP is suitable for construction environment where the demand is discontinues and dependent. On the other hand, JIT is suitable for manufacturing environment where the demand is continues and uniform.

6.0 The Model

The author used the key effectiveness measures identified by Plemmons who also suggested formulas to calculate each of those measures. Based on those formulas, the author build up an excel spread sheet that can easily calculate and sort the results. Now what are the measures and formulas? Here is the list of them:

ACCURACY (AC)

1. material receipt problem (AC1) : which relate the line items received without deficiency (LIRND) to that received with deficiency (LIRWD)

   $AC1 = (LIRND \div LIRND+LIRWD) \times 100$

2. warehouse inventory accuracy: which is relate the number of line item to be counted (ITC) to the number of line item found accurate (IFA)

   $AC3 = (IFA \div ITC) \times 100$

AVAILABILITY (AV)

3. material availability: relating the total number of line item issued (LII) to the number of line item requested (LIR)

   $AV1 = (LII \div LIR) \times 100$

QUALITY (Q)

4. Jobsite rejection of tagged equipment (Q2) relating the number of tagged equipment (NTQ) to the number of the tagged equipment rejected (NTQR)

   $Q2 = (NTQ \div NTQR) \times 100$

5. Piping spool rework relating the number of piping spool (NPS) to the those rejected (NPSR)

   $Q2 = (NPSR \div NPS) \times 100$

TIMELINESS (T)

6. procurement lead time relating the average actual procurement lead time (AALT) to the average planned lead time (APLT)

   $T1 = ((AALT-APLT) \div APLT) \times 100$

7. bid/evaluate/commit BEC lead time relating its average actual lead time (ABECLT)to the average planned lead time (PBECLT)
   $T2 = ((ABECLT-PBECLT) \div PBECLT) \times 100$

8. PO to material receipt duration relating average actual receipt duration (AMRD) to the average planned receipt duration (PMRD)
   $T3 = ((AMRD-PMRD) \div PMRD) \times 100$

9. material receiving processing time relating the average material received in the same day (MRSD)to those received next day (MRND)
   $T4 = ((MRSD-MRND) \div MRND) \times 100$

10. commodity timeliness relating the total number of delivery(TD) to the number of on time promised delivery (OTPD)
    $T5 = (OTPD \div TD) \times 100$

11. commodity vendor timeliness relating the total no of delivery (TD) to the number of delivery on or before the required time (OTRD)
    $T6 = (OTRD \div TD) \times 100$

12. material withdrawal request MWR lead time to relate it average lead time (AMWR) to its planed lead time (PMWR)
    $T7 = ((AMWR -PMWR) \div PMWR) \times 100$

COST (C)

13. construction time lost relating that (CTL) to the construction time (CT)
    $C5 = (CTL \div CT) \times 100$

14. total surplus to relate the value of unused material (VUM) to the value of total purchased material (VTPM)
    $C11= (VUT \div VTPM) \times 100$

7.0 Data collection and input

The study approaches several industrial construction projects managers in the eastern region of Saudi Arabia to assess the use of those measures in a competitive way to rank the projects against each of those measures. 17 project where considered in this study and the data of each was kept confidential by giving a code for each project in data collection and analysis. Table 7.1 below shaows the data collection and analysis spread sheet which was sent to the project managers and site visets were conducted to insuer accurate data collection and full understanding of the requierment be the prject managers.

Table 7.1 The Measuring Model

Type of the industrial project

Refinery O
Petrochemical O

Industrial plant O
Oil & Gas O
Water Desalination O

Type of contract

Fixed Price (lump sum) O
Cost reimbursable O

Unit Price O
Guaranteed Max. Price O

Duration in months

1-12 O
13-24 O
25-48 O
>49 O

Project value ($)

<100,000,000 O
101,000,000-200,000,000 O
201,000,000-300,000,000 O
301,000,000-400,000,000 O
>401,000,000 O

% completion

<25%	
26-49%	
50-74%	
75-100%	

ACCURACY (AC)

1. Materials receipt problem (AC1)

Fixed price only

line items received without discrepancies (LIRND)
line items received with discrepancies(LIRWD)
Act=
(LIRNDLIRND+LIRWD)*100

2. Warehouse inventory accuracy (AC3)

Both fixed price and cost reimbursable

no. of random items to be counted(ITC)
no. of items found accurate(IFA)
AC3= (IFA/ITC)*100

AVAILABILITY (AV)

3 Materials availability (AV1)

Both fixed price and cost reimbursable

total number of line items issued (LII)
Total number of line items requested (LIR)
AV 1= (LI I/LI R)`100

QUALITY (O)

8.0 Output and Results

I order to have the data sorted and organized in ranking way of the projects. The key measures were put in two groups depending on its desired value as low or high.

Group A is for those measures that are desired to be as low as possible and includes:

- Jobsite rejection of tagged equipment Q2
- Piping spool rework Q1.
- Procurement lead time T1.
- Bid/evaluate/commit lead time T2.
- PO material receipt duration T3.
- Material receiving processing time T4.
- Construction time lost C5.
- Total surplus C11.

Group B is for those measures that are desired to be as high as possible and includes:

- Material receipt problem AC1.
- Warehouse inventory accuracy AC3.
- Material availability AV1.
- Commodity vendor timeliness T5.
- Commodity timeliness T6.

We have five types of result output that was extracted from the spread sheet and following is a description of each :

8.1 Matrix format

This integrate all the information collected and sort them in matrix form showing all the key effective measures in the rows and all the projects performance in 17n columns. The output is shown in table 8.1-a and b below.

Table 8.1-a Project Measures 1-9

Key Measures	Project Number								
	1	2	3	4	5	6	7	8	9
1- Material receipt problem (AC1) B	97.98	99.53	99.87	99.04	98.65	99.07	X	99.00	99.80
2- Warehouse inventory accuracy (AC3) B	90.00	X	100.00	85.00	95.00	95.00	X	80.00	X
3- Materials availability (AV1) B	95.00	95.20	100.0	98.40	100.00	99.40	X	94.80	95.00
4- Commodity vendor timeliness (T5) B	85.00	90.90	X	93.75	50.00	94.96	X	80.00	31.25
5- Jobsite rejections of tagged equipment (Q2) A	0.10	1.67	0.00	0.06	3.25	21.34	X	0.00	5.00
6- Procurement lead time (T1) A	100.0	0.00	8.00	200.00	25.00	(28.87	15.38	14.00	0.00
7- bid/evaluate/commit lead time (T2) A	100.0	0.00	33.00	X	25.00	0.00	15.40	0.00	0.00
8- PO to materials receipt duration (T3) A	22.00	33.00	0.00	100.00	0.00	(5.00)	21.70	40.00	0.00
9- Materials receiving processing time (T4) A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10- Materials withdrawal request lead-time(T7) A	0.00	(50.00)	0.00	(50.00)	0.00	0.00	X	100.00	(20.00)
11- Construction time lost (C5) A	14.29	8.33	0.00	X	X	X	2.20	4.17	X
12- total surplus (C11) A	0.10	0.02	X	1.50	2.14	1.08	5.00	X	0.00
Group A Average	29.56	11.63	5.86	58.59	7.91	8.04	9.95	22.60	3.57
Group B Average	91.99	95.21	99.96	94.05	85.91	97.11	X	88.45	75.35

Table 8.1-b Project Measures 10-17

Key Measurements	Project Number							
	10	11	12	13	14	15	16	17
1- Material receipt problem (AC1) B	80.00	100.00	97.57	98.58	98.76	100.00	87.67	96.97
2- Warehouse inventory accuracy (AC3) B	100.00	85.00	X	X	X	95.00	98.68	X
3- Materials availability (AV1) B	100.00	98.50	93.60	93.90	88.00	87.50	86.33	X
4- Commodity vendor timeliness (T5) B	70.00	87.50	89.80	19.93	100.00	78.26	X	13.54
5- Jobsite rejections of tagged equipment (Q2) A	0.00	0.00	0.00	26.67	2.56	4.86	0.00	2.97
6- Procurement lead time (T1) A	(20.00)	0.00	(20.00)	25.00	(34.00)	25.00	14.28	(2.57)
7- bid/evaluate/commit lead time (T2) A	(15.00)	0.00	(14.30)	25.00	50.00	20.00	33.33	14.28
8- PO to materials receipt duration (T3) A	(10.00)	0.00	(16.70)	16.70	(20.00)	33.00	33.33	39.62
9- Materials receiving processing time (T4) A	X	0.00	0.00	X	0.00	X	(33.33)	0.00
10- Materials withdrawal request lead-time(T7) A	X	0.00	50.00	0.00	(20.00)	0.00	X	(50.00)
11- Construction time lost (C5) A	0.00	0.00	0.00	X	33.30	0.00	X	X
12- total surplus (C11) A	0.07	0.00	0.40	0.03	4.00	0.50	X	X
Group A Average	7.51	0	12.68	15.57	20.48	11.91	22.85	21.24
Group B Average	87.50	92.75	93.66	70.80	95.59	90.19	90.89	55.26

Note: the numbers in parenthesis represent negative values, and X represents a missing value.

8.2 Key measurement for each project

Per project performance report representing the project score in each of the key measures comparing to the average score. Sample table is shown below.

Table 8.2 Key Measurements for Project Number 1

Key Measurements	1	Average	Std Dev.
1- Material receipt problem (AC1) B	97.98	97.03	5.41
2- Warehouse inventory accuracy (AC3) B	90.00	92.37	7.03
3- Materials availability (AV1) B	95.00	95.04	4.64
4-Commodity vendor timeliness (T5) B	85.00	70.35	29.37
5- Jobsite rejections of tagged equipment (Q2) A	0.10	4.28	7.96
6- Procurement lead time (T1) A	100.00	32.36	48.73
7- Bid/evaluate/commit lead time (T2) A	100.00	21.58	25.52
8- PO to materials receipt duration (r3) A	22.00	23.00	24.37
9- Materials receiving processing time (T4) A	0.00	2.38	8.91
10- Materials withdrawal request lead-time(T7) A	0.00	24.29	31.06
11- Construction time lost (C5) A	14.29	6.23	10.63
12- Total surplus (C11) A	0.10	1.14	1.65
Group A Average	29.56		
Group A Standard Deviation	44.24		
Group B Average	91.99		
Group B Standard Deviation	5.71		

8.3 Projects performance for the measures

Per measure performance report representing all projects score in that key measure and the average.

8.4 Projects overall ranking

Now comes the importance of the measures grouping, each group will have separate rank for each group and then we combine them in one ranking table which will represent the study model project.

Table 8.4Project Overall Ranking

Project No. [1]	Average [2]	Ranking A No.A [3]	Adjusting Factor [4]	Ranking Value A [5]=[5]*[4]	Average B [6]	Ranking No.B [7]	'Ranking Value [8]=[5]+[7]	Overall Ranking [9]
3	5.86	3	0.66	1.98	99.96	1	3.0	1
6	8.04	6	0.66	3.96	97.11	2	6.0	2
11	0.00	1	0.66	0.66	92.75	7	7.7	3
2	11.63	8	0.66	5.28	95.21	4	9.3	4
14	20.48	12	0.66	7.92	95.59	3	10.9	5
12	12.68	10	0.66	6.60	93.66	6	12.6	6
10	7.51	4	0.66	2.64	87.80	12	14.6	7
9	3.57	2	0.66	1.32	75.35	14	15.3	8
15	11.91	9	0.66	5.94	90.19	10	15.9	9
4	58.59	17	0.66	11.22	94.05	5	16.2	10
5	7.91	5	0.66	3.30	85.91	13	16.3	11
1	29.56	16	0.66	10.56	91.99	8	18.6	12
16	22.85	15	0.66	9.90	90.89	9	18.9	13
8	22.60	14	0.66	9.24	88.45	11	20.2	14
13	15.57	11	0.66	7.26	70.80	15	22.3	15
17	21.24	13	0.66	8.58	55.26	16	24.6	16
7	9.95	7	0.66	4.62	X			
	Average	15.88			87.81			
	Std. Dev.	13.54			11.51			
	Group A Weight		2.24					
	Group B Weight		1.58					
	The Difference(adjusting factor)		0.66					

Note: X represents a missing value

8.5 Projects summary results.

Out put of all key measures and how will the over all projects are doing in each one. This is the benchmarking model that the study is all about. Table 8.5 below.

Table 8.5 Projects Summary Result

S/n	Key Measures	Weight	No. of projects	**Average**	Std. Deviation	The highest	The lowest
1	Materials receipt problem (AC1)	33%	16	**97.03**	5.41	100	80
2	Warehouse inventory accuracy (AC3)	25%	10	**92.37**	7.03	100	80
3	Materials availability (AV1)	67%	15	**95.04**	4.64	100	86.33
4	Commodity vendor timeliness (T5)	33%	14	**70.35**	29.37	100	13.54
5	Jobsite rejection of tagged equipment (Q2)	33%	16	**4.28**	7.96	26.67	0
6	Procurement lead-time (T1)	25%	17	**32.34**	48.73	200	0
7	Bid/evaluate/commit lead-time (T2)	25%	16	**21.58**	25.52	100	0
8	PO to materials receipt duration (T3)	25%	17	**23.00**	24.37	200	0
9	Materials receiving processing time (T4)	33%	14	**2.38**	8.91 -	33.33	0
10	Materials withdrawal request lead-time (T7)	25%	14	**24.29**	31.06	100	0
11	Construction time lost (C5)	33%	10	**6.23**	10.63	33.33	0
12	Total surplus (C11)	25%	13	**1.14**	1.65	5	0

9.0 Observations

While using Plemmons model, some observations were made:

- Group B measures were easily calculated and accurately retrieved due to the nature of the measures and the availability of computers for the managers.
- For some measures of group A, the case was different, for example the construction time lost may not consider time lost unless the master schedule is effected. The field staff is instructed to do other jobs instead of waiting for material or such thing and this will not reflect the same target that we are looking for.
- For PO to material receipt duration, bid/evaluate commit, material withdrawal lad time and procurement lead time, they are difficult to calculate and done by estimation of the managers.

10.0 Conclusions

- There is a sound and effective material management system in those projects under study with an averages of 15.88% for group A measures and 87.8% for group B measures.
- For availability measure, the average was 95%, which is a good result.
- For the accuracy measures, the averages are 97% and 92%, which is another good achievement for the industrial projects.
- For quality measures, the average for jobsite rejection of tagged equipment is 4.28%, which is quite good.
- For the cost measures, the averages are 6.23% and 1.14% which is also an acceptable achievement.
- For the timeliness, the averages are 32.36%, 51.58%, 23%, 2.38%, 70.35%, and 24.29% which are areas for improvement.