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Impact of ERP Systems Implementation on Performance of Construction Material Management for Companies in Terms of Time and Cost

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Abstract-*Material management plays an important role in construction project management as it derives a major part of the cost and time of the project. Nowadays, ERP systems are rampantly used for various functions in Construction project management. The study aims to assess the efficacy and potency of ERP systems implementation for material management and analysis of cost versus benefit for the same. In this cross-sectional observational study, the researcher has derived data from six construction firms out of which three firms are not using ERP systems (Company A, B, and C) and three companies are using ERP systems (Company D, E, and F). data was collected from interviews of project managers and senior purchase executives. Collected data was verified with site engineers. By the analysis of data, it was observed that bottlenecks of management such as time and cost overrun, an emergency of unavailability of material, shortages, and theft of material and rework for each company, which were more with companies not implementing ERP systems in comparison to companies using ERP systems. The researcher analysed fixed costs and project overrun costs. It was also observed that in the long run, successful implementation of ERP systems decreases the time and cost that the companies are incurring for material management. At last, the researcher concluded that though ERP system implementation is expensive in the long run, it proves to be cost and time effective for material management in a construction firm.*

Index Terms— *ERP systems, construction Material management, Time management, Cost management.*

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I. INTRODUCTION

Construction project management is one of the major industries in the world. Nowadays, construction firms are in dire need to increase their performance in terms of efficient project and material management. ERP (enterprise resource planning) is one of the information and communication technology tools which provides an integrated improvement in a different department of construction firms such as material management, human resource, administration, planning, and scheduling the budget.

The first enterprise resource planning system was created decades ago to suffice the needs of the production industry and at that time it was called material resource planning (MRP) (Shi & Halpin, 2003). Construction firms use various project management programs like ERP (enterprise resource planning), PM-ASPs (project management application service provider), WPMS (web-based project management systems), etc. (Arnold & Javernick-Will, 2013). Implementation of ERP in the construction projects has its challenges which are different from manufacturing and other service sectors.

ERP provides better communication, improve responsiveness with customers, strengthen material and information supply chain partnership, and enhance organizational flexibility and decrease project completion duration (Çınar & Ozorhon, 2018). Though the above-mentioned benefits of implementing ERP systems in a construction firm, one of the major challenges is the initial cost of the system which includes software as well as training cost of personnel.

The hypothesis of the study was the ERP system is costly but it is beneficial. So, the cost versus benefit analysis should be done to assess the full range of strategic and tactical implementation(Vaughan, Leming, Liu, & Jaselskis, 2013). It was observed that in the majority of construction projects, more than 55% of the money is spent in material management on the construction site. At a level of material management, ERP enables a firm to make accurate management material in such a way that it is available at the right time, in the right quantity, and at the right place(Patare & Minde, 2016).

A. Objective

- To observe and understand ongoing practice for material procurement, warehousing, and dispatching at a site (for A-class materials only) along with time and cost associated with it.

- To find the bottlenecks in management of the materials that the companies are facing (whether they are using an ERP system or not).
- To study time and cost savings that can be achieved by the implementation of ERP systems.

II. METHODOLOGY

The research is based on a qualitative approach. So, to achieve the objectives, the research work is divided into a few phases namely literature review, data collection, and data analysis. Further bifurcation of the phases is shown in the figure below.

The main stages of the thesis methodology are Literature review, interviews from case study companies and secondary data collection. In interviews, data such Construction material procurement processes, Construction material handling processes on site (warehouse management), good receipt notes, material indents and purchase orders were studied. After data collection, data analysis has been done for which the following aspects were considered:

1. Process mapping of the material management.
2. Identifying bottlenecks in material management processes.
3. Statistical analysis of time and cost overrun of projects and cumulative manhours spent in material management.
4. Percentage cost calculation.
5. Calculation of fixed cost due to time overrun.

A. Primary Data Collection

1) Interviews

Primary data has been collected by the interviews conducted in all of the companies taken as case studies. Questions of the interview were formed such that material procurement strategies of the company can be known. Interviews play a vital role in obtaining information about a company's material procurement process. The company's existing knowledge about the ERP system can also be understood by the interview. Work done by (Ahmed, Ahmad, Azhar, & Mallikarjuna, 2003; Chaudhari & Jain, 2019; Çınar & Ozorhon, 2018; Pagar, Devalkar, & Aher, 2015; Vaughan et al., 2013) were found to help in developing the interview questions

The data were cross-verified by asking the same questions informally to the site engineers of the project on four to five days later of interviewing with the project manager and senior purchase executive. And it was observed that the data collected was accurate and without any mistakes.

B. Secondary Data Collection

To develop further clarity in the concept, secondary data from the case study firms and their vendors were required such as purchase indents, purchase order, goods receipt notes, and pricing details of the materials. It was also required to understand that how the material procurement process of the firms works at the time of rush orders, unavailability of materials at the time of construction due to lack of raw materials or transportation services, or sudden change in the price of the material.

III. DATA ANALYSIS-1

A. Cost-Benefit Analysis

The implementation cost of ERP systems has to be compared with the cost of personnel employed at the site for material management by the amount of time spent by the personnel and cost incurred to the company for the material management by employing the personnel and equipment (Vaughan et al., 2013). The fixed cost that the companies are incurring to manage their construction materials (here construction material management includes procuring, warehousing, and dispatching) has been compared.

B. Process Mapping of the Material Management

A process map of activities and the personnel associated with it along with the time taken to perform the activity has to be calculated so that cumulative manhours spent daily by the company on a project can be obtained. It has to be done to assess the variation in manhours that are to be spent by the company to manage the material with or without the implementation of ERP systems and the results have to be compared. Also, the overall fixed cost spent by each company for material management has been assessed in detail.

C. Bottlenecks in the Material Management Process

A matrix has been formulated to assess where the case study companies are facing problems in terms of managing materials. Detail assessment of bottlenecks in material management with or without ERP systems has been carried out.

D. Statistical Analysis of Time and Cost Overrun of Projects and Cumulative Manhours Spent in Material Management

For time and cost overrun, the researcher applies a chi-square test for assessing the significance of time and cost overrun. For these, simple tools such as Microsoft excel has to be used.

E. Percentage Cost Calculation

A fixed amount of cost that the companies are incurring to manage the materials daily has been calculated so that the comparison of percentage cost can be done which are using ERP systems and which are not using the ERP systems. (Ahmed et al., 2003) have shown the benefit of ERP for overall project management in a time frame.

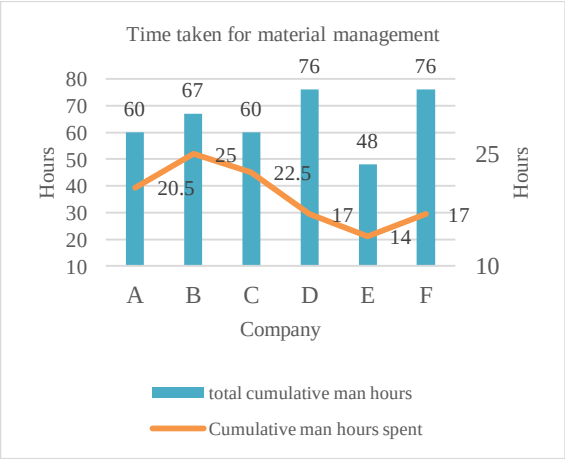
F. Calculation of Fixed Cost Incurred Due to Time Overrun

When the project overruns the time, there are some fixed expenditures that the company has to bear to complete the project. Such cost is significantly higher than that of the implementation cost of the ERP systems. (Patare & Minde, 2016) shown that ERP systems are advantageous and it can have advantages of decreasing manual work and time and cost overrun can be prevented.

IV. DATA ANALYSIS-1

A. Process Mapping of Material Management

Based on data collected, first of all, the process map was formed to calculate the time in terms of man-hours spent daily for material management. a process map for every case study was prepared and shown in the graph.



Comparative graph showing time involved in material management by each company

It can be observed in the graphical figure 5.7 that the companies implementing ERP systems have to invest less cumulative man-hours as compared to the companies not implementing ERP systems.

B. Matrix of Bottlenecks in Material Management

Based on data collected, a matrix was formed as shown in the table below where the bottlenecks observed in the material management were mapped and it was seen that the companies using ERP systems (Company D, E & F) are having advantages over the companies not using the ERP systems (Company A, B & C).

Table: Bottlenecks found in the material management process of Company A, B and C

Sr. No.	**Bottlenecks of management observed**	**weightage**	**Company A**		**Company B**		**Company C**	
			Yes	**No**	**Yes**	**No**	**Yes**	**No**
1	Time overrun	1						
2	cost overrun	1						
3	The emergency of material unavailability	1						
4	shortages or theft of materials	1						
5	Rework	1						
Total		5	0.40		0.4		0.4	
Ongoing projects of the company			5		4		4	
Probability of projects of a company becoming time and cost overrun			0.60		0.60		0.60	

Sr. No.	Bottlenecks of management observed	weightage	Company A		Company B		Company C	
			Yes	No	Yes	No	Yes	No
Number of ongoing projects that are time and cost overrun			3		3		3	

Table above shows the bottlenecks in material management observed in companies A, B, and C. The rework was observed in Company B and C due to improper workmanship. There were instances observed in company A where the work has to be stopped and the labor force has to be engaged in works other than the targeted works because of a shortage of material.

Table Bottlenecks found in the material management process of Company D, E and F

Sr. No.	Bottlenecks of management observed	weightage	Company D		Company E		Company F	
			Yes	No	Yes	No	Yes	No
1	Time overrun	1						
2	cost overrun	1						
3	The emergency of material unavailability	1						
4	shortages or theft of materials	1						
5	Rework	1						
Total		5	0.8		1		0.8	
Ongoing projects of the company			17		7		26	
Probability of projects of a company becoming time and cost overrun			0.20		0.00		0.20	
Number of ongoing projects that are time and cost overrun			4		0		6	

Table above shows the bottlenecks in material management observed in companies D, E, and F. there were no major drawbacks like time or cost overrun unavailability of materials and shortage, or theft of materials. But rework was there in company D and F because of the change of designs from the client. As the on-site stock of material was continuously managed by the ERP systems, the shortage or theft of materials was not observed in companies D, E, and F.

Table Comparision of the total number of projects and projects that are time or/and cost overrun

Company	Ongoing projects of the company	Number of ongoing projects that are time and cost overrun
A	5	3
B	4	3
C	4	3
D	17	4
E	7	0
F	26	6

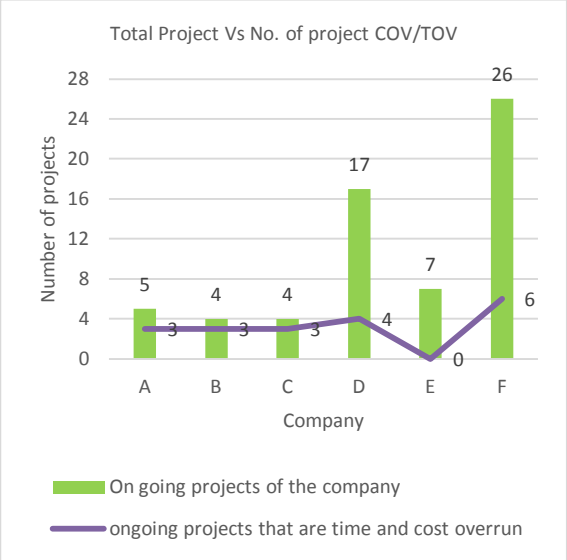


Figure Graphical representation of the total number of projects and projects that are time or/and cost overrun
From the above graphical presentation figure above, it is clear that the companies using ERP systems are having less cost and/or time overruns in the projects as compared to the companies that are not using ERP systems. Which further means that the direct and indirect cost that company have to spent on the project when the project becomes time and cost overrun can be mitigated.

C. Percentage Cost Calculation

The cost of spent by the companies daily was also calculated and it was observed that the implementation of ERP systems can decrease the material management cost. It was observed that the cost of ERP systems implementation is high but it reduces the time that the person needs to spend on material management daily and they were utilizing the time saved in other equally crucial activities. Also, it was concluded by the project managers interviewed that the ERP systems are used although having high implementation costs because ERP systems take care of data such as on-site stock, surplus material available, wastage factors, and done till, generation of a purchase order and material indents, etc. This enables the person to work on the other equally or more crucial works as all the data related to the material management is available on screen in a single unified cloud-based integrated system. The personnel were hesitant in sharing sensitive data such as their salary, so they shared the tentative salary of the designation with the same experience and qualification to calculate the cost incurred by the company on them to manage the materials. The Percentage cost was derived to quantify the ratio of the actual cost of material management to the total cost per day.

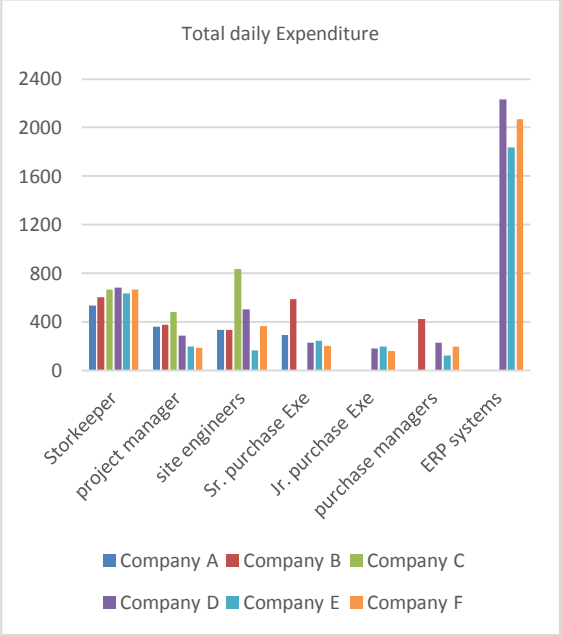


Figure Daily expenditure of all the companies

It was observed the cost of implementation of ERP systems in companies D, E, and F is approximately 45 to 50 percent of the total cost of material management per day. (Vaughan et al., 2013) suggested in their study that, ERP systems are expensive but in the long run, implementation of ERP systems has saved time, material, and labor costs.

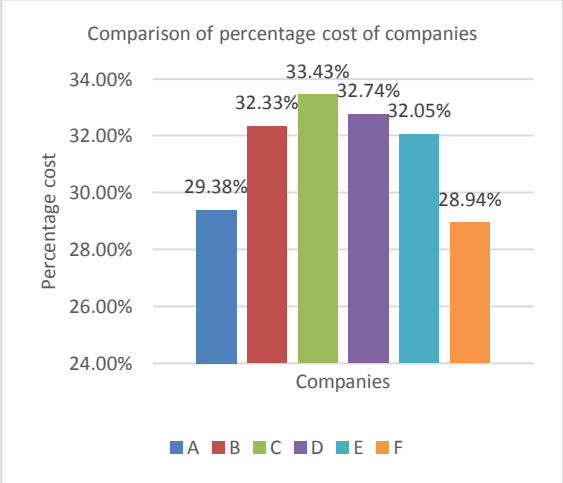


Figure Graphical representation of the percentage cost incurred to the companies

In table 5-11 is concluded, it can be observed that there is a very minor difference in percentage cost that the companies are spending to manage the materials irrespective of the fact that whether they are implementing the ERP system or not, but it was observed in the interviews and data processing that the companies not using ERP systems on the assumption that the ERP systems are costly and very difficult to implement, are having more probability of their projects to become time and cost overrun as compared to the companies that have implemented ERP systems.

D. Calculation of Cost Incurred Due to Time Overrun

Also, the calculation was made to assess that how much amount of fixed cost is incurred to the company to complete the project. The time by which the projects were time overrun (in months) was multiplied by the cost that the companies are spending on monitoring and execution of projects. It was observed that the companies not using ERP systems are spending money in terms of fixed costs that they incur by the delay in the timely completion of projects. The contractor firms not implementing ERP systems struggle with the timely completion of projects due to the factors mentioned above. The client firms are also having problems such as

theft, shortfall of material, emergencies of unavailability of materials, and change in scope of work. At the same time, the companies using ERP systems were not having time and cost overrun in projects. The contractor firms using ERP systems might have a chance of project getting time overrun because of change in scope of work by the client for which, the time will be given to the contractor companies to execute the changes and complete it. The client firm implementing ERP systems predefine the scope of work clearly and do not change it unless and until it is very crucial for the project.

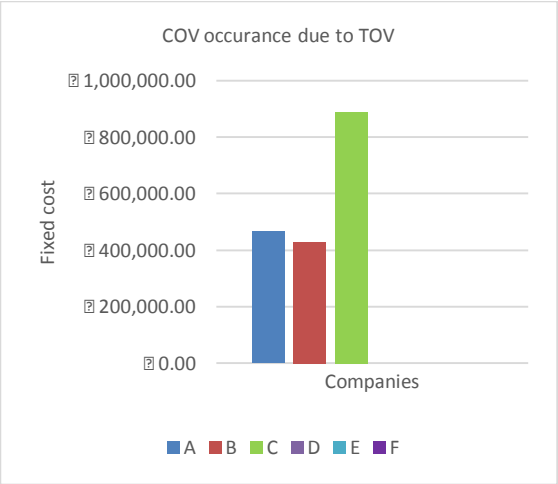


Figure Cost overruns that companies are incurring due to time overrun

Figure above show the extra expenditure of companies A, B, and C because of delays in the timely completion of the project. The problems of material management which cannot be quantified are also there such as material unavailability, shortage of material, and reworks. Also, the figures calculated above are the fixed cost that incurs to the companies to keep the project works ongoing. The dynamic cost such as the cost at which materials are bought at that time, rush orders are placed, cost of time lost in managing mismanagements should be considered as a hidden cost.

The cost incurred to companies in terms of fixed cost that they need to pay to the person when the project overruns were higher than that to the cost of implementation of the ERP systems. Also, the cost incurred to companies not implementing ERP systems has to deal with situations such as material unavailability, shortage of material or rework and there affects both direct and indirect cost of the company by which the company have to suffer losses or is unable to achieve the targeted growth in terms of money. Whereas, the companies implementing the ERP systems do not have to deal with such situations because the successful implementation of ERP systems enables an organization with advantages of proper planning and tracking of materials, real-time decision making, control and monitoring of the process, material usage and wastage.

E. Hypothesis Testing

To assess the significance of results, a Chi-square test was performed. For applying the Chi-square test researcher has grouped the companies in the following manner where group 1 is a group of companies not using ERP systems (Company A, B, and C) and group 2 are the companies that use ERP systems (Company D, E, and F).

1) Statistical analysis of cumulative Man-hours spent

When the Chi-square test was applied to the results obtained of cumulative man-hours spent by the company on material management of a project in group 1 and group 2 companies, it was observed that Group 1 companies have to invest significantly more cumulative man-hours than Group 2 companies. P-value was observed to be .00798 which is much less than .01. so, we accept the hypothesis that Companies using ERP systems are investing less time in material management as compared to Companies not using ERP systems.

Table Chi-Square test performed on Cumulative man-hours spent on material management of a project

	Cumulative man-hours spent	Cumulative man-hours not spent	Total man-hours spent
Group 1	68	119	187
Group 2	48	152	200
	116	271	387

Table Result statistics of Chi-Square test performed on Cumulative man-hours spent on material management of a project

Chi-square value theoretical	Df = 1
0.05	3.84
0.01	6.635
Chi-square value observed	7.037975
P-value	0.00798

Here, the null hypothesis is the time to be invested by the company for material management for a project is independent of the implementation of the ERP systems. And the alternative hypothesis is the time to be invested by the company for material management for a project is dependent on the implementation of the ERP systems. As the chi-square value is 7.037975 which is much higher than 6.635 (that is chi-square value of the degree of freedom 1 at the level of significance .01) and P-value is .00798 is less than .01, researcher accepts the alternate hypothesis and rejects the null hypothesis.

2) Statistical Analysis of Time and Cost Overruns of Projects

When the Chi-square test was applied to the results obtained of units of projects that are time and cost overrun of group 1 and group 2 companies, it was observed that Group 1 companies have time and cost overrun significantly higher than Group 2 companies. P-value was observed to be .0005699 which is much less than .001. so, the researcher accepts the hypothesis that Companies using ERP systems are less likely to have time overrun (TOV) or cost overrun (COV) in projects.

Table Chi-Square test performed on projects that are COV/TOV

Groups	No. of projects COV/TOV	No. of projects not COV/TOV	Total Projects
Group 1 (Company A, B, and C)	9	4	13
Group 2 (Company D, E, and F)	10	40	50
Total	19	44	63

Table Result statistics of Chi-Square test performed on projects that are COV/TOV

Chi-square value theoretical	Df = 1
0.05	3.84
0.01	6.635
0.001	10.82
Chi-square value observed	11.87191756
p-value	0.000569867

Here, the null hypothesis is the projects becoming time or cost overrun is independent of the implementation of the ERP systems. And the alternative hypothesis is the projects becoming time or cost overrun are dependent on the implementation of the ERP systems. As the chi-square value is 11.8719 which is much higher than 10.82 (that is chi-square value of the degree of freedom 1 at the level of significance .001) and P-value is .0005698 is less than .001, researcher accepts the alternate hypothesis and rejects the null hypothesis.

V. CONCLUSION

In a nutshell, ERP system implementation may look expensive but it is cost-effective in terms of money and time in the long run at each level of material management. It has advantageous to implement ERP systems for material management. The researcher recommends that ERP system implementation in material management for better planning and execution of construction projects along with timely completion of projects and avoiding projects becoming time and cost overrun.

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