RESEARCH METHODOLOGY FOR MATERIAL OPTIMIZATION IN CONSTRUCTION PROJECTS

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Abstract

Construction industry deserves the second largest one in India. The infrastructure growth of a country depends on the development of construction industry since it teems with ample employment potential. Implementation of infrastructure projects are usually failing in each stage and ultimately failure occur, which leads to cost and time overrun. The innovation of new technology in the construction field is not being adopted in project implementation. So the growth of construction industry is slow. The real problem is construction become difficult since it will not complete with in the budget cost and time and finally leads to project failure as end result. There are many reasons for project failure and some of them are project specific. The literature survey conducted gives a conclusion that more than 50 percent of the construction cost is shared by materials. Hence material has a dominating role in construction. If the material has controlled dynamically the total project cost would be reduced. In this regard, a research methodology has developed to control the material procurement and carrying cost. The methodology adopted has been validated by a computer program and same is found correct and useful for analysis and controlling any type of projects.

Keywords- Construction – materials management- Optimum material-Research Methodology

1.INTRODUCTION

The construction industry is the largest industry of India, first being agriculture. It makes a significant contribution to the national economy and provides employment potential to large number of people. The use of various new innovations and deployment of project management strategies has made it possible to undertake projects of mega scale. In its path of advancement, and survival the industry has to overcome a number of challenges. Recent experiences of several new mega-projects are clear indicators that the industry is poised for a bright future. It is the second homecoming of the civil engineering profession to the forefront amongst all professions in the country. The growth of construction Industry is rapid in recent years, so the failure rate is also more. Cost and time overrun is the common issue in construction Cost effective construction is the main target in the Industry. This

paper deals with an appropriate solution to control the cost and time overrun. A model is developed for optimize the material requirement for a project.

2. LITERATURE STUDY

Success of a project heavily depends on the ability to complete a project on scheduled time within the budget as per the required quality. Efficiency of a construction firm is to complete in time. Ibbs (2007) expressed his views that project delays are caused due to the direct and indirect cost. Delay of a project during its progress would suffer material loss, machinery idling including tools and plants and equipment. Love,(2000). explains that field overhead damages required proper estimation, even if it was less complicated than home offices overhead charges. Saka, and Mudi (2007) found that the Nigerian construction companies, and most of the contractors collected materials locally instead of collecting from suppliers to maintain long inventory. Modern methods like information and communication technology were not applied. As stated by Iyer (2006) Indian construction projects are facing time overrun, the reasons for which are being studied by researchers to suggest possible remedial measures. The important topics under research were in project management in the concept of project success Ashely et.al.(1987).

Martin (2004) claims that most of the research has been taken up in developed countries, and their applicability in developing countries such as India, is yet to be explored. The Indian construction Industry has gained far more importance in recent times because of the opening up of Indian Markets. The time overrun is the main cause of cost over run and it affects both clients and contractors. Chan and Kumaraswamy (1994) stated that in India the phenomenon was the same. Usually projects taken up in India would be completed at a later stage, or would remain incomplete, and in both cases the end result would be the same. The project would end up with time over run with some reasons. Anderson (1983) expressed that a questionnaire survey was the bridge between researchers, and respondents. The questionnaires were the vital elements which performed the actual interrogation.

Iyer (2003) states that Construction project slippages in India are mainly due to the following three sectors- Project planning and designing, Implementation and material

procurement and storage. For more than sixty years, efforts were being made to improve the technology in the construction industry. These efforts are bearing finets for the adoption of new technology. A country's economy depends on the growth of construction industry, since this is the second largest industry in India.

Sturges,(2000).expressed that several management techniques were available for use for implementing a project successfully. "Construction planners need to schedule and select appropriate resources, including crew sizes, materials, equipment and plant, to execute a construction project. These resources are essential for the successful completion of the project"

Ren (2008) explained that some of the researchers found that construction was delayed due to rapid growth of construction, tight construction schedule, involvement of International contractors, Unique architectural features, etc. on the basis of Dubai construction. However, these reasons cannot be generalized. In Dubai the economic growth is high. The demand of large scale and high quality projects are high. At present there is no universally accepted system in construction engineering field for the implementation of projects. Similarly the areas of procurement and carrying are still dominated by traditional and imperical methods. The usual practice in procurement and storage is to collect construction materials as per the estimation or anticipated requirement or seasonal availability or the order of requirement in construction projects. This system will not have any control over usage, storage, or matching with its procurement cost and storage cost. As a result the material cost will go up which will increase part of the project cost, resulting an increase in the total project cost and time.

"Material Procurement system and operational environments, the booming building and construction Industry, is facing many unique challenges which affect project progress". Factors such as rapid growth in construction, tight construction schedule, unique architectural features, the involvement of international contractors and consultants, multinational work forces, unique culture and religion, readily available investment, and mixed contracts, and conditions generate particular impacts on construction project progress Ren, Z (2008). Kumaraswamy,(1996) expressed his views that, project success was not based only on effective Project management. Project success is measured against the overall project objectives. Project success is also based on the primary objectives

namely time, cost and quality. It depends on the effectiveness in implementation. As per Donyavi, (2009) -"The materials cost on a project can represent anything from 30% to 70% of the cost of the work. Yet materials management has not received attention from researchers.

3. Background and Novelty

Most of the construction projects taken up for implementation are not completed in time. There is no specific system for implementation. They are suffering with cost and time overrun. At every stage of the project execution the projects are found to be affected slippages. The reasons are common to some extent and some are project specific. These project slippages will lead to project loss. Finally the end result will be cost and time overrun. Construction materials will play a dominating role in the project implementation since more than fifty percent of the total project cost will bear on the construction. This study is attempting to propose a method to control the procurement and carrying cost, So that the total project cost can be controlled up to certain extent.

4. Methodology & Stages of Research

The research is carried out in different stages, and the orientation is as detailed in this session. Research problem is derived from the literature review and the field study. The area of research is cost and time overrun in construction project implementation. There is no specific system in project implementation. Most of the projects end up with project loss due to various reasons, irrespective of the reasons the end result is the same. This study is aimed to identify the areas of project slippage and the important reasons which cause the project failure. To find a workable solution to control the material specifically in the procurement and carrying cost and thereby reducing the total project cost. Majority of the projects are implementing without cost effective. The relevance of this area becomes significant when project implementation has always time lag and cost over. There is no perfect solution for this situation. The researchers as well as the project promoters are trying to find an appropriate solution for this.

The field study analysis shows that there are 12 to 15 % of the projects are only planned properly, and 20 to 25% of the projects are somewhat planned. The remaining 60% of the projects are not planned and they will end up with project slippages ultimately leads to cost and time overrun. So the research problem is defined from this observation projects should be planned well before it is being implemented. The role of construction material in a project is significant and more than 50% of the project cost is governed by materials, so material procurement and carrying cost should be controlled for reducing the total project cost. A method is proposed for optimizing the material procurement cost.

4.1. Design of Questionnaire

The questionnaire has designed to extract the true information from the project promoters and their technical heads regarding the facts of the project and the reasons for slippages. A pre-testing regarding the validity and reliability of the questionnaire has checked by consulting with experts and analyzing with statistical tool and found its suitability to use for the survey. Two methods are used to carry out this study. The first method is the questionnaire survey and the second method is case study. The statistics of the questionnaires are shown in Table1.

Table.1 details of questionnaires used for survey.

Sl.no.	Particulars of questionnaires	
1	No. of questionnaires distributed	100
2	No. of questionnaires received	77
3	No. of questionnaires considered for analysis	72

The questionnaires were given to the respondents in person and after 15 days the same has collected back. The responses were analyzed in detail. The questions are prepared in consultation with experts and after a pre-test analysis. It is found all questions satisfies the requirement to be included in the format. The questionnaire format is prepared by containing part -A and Part-B which is not specifically mentioned. Part A contains 8

questions from the planning area and part-B contain 7 questions from the materials procurement area. There are different methods for the study, the first one is questionnaire survey and the second one is case study. The details of the case study project such as are of each floor, number of apartment, number of floors, are given in the following table No.2

Table 2 Case study project- details.

Sl.no	Particulars	Nor of units	Area per floor	Total area
1	Project -1, (14 floor)	8 units in each floor	1730sq.m/floor	24220sqm
2	Project-2, (9floor)	4units in each floor	825sqm/floor	7425sqm

The first and second projects were analyzed separately and the observations were given in detail. Both the projects are subjected to project slippage due to non-planned material procurement

4.2 Data Collection

The designed questionnaire has been pre-tested and its validity and reliability have been checked with statistic tool and discussed with experts in this area. As part of the survey hundred project promoters were identified and were given the questionnaire in person. After completing the format the questionnaires were received back in person. There are 77 formats were received back and out of 77 only 72 formats were completed in all respects for analysis. The field responses were analyzed by SPSS.

4.3 Data Analysis

Data Analysis- is done by statistic tool SPSS. The Confirmatory Factor Analysis, and Exploratory Factor Analysis, Content validity, Co-relation, Ccronbach's Alpha, factor, Reliability tests have been performed. The result obtained shows the questions satisfies the

requirements for the survey. The inference of the analysis is matching with the objective of the study.

5. Research Model

A new model has been proposed for procurement and carrying cost of materials with an objective to the total project cost control on the basis of the case study analysis. The new model is prepared from the project estimate and schedule of the project. The total material required for the work is calculated. Based on the schedule the monthly material requirement is also calculated. The unit cost of each material is worked out from the weekly cost collection data of prices from the open market or from the manufacturer. ABC analysis is conducted to find the cost controlling material

5.1 FLOW CHART FOR OPTIMIZATION OF MATERIALS

YES **NO**

Fig..2 Flowchart to optimize material

A new method is derived and proposed, for this loss. The method proposed is optimization of construction material consumption by just in time methodology. A flowchart and computer program is developed. Suggestions are also given to generalize this method to other projects as a general case, with suitable modifications. This cost controlling materials in the order of preference taken for resource allocation. This will result optimum quantity of requirement will be obtained. This quantity of material requirement for every month will be minimum. This will reduce the procurement and carrying cost to the minimum. This is the Economic Order Quantity. This quantity will be subjected to further check to know whether this quantity will be sensitive or not. Sensitivity analysis is conducted on this EOQ model. If not sensitive this quantity will be procured in each time. If sensitive the quantity will be considered for the exact EOQ. Thus the total cost on the procurement of material is controlled and thus the project cost is controlled to the optimum always. The model is shown in Fig.2

5.2 **Validation**

Validation of new model is done through a computer program. This is a three stage optimization program. The first stage is ABC analysis to find the controlling elements. The cost controlling materials are identified and those materials are taken for resource allocation. The Economic Order Quantity will be obtained after resource allocation. The third stage is

the sensitivity analysis on this EOQ model. If not sensitive the EOQ will be the solution, or there are two options either to stick on the EOQ or to re-iterate at a later stage.

6. Tools and Techniques

This session deals with the major tools and techniques used for the research. Scale refinement and validation- validity is the most critical evaluation and indicates the degree, what it supposed to measure. The major forms of validity are content validity, construct validity, and face validity

The EFA, CFA and Cronbach.s alpha scale reliability coefficient. Alpha to overcome the limitations of EFA analysis. CFA is used in stages of scale refinement and validity. Reliability depends on the degree of dependability, Consistency, and stability, of a scale. Internal consistency is estimated by using Cronbach's Alpha. An alpha value is above 0.7 is considered to be strong, and above 0.6 is considered to be significant. In the EFA test, the Kaiser Meyer – Oklin value were 0.656, 0.626, and 0.688 respectively in Technology, Material, and Success. This is supporting the factorability of co-relation matrix.

Confirmatory factor analysis- Structural equation modeling (SEM) was performed to test the fit between the research model and the data obtained. All values in this test are in the acceptable limit.

Content validity-.Systematic examination of the test to determine whether to cover a representative sample of behavior domain to be measured.

Face validity- to estimate whether the test appears to measure certain criterion. Face validity is very close to content validity.

Convergent validity- is one of the approaches to construct indication of strong convergent validity.

Uni-diamensionality analysis is a necessary condition for realibility analysis and construct validation. The comparative fit index value 0.9 or more indicates strong uni-diamensionality.

One sigma limit- The mean score greater than the upper limit is classified as excellent.

6.1 Structural equation modeling for finding the dominating factor

The main aim of the study is to investigate the extent to which the Technology Acceptance and material management explains the success of the of the Multi-Story Construction project

The research hypothesis is

H1: the success of the Multi-Story Construction project significantly influenced by the adoption of project planning and material management.

In this chapter we use the factor analysis method both exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) approach, to identify he dominating factor of the success of the Multi-Story Construction project. The 15-item scale was designed to measure problems and success of Multi-Story Construction project. The subjects were asked to respond using a five-point scale (strongly agree, agree, neutral, disagree, and strongly disagree). The score 1 represented the option “strongly disagree” while score 5 on the scale represented the category “strongly agree.

6.3 Scale refinement and validation

Validity is the most critical evaluation and indicates the degree to which instrument measures, what it is supposed to measure. Validity can also be considered as utility, in other words validity the extent to which, differences found with a measuring instrument reflects the true differences among these being tested. Empirically validated scales can be used directly in the other studies in the field for different programs. A scale for a construct is useful for application by different researchers in different studies if and only if , it is

statistically reliable and valid. The major forms of validity are content validity, construct validity and face validity

9.3 Different approaches to scale refinement and validation

Exploratory factor analysis (EFA)

The major approaches used by the researchers for scale validation and refinement are EFA and CFA. EFA is a conventional approach to scale refinement consists of following steps a) identifying the items relevant to the particular domain from literature b) Designing a survey instrument to measure these items c) Conducting a field survey d) performing EFA (often with varimax rotation) on the item responses to identify the major factors according to the item factor loading and e) Refining the scales using cronbach's scale reliability coefficient alpha. The major disadvantage of pure exploratory factor analysis lies in the difficulty involved in interpreting the factors. The EFA is done using SPSS-17.

To overcome the inherent limitations of EFA, the scale refinement and validation using the alternative approach has been pursued. This approach uses CFA in various stages of scale refinement and validation. CFA is similar to EFA except that the hypothesis that form constraints are embedded in the analysis .Research in social sciences and marketing disciplines has increasingly preferred this approach due to its conceptual strength.

Confirmatory factor analysis (CFA)

CFA is a type of structural equation modeling (SEM), which deals specifically with measurement models, that is relationship between observed measures or indicators (eg. Test items , test scores etc) and latent variables or factors. A fundamental feature of CFA is its hypothesis –driven nature. in CFA, the researcher specifies the number of factors and the pattern of indicator of indicator factor loading in advance, thus the researcher must have a firm a prior sense, based on past evidence and theory of the factors that exist in the data. CFA is used for four major purposes 1) psychometric evaluation of measures

(questionnaires) 2) construct validation 3) testing method effects and 4) testing measurement in variance (across groups or population). In social research works, researchers need to have measures with good reliability and validity that are appropriate for use across diverse populations. Development of psychometrically sound measures is an expensive and time consuming process, and CFA be one step in the development of process, because researchers often do not have the time or resources to develop a new measure, they may need to use existing measures. in addition to savings in time and costs, using existing measures also helps to make research findings comparable across studies when the same measure is used in more than one study. However, when using existing measure, it is important to examine whether the measure is appropriate for the population included in the current study. in these circumstances, CFA can be used to examine whether the original structure of the measure works well in the new population

Reliability

An assessment of the statistical reliability is necessary before any further validation analysis. Reliability refers to degree of dependability, consistency or stability of a scale. Unreliable scale will lack consistency of measuring the same item to the extent. There are four good methods of measuring reliability. Test-retest technique, multiple forms, inter-rater, Split half reliability, now a days , particularly for field survey internal consistency is estimated by using Cronbach's alpha. An alpha value of 0.70 or above is considered to be criterion for demonstrating strong internal consistency, alpha value of 0.60 or above is considered to be significant.

6.5 FINDINGS

The statistical analysis comprised two stages. The first stage examined the descriptive statistics of the measurement items and assessed the reliability and validity of the measure used in this study. The second stage tested the proposed research model and this involved assessing the contributions and significance of the manifest variables path coefficients.

7. Concept of Inventory Model Suggested

The concept is that procurement and carrying costs are controlled, the total project cost can be reduced to certain extent. The material contribution in a project is more than half of its total cost. The cost bearing few items are dominating over the materials. So control is to be effected on this few materials. Optimize the A- category materials in their procurement, consumption to the project, and storage, and order cost by dynamic control. The new method suggested is ideal for controlling the A- category materials. The proposed method is explained in Fig.3

7.1. METHOD PROPOSED

Literature study revealed the fact that material cost alone contribute about 60% (Kumaraswamy 2000) of the project cost. There is no effective method to control the procurement and carrying cost of a project. A simple method is suggested in this study. The method is applicable for all types of construction projects and can be used at any stage. The flow chart of the proposed method is shown in Fig.2

Fig.2 Model Proposed for optimization of materials.

The input is the estimate of the project in which special skills are not required. The project estimate changes as per the design are to be incorporated to the input of the program. The method is based on the principle that few materials cost about 70% of the project value, and those few materials are alone controlling throughout the project. The procurement and storage cost is optimized. The procured materials are just for immediate use and not intended for long term storage. The software like M S Project, Primavera, construction software and the like have limitations that they require special skills to train others or to

operate. Another drawback is that most of the time skilled people are not readily available to operate and those soft wares are expensive also. The new method proposed is simple, use-of friendly, less expensive, and with good results.

The method is structured to incorporate the Design, drawing, estimate, schedule of work and work brake down structure (WBS). The total material requirement to complete the project can be calculated. The monthly material requirement and unit cost of each material are also provided. The unit cost is collected either from the source of origin or from open market. A sequential operation of ABC analysis, Resource allocation, by resource leveling and smoothing is done to optimize the material requirement. Economic Order Quantity is calculated after resource allocation. Finally sensitivity analysis is conducted on this EOQ model to refine the order quantity. This is done by what-if analysis. This analysis is to check the change in total project cost if slight changes upward or downward of 5 to 10% made in the order quantity. If the result is not so significant then the order quantity may have flexibility for the nearest lot size or in other wise we may have to stick on to the Economic Order Quantity. The result obtained will be the optimum solution for ordering material.

Sensitivity of a material is due to different reasons either it may be due to its availability in the market is remote, or when its production is under the demand, or its process are highly fluctuating due to non-availability of raw materials or conveying system. The material requirement can be made optimum if all the above process is done in the sequential order. The process will be continues operation before each procurement is made. Thus the procurement and carrying cost can be controlled.

7.2 ALGORITHMS FOR THE MODEL

The algorithm for ABC analysis, Resource allocation and Sensitivity analysis is shown in appendix - 1.A computer program is also developed to validate this model and analysis of projects.

8. Future Scope and Limitations

This research study will have future scope if incorporating all types of projects for a better result since it is not included in the current research work. The study may be extended incorporating the urban and rural area constructions the result will be generalized one, which could not included in this study. The present study is conducted only one ie. Material, but if the four resources are included the construction promoters will be more benefitted. The study result will be more refined one if case study is conducted with representative samples from allover the states from India.

Like all the major researches this research also has certain limitations which ate illustrated in this section. In this study is considered high rise building projects in Kerala. If this is extended all types of projects the results will be more general. The second limitation is that construction material procurement and carrying are considered, instead of that all the four resources like Human resources, Machine power, Money flow, and Material resources are considered we get some more economic result. The third limitation is that all projects are concentrated in Cochin and in Kerala, but projects from other states are included the result will be more reliable. The fourth limitation .is that the apartment projects are normally located in urban areas and we do not know what is the trend in construction of rural areas, so if some projects are included from the rural areas the results may vary slightly. The future scope are (i) If a study is conducted incorporating all types of projects better results will be

obtained. (ii) Construction in Urban area is different from rural area so incorporating rural area construction a varying result will be obtained. (iii) The study is continued with all the four resources the result will be different. and (iv) A wider area is selected for this study we will get some more refined result.

The impact of this research study is mainly to stream line the project implementations. The schedule of the project can be maintained on close and stringent monitoring and the project can be completed with in the time stipulated period. The benefit of the project can be enjoyed at the earliest. The most important aspect is that the project can be completed with cost effective. The revenue from the project will start yield soon after completion of the project. The is an important advantage of the project implementation.

9. Conclusion

From the questionnaire survey conducted and the case study research a snap shot of the project projects failures can be witnessed. As a rule, 12 to 15 percent projects are well scheduled. However, about 20 to 25 percent projects are somewhat planned with the available resources. These projects may complete in time but always there is an uncertainty to its completion time and cost. About 50 to 60 percent projects are not planned. Those projects, the chances are to fail during implementation. From the literature study it is clear that more than 50 percent of the cost is shared by materials. In most of the projects there is material management. Material itself is making loss to the project. A control over the procurement and carrying of materials will definitely reduce the total project cost. From the literature there is no such system so far developed. Hence a model has been proposed to optimize the material purchase and storage. The model is also competent to adopt new unit cost which is arrived by obtaining the average value of materials from the open market. This

method explained in this study is the most optimum cost in which a project can be completed.

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