Optimization of Resources in Civil Engineering Projects
(Building and Highway projects)

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ABSTRACT
Construction is a high-risk activity, which must be managed from procurement, through the design process and to the end of the construction stage. Thousands of tasks must be precisely controlled if a project is to run smoothly, on time and in budget. The completion of a construction project requires the judicious scheduling and allocation of available resources; Manpower, equipment and materials are important project resources that require close management attention. The project is carried out to have a comprehensive study about resource management and its optimization. The study is carried out based on the data collected through questionnaire survey. Resource leveling and resource leveling is carried out by checking over allocation of resources, thereby keeping the project “on time and under budget”.

Keywords---- Constructions, Productivity, Questionnaire

I. INTRODUCTION
1.1 GENERAL
Construction projects are more complex than ever before. Thousands of tasks must be precisely controlled if a project is to run smoothly, on time and in budget. The completion of a construction project requires the judicious scheduling and allocation of available resources, Manpower, equipment and materials are important project resources that require close management attention. The supply and availability of these resources can seldom be taken for granted because of seasonal shortages, labour disputes, equipment breakdown, competing demands, delayed deliveries, and host of associated uncertainties. Nevertheless, if time schedules and cost budget are to be met the work must be supply with necessary workers, equipment and materials when and as they are needed on the job site.

The basic objective of resource planning and resource allocation is to supply and support the fields operation so that established time objective can be met and costs can be kept within the construction budget. It is the responsibility of the project manager to identify and schedule future job needs, so that most efficient employment made of the resource available. The project manager must determine long-range resource requirement for general planning and short term resource for detailed planning. The project manager must establish requirement on site and its quantity. The project plan and schedule may have to be modified to accommodate or work around supply problems.

The term resource allocation is used in the case where required resources are assigned such that the available resources are not exceeded. Resource levelling is an attempt to project activities in a systematic manner that will improve productivity and efficiency.

1.2 RESOURCE OPTIMIZATION
Resource optimization is the set of processes and methods to match the available resources (human, machinery, financial) with the needs of the organization in order to achieve established goals. Optimization consists in achieving desired results within a set timeframe and budget with minimum usage of the resources themselves.

The need to optimize resources is particularly evident when the organization’s demands tend to saturate and/or exceed the resources currently available. Effective construction planning and scheduling is the first and crucial step towards a successful and efficient construction project. All succeeding tasks, or activities, should follow the planning stage. The planning and scheduling process is arduous, complex and time-consuming. Even experienced construction planners find it impossible to construct a comprehensive and faultless master construction plan, and during construction operations make reviews and updates as necessary. These reviews and updates bring waste and increase the project duration and cost.

In highway projects, the same resource is often used for different activities and the productivity of that resource being different for different activities, it becomes inevitable to know the correct norms for correct estimation, planning and monitoring.

1.3 OBJECTIVE
• To manage the resource usage in construction projects by resource loading and resource
leveling by checking over allocation of resources, thereby keeping the project “on-time and under budget”.

- Identify the float times and check the possibilities to shift the non-critical activity to prevent any delay in project completion date.
- Directly measuring and minimizing undesirable resource fluctuations to maximize resource utilization efficiency.

II. LITERATURE REVIEW

Khaled El-Rayes, M.ASCE; and Dho Heon Jun (2009), studied with Optimizing Resource Leveling in Construction Projects. Construction schedules, generated by network scheduling techniques, often cause undesirable resource fluctuations that are impractical, inefficient, and costly to implement on construction sites.

Dho Heon Jun, Ph.D. and Khaled El-Rayes, M.ASCE (2011), studied resource optimization. Construction scheduling techniques often generate schedules that cause undesirable resource fluctuations that are inefficient and costly to implement on site. This paper presents the development of a novel multi-objective optimization model that is capable of measuring and minimizing these undesirable resource fluctuations to maximize resource utilization efficiency and minimize project duration while complying with all precedence relationships and resource availability constraints.

Jaeho Son1 and Kris G. Mattila2 (2004), studied binary resource leveling model: activity splitting allowed. The resource leveling problem is common and has been studied numerous times. In these studies and the resulting solutions, there exists a common element, which is once an activity is started, it cannot be stopped and restarted again. That is, it cannot be split. In many instances in actual construction, there exist activities that can be stopped and restarted.

Ming Lu, M.ASCE; and Hoi-Ching Lam (2008), studied Critical Path Scheduling under Resource Calendar Constraints. Construction scheduling techniques often generate schedules that cause undesirable resource fluctuations that are inefficient and costly to implement on site. Resource calendars specify nonworking days of driving resources involved in construction projects. As part of the resource availability constraints in critical path method _CPM_ scheduling, resource calendars may postpone activity start time, extend activity duration, and hence prolong the total project duration.

2.1 SUMMARY OF LITERATURE REVIEW

From the literature study conducted it is found that none of available resource utilization optimization models have focused on (1) directly measuring and minimizing undesirable resource fluctuation to maximize resource utilization efficiency; (2) generating optimal tradeoff between resource utilization efficiency and project time to support a construction planner in selecting the best solution that satisfies the special requirements of project being considered; (3) considering optimization of multiple shifts schedules and resource utilization for accelerating a project using time-cost trade-off analysis.

In recent years, project management software systems like MS Project, Primavera etc. have been improving continuously and recent versions have exhibited better interfaces, integrated planning and control features, and Internet capabilities. Yet, basic project management functions such as resource allocation, resource leveling, and time cost trade-off analysis have been the least improved. Still, to some software systems provide merely powerful presentation capabilities and real savings can be achieved only by putting a hammer to a nail. It is hoped that practical implementations of new approaches such as genetic algorithms justify the effort spent in proper planning and scheduling as keys to effective project management and ultimately to actual savings in project time and cost.

III. METHODOLOGY

3.1 GENERAL

The methodology chapter discusses and explains the project design which was used to be analyzed. Also, the sampling size and techniques, as well as the data collection procedure which includes the questionnaire design and administering the questionnaire, have been described in figure 3.1

Fig 3.1 methodology of work

1. Collection of literature
2. Questionnaire preparation
3. Questionnaire survey
4. Analysis of data obtained from questionnaire
5. Identify datas which is most affected
6. Case study
7. Scheduling of activities by resource loading and resource levelling
8. Concludes by stating the need and scope of resource management
IV. CONSTRUCTION RESOURCES MANAGEMENT

4.1 MATERIALS MANAGEMENT

Construction materials constitute a major cost component in any construction project. The total cost of installed materials (or value of materials) may be 50% or more of the total cost. Construction materials typically account for 40–45% of the cost of all construction work. In such a highly competitive environment nowadays, it is necessary for every construction company to maintain an efficient and effective material procurement to cut administrative cost, and to keep abreast of the market condition to procure materials at the right price, quality and time (Stephen et al., 2004). Poor planning and control of materials, lack of materials when needed, poor identification of materials, re-handling and inadequate storage cause losses in labour productivity and overall delays that can indirectly increase total project costs.

Effective management of materials can reduce these costs and contribute significantly to the success of the project. When the supplies managed by procurement represents 50%, 60%, and up to 70% of the total cost for the project, it is imperative to have a strict and permanent control of the acquisitions, having in mind the financial approach being represented by such situation.

Both material purchasers and sellers can be benefited from information sharing as purchasers can get more comprehensive material information while sellers can know more on the current market situation.

4.2 HUMAN RESOURCE MANGEMENT

Labour is defined as the on-site workforce employed by contractors. Human Resource Management (HRM) is of strategic importance in all organizations. It contributes to the success of the organization and creates competitive advantage for the organization. The way HRM practices and policies take shape also affects the employee’s experiences of work and the employment relationship. HRM is therefore important in any organization. HRM includes: organizational planning, staff accusation, and team development. However, training and motivation are the two main parts of team development practices. Human resource management (HRM) has been broadly defined as a field of organizational activity and professional practice. It has remained a complex and obscure entity, variously interpreted by practitioners and researchers.

It is generally accepted that human resources (HR) represent the most variable, uncontrollable, and important element in production. Moreover, because HR serves as the connecting link in all production inputs appropriate to clients demands. With rapid changes in technology, worker’s needs, current market, and competitive environment, planning for human resource have become an important and challenging task for development. HR planning involves plans for future needs of employees, their required skills, acquisition of employees, and personnel development. With the increasing complexity of modern construction project demand for efficient and competent managers in the industry grows. A manager must be able to organize not only technologies but also human resources. Managers are responsible for selecting, obtaining, distributing, organizing, and putting to use all of those resources that are necessary to pursue and achieve an organization’s objectives. Manpower or labour has four major aspects that are of interest to management properly understand the management and control of labour as a resource, the manager must be aware of the interplay among the following elements: labour cost & labour productivity, labour organization.

4.3 CONSTRUCTION EQUIPMENT MANAGEMENT

The cost of equipment in projects varies from 10 to 30% of the total cost of the project, depending upon the extent of mechanization. In modern fully mechanized project the cost of equipment goes up to 30%. Proper planning, selection, procurement, installation, operation, maintenance and equipment replacement police plays an important role in equipment management for the successful completion of the project. With the growing use of machinery it has become necessary for construction engineers to be thoroughly familiar with the construction application and upkeep of the wide range of the modern equipment. Since modern construction projects require a huge amount of capital, construction team have to adopt latest technology, modern equipment and modern management techniques to achieve economy, quality and quick results.

V. DATA COLLECTION

5.1 FIELD WORK RESEARCH

The problem solving approach accompanied with a field survey was adopted for conducting this research. A questionnaire was designed and constructed to survey the situation and reality of construction resource management practices of South Indian contracting companies. The data which was collected by the questionnaire is analyzed and discussed.

5.1.1 Validity Test

Using expert validity, the questionnaire may be sent to experts in a particular field of research across the area for their evaluation of the content. After preparing the questionnaire in its initial form, the researcher presents it to five experts to examine its validity. The five experts are two lecturers in a University, two contractors and one expert in construction management field. The experts generally manifest comforting complacence toward the questionnaire. However, they provide the researcher with some comments and suggestions which are taken into consideration while modifying the questionnaire structure.

5.1.2 Pilot Study

A pilot study provides a trial run for the questionnaire, which involves testing the wording of questions, identifying ambiguous questions, testing the technique that used to collect the data, etc. After the preliminary testing, a pilot study was conducted to evaluate the questionnaire; the researcher distributed the questionnaire to a sample of five different contracting companies to fill them. The purpose of this step is to
discover if the questions are well understandable or not, also to find out any problem that may raise in filling the questionnaire. Generally speaking, it appeared that respondents had no difficulty in understanding the items or the instructions to complete the questionnaire. The validity content of the questionnaire was tested by the five contractors. Each of them has full information about the research objectives. Each of them was requested to evaluate validity content for each item based on rating the index of content validity. The contractors were then requested to rate each item based on relevance on the four point ratings scale. The point scale developed by Yaghmaie as:

1 = not relevant;
2 = item need some revision;
3 = relevant but need minor revision
4 = very relevant

Based on comments of the contractors some minor changes, modifications, and addition were introduced to the questions.

The relative importance index is computed as:

$$RII = \frac{\sum W}{A \times N}$$

Where:

- $W$ = weight given to each factor by the respondents and ranges from 1 to 5
- $A$ = the highest weight = 5
- $N$ = the total number of respondents

VI. SURVEY RESULT

6.1 Benefits of Implementation of Resource Management on Construction Projects

Table 6.1 outlines the benefits of construction materials management systems. According to contractors' opinions, most of contractors believe that proper resource management helps them to forecast resources. (Rank 1). Proper planning by means of micro level scheduling will lead to forecasting. Required quantity of material, labour and machinery can determine from the activity schedule. Also, material store room is a great problem faced by contractors. Most of the contractors have space constrain. They have to store required amount at required time, without proper amount constructions work won’t go with a flow, also storing excess material needs more space.

As table 6.1 says most of the contractors think that second most important benefit of resource management is “better control on their resource” (Rank 2). On the other hand, the factor which they believe has the lowest effect on resource management is “more safe time”. From the practical experience of construction field they think that resource management cannot make a profit of time (Rank 14).

<table>
<thead>
<tr>
<th>Benefit</th>
<th>N</th>
<th>Mean</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forecasting of resources become easy and accurate</td>
<td>38</td>
<td>3.66</td>
<td>1</td>
</tr>
<tr>
<td>Better control on resources</td>
<td>38</td>
<td>3.47</td>
<td>2</td>
</tr>
<tr>
<td>Better priority in assigning work</td>
<td>38</td>
<td>3.37</td>
<td>3</td>
</tr>
<tr>
<td>Effectively utilize machineries</td>
<td>38</td>
<td>3.34</td>
<td>4</td>
</tr>
<tr>
<td>Effective distribution of labours</td>
<td>38</td>
<td>3.32</td>
<td>5</td>
</tr>
<tr>
<td>Effectiveness of multi tasking</td>
<td>38</td>
<td>3.18</td>
<td>6</td>
</tr>
<tr>
<td>Reducing cost</td>
<td>38</td>
<td>3.11</td>
<td>7</td>
</tr>
</tbody>
</table>

![Fig.6.1 Bar chart showing benefits of resource management](image_url)
6.2 Causes of Failure of Resource Management

Table 6.2 represents the factors related to failure of resource management. Failure will also cause to failure of resource management.

On the other hand, most of the contractors think that natural causes like wind, rain etc. have lesser effect on failure of resource management. Even though, it depends on state to state. In Kerala, natural causes like rain are more severe when compared to Tamil Nadu.

Table 6.2 Causes of failure of resource management

<table>
<thead>
<tr>
<th>N</th>
<th>Mean</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>1.84</td>
<td>1</td>
</tr>
<tr>
<td>38</td>
<td>1.79</td>
<td>2</td>
</tr>
<tr>
<td>38</td>
<td>1.74</td>
<td>3</td>
</tr>
<tr>
<td>38</td>
<td>1.58</td>
<td>4</td>
</tr>
<tr>
<td>38</td>
<td>1.42</td>
<td>5</td>
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<tr>
<td>38</td>
<td>1.16</td>
<td>6</td>
</tr>
<tr>
<td>38</td>
<td>.89</td>
<td>7</td>
</tr>
<tr>
<td>38</td>
<td>.68</td>
<td>8</td>
</tr>
</tbody>
</table>

Fig 6.2 Bar chart showing causes of failure of resource management

6.3 Factors Affecting Resource Fluctuation.

Construction scheduling techniques often generate schedules that cause undesirable fluctuations in resource utilization levels and unintended peak resource demands that exceed availability limits. These undesirable resource fluctuations and peak resource demands are inefficient and costly to implement on site, as they (1) require additional cost to hire additional resources (2) require the hiring and releasing of workers on a short-term basis; (3) create difficulties in attracting and keeping top-quality workers if stable employment is not guaranteed (4) produce disruption in the learning curve effects; and (5) require contractors to maintain an unproductive level of workforce on site that keeps some workers idle during low demand periods.

From field study, the main causes of resource fluctuation are found out and they are listed out as in Table 6.3. Most of the contractors opinioned “untimely information from staff” is the main cause of resource fluctuation. Second most affecting factor is “unexpected failure of equipment”. Through proper maintenance of machineries “unexpected failure of machineries” can stop up to some extent.

Table 6.3 Causes of resource fluctuation

<table>
<thead>
<tr>
<th>N</th>
<th>Mean</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>3.79</td>
<td>1</td>
</tr>
<tr>
<td>38</td>
<td>3.55</td>
<td>2</td>
</tr>
<tr>
<td>38</td>
<td>3.26</td>
<td>3</td>
</tr>
</tbody>
</table>
Failure of hiring tools 38 3.11 4
Inconsistent performance of equipments 38 2.87 5
Time delay in procurement 38 2.53 6
Tool failures 38 2.24 7
Fluctuations in cost of labours 38 2.18 8
Construction plant availability 38 2.16 9
Fluctuations in hiring cost 38 2.08 10
False information from reporting staffs 38 2.03 11
Availability of hiring tools 38 1.97 12
Inflation 38 1.79 13
Inconsistent performance of subcontractors 38 1.74 14
Contract failure 38 1.55 15
Natural problems like rain, wind, snow …etc. 38 1.42 16

VII. CASE STUDY

7.1 INTRODUCTION
Project monitoring and control is the process of collecting, recording, and reporting information concerning project performance. Project controlling uses the data from monitor activity to bring actual performance to planned performance. The present study deals with the project monitoring process of “MPG CINE-PLUX”, a four storied (G+3) factory building whose construction is in progress at Trivandrum, Kerala. A comparison between the planned progress of construction work and actual progress is performed in this study using project management software Primavera P6. Despite well-established principles and policies of project monitoring the process itself may not be efficiently accomplished in a project, because of those practical problems existing or arising in the project such an attempt in realizing the practical problems in implementation of resource management will contribute to proper recognition of the problem areas.

The main objectives of this study are:
• To suggest the importance and purpose of monitoring the construction work.
- To suggest guidelines to contractors for updating the project.
- To present an ideal schedule for the factory construction process.
- To suggest a layout for updating the schedule.
- Suggest a systematic resource management system.

All activities and their sequence of occurrence, duration, and resources required are studied. The organizational breakdown structure of company and work breakdown structure of the project are noted. Tacking of the completed activities and analysis are done. This gives an idea about the resources involved in the completed work. “Project management is the application of knowledge, skills, tools and techniques to project activities to meet the project requirements” (PMBOK, 2008). K Chithkara has defined project management as an art and science of mobilizing and managing people, materials, equipment and money to complete the assigned project work on time within budgeted costs and specified technical performance standards. Mainly project management process comprises five process groups (PMBOK, 2008). They are initiating, planning, executing, monitoring and controlling, and closing. Monitor and control of project work is the process of tracking, reviewing and regulating the progress to meet the performance objectives defined in project management plan. Monitoring is an aspect of project management performed throughout the project. It includes collecting, measuring, and distributing performance information, and assessing measurements and trends to affect process improvements.

Table 7.1 case study details

<table>
<thead>
<tr>
<th>Owner</th>
<th>MPG Hotels &amp; Infrastructure PVT LTD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project</td>
<td>Construction MPG Cine-plux</td>
</tr>
<tr>
<td>Location</td>
<td>Trivandrum</td>
</tr>
<tr>
<td>Nearest airport</td>
<td>Trivandrum International Airport</td>
</tr>
<tr>
<td>Rainfall details</td>
<td>a) Annual rainfall - 300 cm/ year</td>
</tr>
<tr>
<td></td>
<td>b) Maximum intensity - 90 mm/day</td>
</tr>
<tr>
<td></td>
<td>c) Period of rainfall during the year</td>
</tr>
<tr>
<td></td>
<td>- June to October</td>
</tr>
</tbody>
</table>

Main steps involved in factory construction work apart from initial planning are:
1. Mobilization
2. Column& beam concreting
3. Slab & stair concreting
4. Post concreting works
5. Masonry work
6. Plastering
7. Flooring
8. External wall plastering
9. Finishing

7.2 DELAY ANALYSIS

- The following reasons were observed during this study which can be held responsible for delays:
  - Lack of knowledge about advanced tracking methods and software’s.
  - Insufficiently skilled staff.
  - Lack of proper fund flow throughout the project progress.
  - A major portion of labour force was from West Bengal and Orissa. Regional festivals in these areas cause sudden delays in work progress.
  - Even though delay due to monsoon rain was already accounted in the baseline schedule, unexpected extension of monsoon caused further delay in project progress.
  - Sand unavailability due to legal restrictions.
  - Late delivery of resources.

7.3 SUGGESTIONS

- Absents of proper resource management will lead to many problems, but proper resource management can save the budget up to 30 %. So, resource management can be implemented on every civil engineering project.
- Micro activity scheduled projects are more preferable than macro activity scheduled.
- Scheduling and resource loading shall conduct with coordination of all departments of project. Lack of coordination between departments makes an improper and inefficient schedule.
- Resource loading, resource leveling, resource pooling and resource smoothing can be done easily with the help of PRIMAVERA.

VIII. CONCLUSION

The project was carried out to have a comprehensive study about resource management and its implementation. Data collected by questionnaire survey and it was used to find Benefits of resource management, causes of failure of resource management and causes of resource fluctuation. Due to large number of input data, computer based software SPSS (Statistical Package for Social Science) is used as analyzing tool. Reliability is confirmed by Cronbach’s coefficient – Alpha (α). The construction project, especially highway projects uses huge amount of resources on and off the field in various forms like materials, plants, human resource along with money, time and space. Resource management using project management software is a systematic methodology to avoid idleness of labour, machineries, also it avoids wastage of material.

Summary of the results obtained from the study lead to following conclusions:

- While implementing resource management in a construction project, “forecasting of resources” becomes easy.
- Proper resource management can improve the control on resources. Control is used to reduce idleness in case of machineries, labour. And in case of material, required amount at required place
- The main cause of failure of resource management is procurement time loss. Procurement time loss is due to the absence of proper planning.
• Availability of raw materials in site is also a main problem in Kerala, among that, sand availability is the most crucial part.
• Most affecting factors of resource fluctuations are Untimely information from reporting staff and unexpected failure of machineries.
• Manual resource loading in a schedule is highly sophisticated and also less reliable, but project Management software like Primavera P6 will do the work with high reliability within lesser time.

Absence of systematic method is the main cause of resource management failure and resource fluctuation, so systematic methods like Primavera (p6), MS project has to be implemented in every site.

REFERENCES