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RESOURCE CONSTRAINTED PROJECT SCHEDULING PROBLEM (RCPSP)

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Abstract - The Multi-mode Resource Constrained Project Scheduling Problem is characterized by a set of tasks, resources and an objective function. The project scheduling problem is both practically and theoretically of paramount importance. From the practical perspective, improvement of project scheduling as a critical part of project management process can lead to successful project completion and significantly decrease of the relevant costs. From the theoretical perspective, project scheduling is regarded as one of the interesting optimization issues, which has attracted the attention of many researchers in the area of operations research. At present, around 71% of the projects related to the software industry are renegotiated or canceled causing negative impacts on both, social and economic areas. Project scheduling with limited resources is one of the most famous problems in the research operations and optimization cases. Therefore, the project scheduling issue has been significantly evaluated over time and has been developed from various aspects. In this research, the topics related to Resource-Constrained Project Scheduling Problem (RCPSP) are reviewed, recent developments in this field are evaluated, and the results are presented for future studies. This kind of problem can be presented as an optimization problem subjected to two groups of restrictions: precedence relations and resource constraints.

1. INTRODUCTION

Project management is a system of managing nine knowledge areas pertaining to projects time, cost, scope, quality, risk, procurement, human resource, communication and integration. Integration of these nine knowledge areas makes the project management a complex decision making process. A project manager always has a pressure to satisfy the demand of its stakeholder in terms of cost, quality, time and scope. A typical project management problem consists of planning and scheduling decisions. In the planning process, project manager distributes the total project work into manageable activities. The manager estimates demand for variety of resources and time of all the activities involved in the project.

1.1 Resource Levelling

When performing project planning activities, the manager will attempt to schedule certain tasks simultaneously. When more resources such as machine or people are needed than are available or perhaps a specific person is needed in both tasks, the tasks will have to be rescheduled concurrently or even sequentially to manage the constraint. Project planning resource levelling is the process of resolving these conflicts. It can also be used to balance the workload of primary resource over the course of the project, usually at the expense of one of the traditional triple constraints (time, cost, scope). Resource levelling is also useful in the world of maintenance management. Many organizations have maintenance backlogs. These backlogs consist of work orders. In a “planned state” these work orders have estimates such as 2 electricians for 8 hours. These work orders have other attributes such as report date, priority, asset operational requirements and safety concerns. These same organizations have a need to create weekly schedules. Resource-levelling can take the “work demand” and balance it against the resource pool availability for the given week. The goal is to create the weekly schedule in advance of performing the work. Without resource-levelling the organization is most likely performing subjective selection. Project scheduling is the process of allocation of the given resources to the project activities to determine the start time and finish time of each activity. If resources are adequate but the demand varies widely over the life of the project, it may be desirable to even out resource demand by delaying noncritical activities to lower peak demand and thus, increase the resource utilization. This process is known as resource levelling or smoothing. On the other hand, if resources are not adequate to meet the peak demands, the late start of some of the activities must be delayed, and the duration of the project of the project may be increased. This process is known as resource constrained scheduling.

1.2 Critical Path Method

The CPM has been widely used for project scheduling, helping managers to guarantee the in time and on budget completion of the project. CPM provides useful information for the project, such as the critical path and free and total float, which are essential for the efficient planning of the project. An advantage of CPM is the ability of managing by exceptions especially in large-scale projects. However, CPM i based on the assumption that there are unlimited resources for the execution of the activities. Though in real projects,

resource are not unlimited. Thus, scheduling without considering resource constraints gives unreliable schedules.

1.3 Resource Levelling in MS Project

A survey conducted by Liberator et al. Shows that 83% of professional project management software for planning and control, and that in construction industry resource levelling is used by 58% for planning and by 44% for project control. From the same survey it was derived that MS project is the most popular package used for construction projects. Resource levelling in Microsoft project is probably one of the most misunderstanding features available, yet it is one of the most important tools in the proactive project manager's tool kit. We will provide a very comprehensive review of resource levelling in this article to help you get over any concerns you may have about it, and to hopefully convince you that it really does help develop a very effective project schedule (that doesn't burn out your team from over-allocation).

1.4 Aim and Objective

- To evaluate the efficiency of resource levelling in a construction project.
- To avoid the formation of fluctuation among resources.
- To eliminate several issues related to resource constraints.

2. LITERATURE REVIEW

- In **A. Kastor, K. Sirakoulis's The effectiveness of resource levelling tools for resource constraint project scheduling problem** in **International Journal of Project Management** States that the PERT/CPM network techniques are based on the Assumption that all needed resources will be available. The scarcity of resources is a usual reason for project delays. For the solution of the Resource Constrained project Scheduling Problem (RCPSP) other methods have been applied. The objective of these methods consists in minimizing the project's duration by considering both the precedence and resource constraints. Project Management software packages solve the resource conflicts using resource levelling. The paper evaluates the effectiveness of resource levelling tools of three popular packages by comparing the results when levelling two real construction projects as case studies.

- **Mustafa E. Shehata, Khaled M. El-Gohary's "Towards improving construction labour productivity and project's performance"** in **Alexandria Engineering Journal** states that the Proper management of resources in construction projects can yield substantial savings in time and cost. This paper focuses on labour productivity in the construction industry. This study considers the current state-of-the-art issues relevant to this subject. It covers the construction labour productivity definitions, aspects, measurements, factors affecting it, different techniques used for measuring it and modelling techniques. The main outcome from the literature is that there is no standard definition of productivity. This study provides a guide for necessary steps required to improve construction labour productivity and consequently, the project performance. It can help improve the overall performance of construction projects through the implementation of the concept of benchmarks. Also it gives an up to date concept of loss of productivity measurement for construction productivity claims. Two major case studies, from the literature, are presented to show construction labour productivity rates, factors affecting construction labour productivity and how to improve it.

- In **Boong Yeol Ryoo, Mike T. Duff 's Understanding the Occurrence of Two Total Floats in One Activity and Schedule Crashing Approaches for That situation** in **Journal of building construction and planning research** states that the Critical Path Method (CPM) Scheduling has proven to be an effective project management tool. However, teaching the topic has proven it difficult to include all elements of CPM yet keep it simple enough for students to understand. In an effort to simplify the teaching of critical path method scheduling, the issue of two total floats in an activity does not get the attention necessary to address its occurrence. The objective of this paper is to present a mathematical method to show multiple total floats are possible for an activity. Also presented are suggestions for schedule crashing when multi-plea total floats are found. Two totals floats can be found if constraints (Lag or Lead) or non-Finish-to-start (FS) relationships, or both are used in a network diagram. Situations are possible where an activity many have a start total float (STF) of zero but a finish total float (FTF) greater than zero, or vice versa. Because the critical path generally follows the zero total float, these situations, where either the STF or the FTF is critical while the other is not, determine how the critical path activity must be controlled and crashed. This paper will present approaches of how to crash the schedule when a portion of the activity, either start or finish, is critical. Also presented will be methods to teach the subject matter with or without the use of scheduling software. Critical Path Method was revisited to see what the mini-mall conditions are needed to have activities with two total float. Generalized crashing crashing methods were studied to see if the methods can be used when two total floats exist.

- In **track hegazy's optimization of resource allocation and levelling using genetic algorithms resource allocation and levelling are among the top challenges in project management** states that the Due to the complexity of projects, resource allocation and levelling have been dealt with as two distinct sub problems solved mainly using heuristic procedures that cannot guarantee optimum solutions. In this paper, improvements are proposed to resource allocation and levelling heuristics, and the genetic algorithms (gas) technique is used to search for near-optimum solution, considering both aspects simultaneously. In the improved heuristics, random priorities are introduced into selected tasks and their impact on the schedule is monitored. The procedure then searches for an optimum set tasks' Priorities that produces shorter project duration and better-levelled resource profiles. One major advantage of the procedure is its simple applicability within commercial project management software systems to improve their

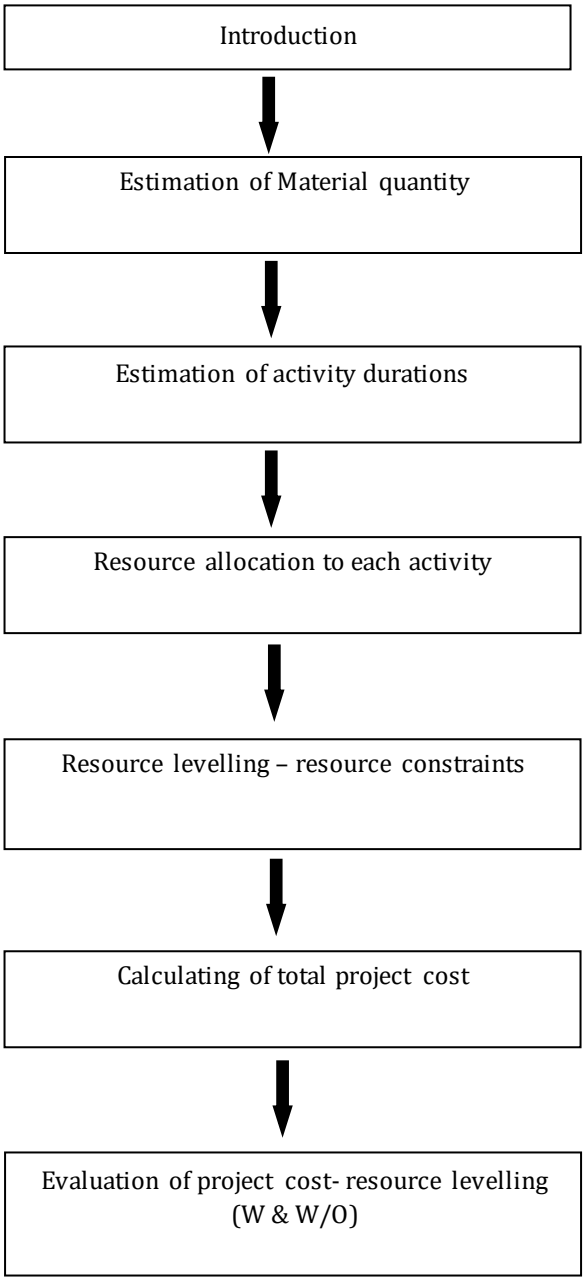
performance. With a widely used system as an example, a macro program is written conducted to demonstrate the multi objective benefit of the procedure outline future extensions.

- In **Aftab hameed Memon, Ismail Abdul Rahman, Ade Asmi Abdul Aziz, Kumarason V. Ravish, and Noor Ikmalah Mohammad Hana's Identifying Construction Resource Factors Affecting Construction Cost: Case of Johor** states that the success of any construction project highly depends on proper and effective management of construction resources flow. Studies show various resources factors that affect the cost management resulting in significant amount of cost overrun. This study focuses on the significant resource factors causing construction cost overrun in the state of Johor. Data collection was carried out through a comprehensive questionnaire survey consisting of 16 factors identified through a comprehensive literature review. Data was analyzed with statistical software package SPSS. It was found that average cost overrun for this study is in the range of 10% to 15% of the project cost. The Cranach's alpha of the data was 0.910 Which means that the data collected was highly reliable. The factors were ranked through mean rank calculation and it was found that fluctuation of prices of materials, cash flow and financial difficulties faced by contractors and shortages of materials were the significant factors affecting construction cost overrun. Insufficient numbers of equipment, relationship between management and labour, and labour absenteeism were found as factors of least significance causing cost overrun. The result of spearman test indicates that cash flow and financial difficulties faced by contractors, and financial difficulties of owner correlates with each other at a significant value of 0.752. Furthermore, equipment availability and failure, and insufficient numbers of equipment are correlated with the value of correlation 0.703. Similarly, shortage of site workers, financial difficulties of owner, and cash flow and financial difficulties faced by contractors are inter correlated significantly between them.

- In **Rama Devi P. V's Design of System for Controlling, Scheduling and Monitoring of Construction Project using System Software** states that the construction monitoring, controlling and scheduling is one of the important tool in a construction project. Every construction project involve with a lot of activities which need to be planned, monitored, controlled and scheduled properly to ensure the completion of the project. These project management techniques of planning, scheduling and controlling are used to complete the project within the stipulated time, scope, quality and cost. These techniques can be applied to all type of project, Resource allocation and levelling are among the top challenges in project management, due to the complexity of project. The main objective of this project is to optimize the resource schedule of construction project activities in order to minimize the total duration of the project, maximization of net present value, or minimization of average tardiness subjected to both precedence and resources constraints using an optimization technique called ant Colony Optimizing Algorithm (ACO), This work describes an algorithm approach to Resource Constraints Project Scheduling Problems (RCPSP) in construction industry. The study on the optimization technique that is genetic algorithm and its terminology, operator, parameter used is clearly depicted

3. METHODOLOGY

3.1 Flow Chart



3.2 Identification Of Activities

Every operation is connected with the quality of the Before estimating activity time duration and cost, relationships among activities must be identified

- What task immediately precedes this task?
- What task immediately follows this task?
- What task can be done concurrently?

These are referred to as precedence relationships.

The main relationship for scheduling is 'what task immediately precedes the current task', which is referred to as the immediate predecessor task.

3.3 Estimation

3.3.1 Estimation of material quantity

In addition to precedence relationship and time durations, resource requirements are usually estimated for each activity. Since the work activities defined for a project are comprehensive, the total resources required for the project are the sum of the resources required for the various activities. By making resource requirements estimates for each activity, the requirements for particular resources during the course of the project can be identified. Potential bottlenecks can thus be identified, and schedule, resource allocation or technology changes made to avoid problems.

3.3.2 Estimation of activity duration

In most scheduling procedures, each work activity has associated time duration. This duration are used extensively in preparing a schedule. For example, suppose that the durations shown in Table 9-3 were estimated for the project diagrammed in Figure 9-0. The entire set of activities would then required at least 3 days, since the activities follow one another directly and require a total of 1.0+0.5+0.5+1.0=3 days. If another activity proceeded in parallel with this sequence, the 3 day minimum duration of these four activities if unaffected. More than 3 days would be required for the sequence if there was a delay or a lag between the completion of one activity and the start of another.

3.4 Resource Allocation

A resource is a physical variable quantity such as manpower, material, money, equipment, time or space which is required for carrying out a project. While developing CPM and PERT networks, we generally assume that sufficient resources are allocated to perform the various activities and complete the project. But in real practice resources are always limited and limitation on resources can significantly affect the initiation performance and completion of activities on the schedule time and can cause the project to be extended beyond the schedule duration. Therefore, the various activities of the project are to be scheduled in such a manner that there is best possible utilisation of available resources.

3.5 Resource Levelling

There are various activities in a project demanding varying levels of resources. The demand on certain specified resources should not go beyond the prescribed level. In the process of resource levelling, whenever the availability of resources becomes less than its maximum requirements the only alternative is to delay the activity having larger float. In case two or more activities require the same amount of resources, the activity with minimum duration is chosen for resource allocation. Resource levelling is done if the restriction is on the availability of resources.

3.5.1 Steps:

- Lower the peak requirement of the resource by staggering the resource input on non-critical activities. If necessary, sub-critical and critical activities can also be tackled to bring peak demands below the specified levels. Thus completion of work way is delayed due to resource constraints.
- Either increase the duration of critical activities or place some of the concurrent activities in series to reduce the peak demands of the scare resources. This will increase the duration of the project.
- Re-arrange the activities in descending order of the magnitude of the positive float, as resource can be conveniently diverted from the activities which posses large amount of float. Firstly lower the high peaks of resources demand by utilising the free floats of the activities, then non-critical activities should be rescheduled to the extend required by utilising the floats starting with the activities having the highest float. Critical activities can be tackled last, if necessary.

3.5.2 Resource levelling techniques:

Critical path is a common type of technique used by project managers when it comes to resource levelling. The critical path representation for both the longest and shortest time duration paths in the network diagram to complete the project. However, apart from the widely used critical path concept, project managers use fast tracking and crashing if things get out of hand.

Fast tracking – this performs critical path tasks. This buys time. The prominent feature of this technique is that although the work is completed for the moment, possibility of rework is higher.

Crashing – this refers to assigning resource in addition to existing resource to get work done faster, associated with additional cost such as labour, equipment, etc..

3.6 Total Project Cost

Direct cost: Direct costs are costs that can be correlated to a specific activity or a work item, which is being done or produced. Direct cost of permanent work item=direct material cost+ direct labour cost other direct expenses. Direct material costs cover all costs connected with materials, which are incorporated into permanent works of the projects. Direct labour costs cover net expenses for procurement, maintenance, and wages of all categories of workers employed at the work site for the execution of an item of project. Other direct expenses include all other expenses on account of services rendered, which can be directly attributed to and clearly identified with the execution of an activity or work item.

Indirect costs: indirect costs include all costs, which are attributable to a given project but cannot be identified with the performance of a specific activity or a work package. In other

words, all costs other than direct costs are covered under indirect costs.

3.7 Effectiveness Of Resource Levelling

The effectiveness of resource levelling can be identified by subcontracting the total cost of the project with resource levelling to the same project without resource leveling

4. ANALYSIS

4.1 Without Resource Levelling

When a resource is assigned to the tasks and it spends more time than its work calendar permits on a single task or combination of tasks occurring at the same point in time. once resource are assigned for each task in a project ,it is necessary to check whether any over allocated resource. the over allocation is indicated in an indicator field in gantt table it is also indicated in resource sheet.

In resource sheet the over allocation will be show in red colour indicator. the column interface is a great way to prepare to assign resources to view clearly show to which group of resources belongs. In resource graph clearly shows over allocation, it is easy to identify the problem in graphical representation. The resource graph views shows in a project how particular resource is used in resource graph view you can identify the spot and correct resource which are over allocated.

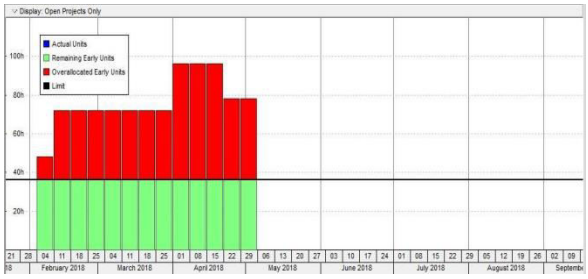


Fig – 1 Over allocation in Labor

4.2 With Resource Levelling

Resolving resource conflict or over allocations are solved by delaying, splitting certain tasks or optimized levelling when project levels a resource, it is selected assignments are distributed and rescheduled. this way over allocated resources can be fixed. When a resource is assigned to the tasks and it spends more time than its work calendar permits on a single task or combination of tasks occurring at the same point in time.

Other than resources standard work hours if any work schedule is above and beyond then the overtime takes place. overtime work can have a different rate assigned to it than a resources regular rate. overtime work does not represent additional work on a task. instead it represents the amount of time it takes to spent on a task than regular hours.

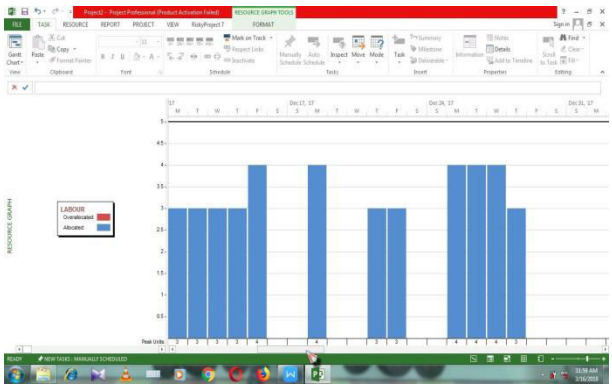


Fig – 2 Resource Levelling in Labor

4. CONCLUSION

Project scheduling is the process of allocation of the given resources to the project activities to determine the start time and finish time of each activity. The resource levelling and the resource allocation in the project is to be estimated in this project. The various activities of the project are to be scheduled in such a manner that there is best possible utilisation of available resources.

- Calculating Project cost
- Evaluation of project cost- with resource levelling
- Evaluation of project cost- without resource leveling

The objective of these methods consists in changing the project duration by considering both the precedence and resource constraints. Project management software packages solves the resource levelling for a real construction problem. In this paper two numbers of schedule has been prepared, In that first schedule does not has any resource constraint and the other one has the total cost of those 2 schedules were been analysed and it showed that the schedule which has resource levelling has got higher duration than the schedule which has not resource levelling, even though with that higher duration it showed lesser cost than the schedule which has not resource levelling. So it has been concluded that the resource levelling will show good results in terms of cost, but it would not be appropriate for the projects which has time constraint.

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