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INTRODUCTION OF LEAST COST SCHEDULE AND ITS APPLICATIONS

[1]Nasser Majrashi, [2]Ahmed Althobaiti

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Abstract: **Least cost scheduling of construction projects is obtained by time management with optimum cost which is also termed as crashing. Although papers published in major journals have documented real applications for schedule crashing such as working overtime, working double shifts, adding additional resources, employee productivity, and relaxing activities. The objectives of the paper are to study the algorithms from the previous studies and their impact on the real-life project crashing. And in addition to that the paper discussed the main idea of crashing PERT/CPM network. To achieve such objectives, studies about crashing algorithm/programing, data collection, and PERT/CPM network crashing technique were carefully explored and scrutinized. Suggestions for further research are for preventive actions for nonconformance risk activities may suffer additional cost, and to use this data to create new procedures that incorporate quality concepts into project scheduling difficulties.**

Keywords: **Least Cost Scheduling, Crashing using algorithms, PERT/CPM network.**

1. INTRODUCTION

Time and cost are two of the most critical performance indicators of construction projects. Therefore, project crashing is one of the effective methods for solving time-cost trade off problems. However, the project can be defined as a unique set of actives in an organized sequential that ensure the final goal is delivered with the desired deadline. One of the main construction projects deliverables is the schedules. Even though, the schedules are developed by SMEs in estimation based on previous experiences, through well practiced methods such as Critical Path Method (CPM) or Program Evaluating Review Technique (PERT), short comings those potentially results to delay the project through execution are occurring; or projects' owner or contractor may found themselves in situation where they need to even accelerate the project to antedated completion date than the agreed normal schedule. In summary, there are two main uses for the presented technique: it can be used to shorten a project's planned duration if the project is scheduled to end after a specific deadline, or it can be used as a part of a control procedure when a project runs behind schedule, to reduce or eliminate schedule overruns. (Bakry 2013). Another incentive to utilize these tactics is reducing the overall project cost as the reduction of the project lifetime will decrease the

Therefore, Time management with optimum cost has a vital role in any project. In the construction projects, there are many unexpected difficulties that can cause delays during the implementation of the work. This situation includes several variables (number of resources, time of execution, costs and expenses, working area availability, etc.) [2] due to complexity of nowadays projects and because of dependency on the conventional tool to plan, schedule and control the project progress. Effective project management is the management of project resources, which involves project completion within the assigned time period and within the given budget of cost. Time (indicated as a given schedule), cost (restricted by the budget) and performance (defined as quality requirements for given specifications) are the three major project management dimensions.[3] The need for constant control of time, cost and performance of project also can help in completion on time with good quality and within the assigned budget. Project duration can often be decreased by assigning more resources to project activities, in the form of overtime, and by assigning more resources such as material, equipment, etc. However, additional human power and resources increase the project cost. Therefore, the decision to decrease the project length should be established on an analysis of the trade-off between time and cost since the time and cost are variables that must be minimized. Project crashing is a technique for shortening the project duration by decreasing the time of one (or more) of the critical activities in the project to less than its normal activity time. This decrease in the normal activity time or acceleration of the project is termed as crashing.[1]

Hence since 1993 least cost scheduling of construction projects and construction project schedule crashing has been strongly used in many research papers to assess the impact of cost after crashing the project with different approaches, so in this literature review we collected 21 research papers and the researchers have suggested the advantages/disadvantage of various aspects of this topic.

So, a logical review of relevant least cost scheduling of construction projects and construction project schedule crashing studies is undertaken in this article. Three research objectives have been derived:

(1) Compare the findings of the studies by use of a structure set for this paper. This structure is built up by empirical and non-empirical studies.

(2) To provide visions for directing further least cost scheduling of construction projects.

(3) construction project schedule crashing research's. By conducting more research.

(4) Find most optimal approach to conduct the least cost scheduling of construction projects and construction project schedule crashing.

This paper will start with the background of the least cost scheduling of construction projects and construction project schedule crashing with more elaboration on its definitions and various form. Then we will review the methodology used in all papers and classify the topics of relevant papers, moreover, finding section presents the comparison results with discussion section. Lastly, we will present the conclusion and summarizes the research.

2. BACKGROUND OF THE LEAST COST SCHEDULING OF CONSTRUCTION PROJECTS AND CONSTRUCTION PROJECT SCHEDULE CRASHING.

2.1. What is the definitions of least cost scheduling of construction projects and construction project schedule crashing?

Project crashing in project management is a method used to accelerate a project's timeline by adding up extra resources without changing the scope of the project. Crashing activities in project management could involve adding up additional employees to a task to finish it more quickly, or it could include giving a bonus for a faster outcome.

In additional to that project crashing is when you reduce the duration of a project by reducing the time of one or more tasks. Crashing is done by adding the resources to the project, which helps make tasks take less time than what they were planned for. This also will add to the cost of the overall project. Therefore, the primary purpose of project crashing is to reduce the project duration while also keeping costs at a minimum.

A result of project crashing can be a change to the critical path and the rise of a new critical paths. Project crash management needs to return to your project schedule to make sure we are aware of modifications that have happened there because of the project collapsing.

In additional the theory of project crashing needs the investment of extra budget to reduce the duration of the activity so that the project can meet the targeted date. The delay of the activities on critical path makes the delay of the entire project.[4] So, if we can end the critical path activities prior to their normal estimated times, the project will be finished on or before the targeted date. For this, the additional budget will be spent for the activities along the critical path. The raising of budget in critical path activities will reduce the total project duration and will increase the possibility of the project completion on or before the targeted date. [3] Activity time-cost relationship:

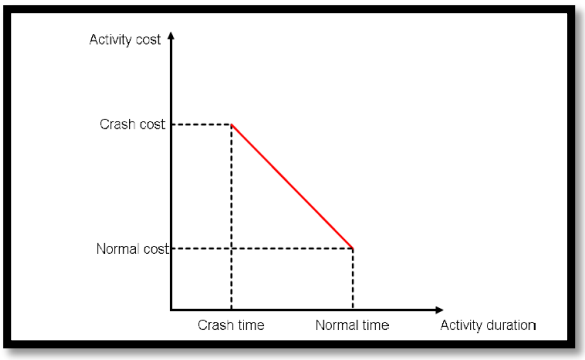

Fig 1: Linear time and cost trade-off for an activity.[3]

The below Diagram was quoted from Construction Planning and Scheduling - Hinze Jimmie where it shows the least cost schedule which also known as optimum cost schedules that it is not the least schedule duration neither the duration of all normal schedule. That equilibrium can not be reached without a systematic approach of crashing certain activities with algorithmic and practical approaches with acceptable risks.

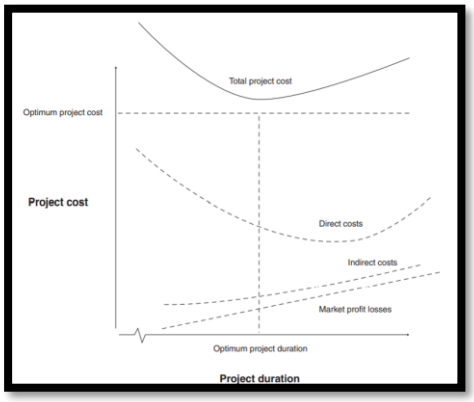

Figure 2: General relationship of project cost to project duration.

3. RESEARCH METHODOLOGY

In this review we accumulate papers relevant to least cost scheduling of construction projects and construction project schedule crashing published in the following journals: Automation in Construction Elsevier, Journal of Business Research, International Symposium on Automation and Robotics in Construction and Mining , International Journal of Project Management , International Conference On Emerging Trends In Civil Engineering , International Journal of Electrical and Computer Engineering.

3.1 Data collection

In this literature review capitalized on the web based published relevant scientific researchers, case studies and articles with total of 37 read papers the writers could distinguish them into empirical and conceptual studies those were developed by other reliable academic member and industrial subject matter experts (SMEs) which their works were published in renown global scientific and engineering jornals and browsers including the following: American Society of Civil Engineers (ASCE), Institute of Electrical and Electronics Engineers (IEEE), Construction Engineering and Management (CEM), Automation in Construction (AC), …….. Those studies where published through scattered period.

3.2 Data analysis

The writers initially searched for total number of 37 of relevant publication of least cost scheduling of construction projects / construction project schedule crashing and reviewed their contents thoroughly. This practice followed by further analysis of these selected paper to differentiate among them as empirical and conceptual groups, then followed by quantitative and qualitative subgroups. In addition of that, the authors broke down the title into three subcategories including 1) Programming and Algorithmic approach, 2) Acceleration/Crashing Application and 3) PERT/CPM Crashing in construction projects.

4. PREVIOUS STUDIES OF LEAST COST SCHEDULING OF CONSTRUCTION PROJECTS AND CONSTRUCTION PROJECT SCHEDULE CRASHING IN CONSTRUCTION:

Of the 37 reviewed papers only 18 relevant papers selected, more than half involved a certain degree of empirical work. Empirical studies involve the collection of primary data. These studies have covered a wide range of specific research foci, which can be grouped into three major themes:

- **Algorithm/Programming** (e.g. Rogalska , Bożejko , Hejducki 2008, Islam, Rana , Rafique and Aziza 2004 , Subhya , Georgyb and Ibrahimc 2014, Yang 2007 , Islam 2013 , Fachrurrazi, Abdullah, Away and Aulia 2018, Garg 2016).
- **Application of strategies**: (Bakry, Zayed & Mohesli 2013), (Kuhl&Tolentino-Pena 2008, (Mathew, Paul, Dileeplal and Mathew 2016, and Bakry, Zayed & Mohesli 2015),
- **PERT/CPM Crashing**: (Catherine, Sequira, Ratna, Priya, and Sanghamitra, Sen 2017, Bosurgi1, Federico Carbone, Pellegrino, and Sollazzo1 2016, M. nazrul Islam, M. Sharif uddin and Aminur r. khan 2014, Andiyan 2021, Trietsch , Kenneth R. Baker 2011, Michael E. Kuhl & Tolentino-Peña 2008, JongYul Kim a, ChangWook Kang , InKeuk Hwang 2011)

4.1 Research into Algorithm/Programming.

Research using algorithm or programming approaches can enhance the project crashing by select the must optimal least cost that result in reduce the project duration.

However, such scheduling methods as: the Linear Scheduling Model (LSM), Line of Balance (LOB) charts and CMP/PERT network planning. these techniques consider several quantitative functions such as: the least cost, the least time, limited resources, work priorities both in the deterministic and probabilistic methodology. As per Rogalska , Bożejko , Hejducki 2008 paper an analysis of the time/cost correlation, made using a modified hybrid evolutionary algorithm (HEA) used by Bożejko and Wodecki for optimization.

Aziza 2004 paper provided a framework for reduction of project duration at the least cost by crashing the project network using Linear Programming LP. therefore, the model is solved with hypothetical data of a hypothetical project by applying Solver in Microsoft Excel.

Subhya , Georgyb and Ibrahimc 2014 paper used the combination of resource patterns for project activities that delivers the minimum project cost is then utilized to produce the optimal-cost project schedule. The computer-automated algorithm is exemplified via a simple project situation that results with compared to the traditional approach for least cost scheduling, which show how ignoring the uncertainty dimension could result in must optimal approaches to crash the project.

In additional Yang 2007 paper develops and tests a particle swarm optimization (PSO) algorithm to aid in the project crashing assessment. The optimization results include project cost curves, both of which can assist project managers in implementing what-if analyses on the project target final date and cost. This algorithm is demonstrated through an example project and a real-life case. The final results demonstrate the likely performance of the proposed algorithm. Insights are also given to the impact of algorithm parameters.

Furthermore, Fachrurrazi, Abdullah, Away and Aulia 2018 paper presents Multi-Objective Integer Non-Linear Programming (MOINLP) involving Negative Total Float (NTF) for improving the basic model of Multi-Objective Programming (MOP) in case the optimization of the additional cost for Project Scheduling Compression (PSC).

Lastly Islam 2013 paper find out that the traditional technique of crashing only reflects average activity times for the calculation of the critical path by ignoring the nature of activity time. Therefore this paper develop an algorithm for optimal crashing method to reduce the required cost while achieving a specified completion time.

4.2 Application for least cost/least schedules crashing

4.2.1 Working overtime

Allow certain number of construction manpower to work overtime to accelerate achieving certain activities within the critical path which will reduce the duration of the crashed activity to allow the successor activity start after.

4.2.2 Working double shifts

Add additional crew to the original crew in another working shift i.e., one crew morning time and the other works evening and nighttime to crash and accelerate the overall critical path.

4.2.3 Working weekends

Stretching the working days into the weekends to accelerate the achievement or even recover from the occurred delay. (Bakery, Zayed and Moselhi 2013)

4.2.4 Employing more productive crews

Recruit additional high skilled and productive labors as this measure will ensure the work will completed on an expedited manner with less deficiencies and potential rework.

4.2.5 Additional recourses

Hiring additional manpower either as labors or supervisory to crash the activities. Hiring additional specialized and productive crews. However, these associated costs are increased direct costs as in labor wages and equipment running costs, and indirect costs in the form of increased supervision and loss of productivity due to congestion in case of increased crew size. (Arditi, Tokdemir and Suh 2002)

4.2.6 Relaxing Activities

By relaxing a converging activity's rate or introducing an intentional break it can start earlier, and its successor can start earlier. Relaxing an activity might cost less money as it leads to assigning fewer resources, however it might cost more. For example, relaxing an activity could mean increased renting period for equipment and increased supervision man hours. (Bakry 2013)

4.3 Crashing of PERT/CPM Networks:

A critical part of project management is risk management. Several types of risk are present in any given project, but the focus of this research will be more emphasized on schedule/time risk and related costs.[5] The schedule/time risk essentially implies not finishing project activities on time, resulting in a late completion of the project. Late project completion generally has undesirable consequences for the company like penalty costs and customer disappointment. If a project is running late project managers might be able to bring the project back on track by integrating extra resources (Eisner, 2002). In project management, this method of alleviating the risk is known as crashing. The connection between the crashing amount the cost of penalty is as shown in the figure below. [6] Objective of this paper is to analyze some project management techniques and propose a solution for time minimization in project crashing. Now, the idea is to reduce the total project time by reducing the pessimistic time of critical activities through the PERT network by investing extra amount of money to the project. The increase in the investment, not only reduce the pessimistic time of the activities along the critical path, but it also reduces the expected time of the activities along the critical path and the entire project completion time.[3]

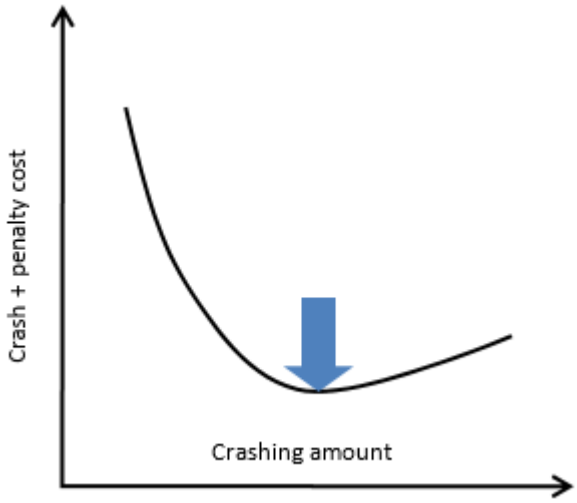

Figure 3: Relationship between crashing amount and the total cost (crash + penalty).[6]

The paper has presented a system that classified previous studies. The review of these studies has provided insights for designing future research agendas. The following discussion thus recommends some possible research plans.

Previous studies in algorithm and programming area have attempted to find new approaches in crashing the project

For example, more work is currently underway to improve both over all duration and total cost simultaneously. This can be done by developing a bi-criterion PSO algorithm to construct the complete Pareto front for the time–cost tradeoff analysis.

Additionally in order to remain resilient in the construction industry with the current momentum toward the agility the construction project contractors and owners are recommended to adopt measures to enforce least cost, least time scheduling and crashing as a tool with the following recommendations:

a. Adopt algorithmic and programing applications that can run a systematic model in order to come up with least possible cost and time schedules.

b. These algorithms shall also identify which activity has more value once its crashed; and

c. Evaluate the crashing applicable practices and select the most appropriate practice with respect to site, contractor, financial, type of project, constructability, etc. limitations.

5. RECOMMENDATIONS

potential drives to adopt or at least consider them in any construction project wither to accelerate it from the beginning or recover for an occurred delay. In addition to that, Preventive actions for nonconformance risk activities may suffer extra cost. In future research, a model may be developed to extended to predict the extra costs of preventative actions that are related to nonconformance risk activities and to use this data to formulate new methods that integrate.[7]

6. CONCLUSION

As a conclusion for construction projects contractors least cost scheduling and least time scheduling and crashing will give additional competitive advantage whenever an accelerated project is on table of tendering, in addition to this, the contractor and the owner of the project can have the capability to recover from any occurred delay. Furthermore, regardless of the intensive effort those required initially to plan strategic plan to adopt the least cost, least schedule or crashing the activities they will be number of potential drives to adopt or at least consider them in any construction project wither to accelerate it from the beginning or recover for an occurred delay.

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