THE FACTORS AFFECTING THE METHODS OF CONSTRUCTION PROJECTS SCHEDULING: AN STATE OF THE ART AND OVERVIEW

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ABSTRACT

The successful completion of the project within the estimated duration is the main target to many schedulers, this will cause the contractor to gain more reputation, and the owner will start to reap the revenue from the project. Thus, effective scheduling of construction projects is a crucial aspect of construction management to avoid any delay and deliver the project within the estimated time, cost, and quality. The difficulty of scheduling process results from three main reasons; uniqueness of the projects even though they have the same function, variability between projects regarding cost, time, and quality, and ambiguity which refers to unclear data, and inaccurate estimate. Thus scheduling is a heuristic process, which depends mainly on a high knowledge and experience. This enables the scheduler to take the right decisions when defining the precedence relationships between activities and assigning the available resources to different activities. As a result, it will reduce resources' idle times and increase the utilization factors of different resources. Traditional scheduling methods have many drawbacks especially when the projects become very big and more complicated, which makes the control process very difficult. This problem put high pressure on researchers to develop more realistic and effective methods of scheduling construction projects. Although many articles published to solve certain problems in scheduling construction projects, still the critical nature of scheduling process sexists. The main objective of this article is to highlight the main factors affecting project scheduling and the developments in scheduling techniques during the last five years by reviewing the different articles published in this field. This provides a good base to many researchers interested in scheduling process to contribute more in this field.

Keywords: Scheduling, Construction Management, Heuristic, Knowledge, Idle time, Utilization factors, Traditional methods.

INTRODUCTION

Scheduling in construction management means to identify the milestones, activities, and deliverables of a certain project along with the timing and dependency relationships between the different activities. So successful scheduling is a necessity to deliver the project without any delays this causes many benefits to all participants:

For contractors:

i. Good reputation for the contractor's business, which enables him to bid on more projects.
ii. Reducing the direct costs especially labor and equipment costs.
iii. Gaining more incentives and bonuses, when finishing early or within the estimated time.

iv. Reducing overhead costs, liquidated damages and other liabilities.

For owners:

i. Receiving return on investment as soon as possible.
ii. Good marketing impacts.
iii. Avoiding problems in cash flow.
iv. Commitment to clients promises.

Scheduling any construction project requires selecting the exact number of required resources for each activity, which guarantees the effective use of these resources without any idle times.

Traditional scheduling methods can be classified into three main groups:

Experience-based Methods

These methods depend mainly on the long experience of the scheduler and can be applied to small projects such as the bar chart method.

Deterministic Methods

The precedence relationship between the different tasks required to complete the project should be determined along with the duration for each task then a network of the whole project is created where the long path is considered as the critical path. These methods include critical path method (CPM) and line of balance (LOB), these methods can be applied to intermediate size projects.

Probabilistic Methods

The method such as the project evaluation and review technique (PERT), which is a statistical method used to determine the duration of different activities based on uncertainty. This is translated by determining the optimistic, pessimistic and average duration of a certain activity. This method is used in complex and large-scale projects where the main concern is the time rather than the cost.

Despite the common use of traditional scheduling methods, they have many problems especially for big and complicated projects, for example, it is very difficult to identify the critical path for complex project if there are many paths having the same duration, and also designing the CPM for a big project is time consuming especially in multidimensional projects. In addition, resources cannot be monitored effectively using CPM and bar charts and lastly, sudden changes in the project will require rescheduling the whole project, which is not an effective way to adapt to any necessary changes.

FACTORS AFFECTING CONSTRUCTION SCHEDULING

In this section, a wide literature review is made to identify the main factors affecting the scheduling of construction projects in different countries.

Vidhyasri and Sivagamasundari (2017) made a wide literature review to identify the substantial factors, which should be considered when planning and scheduling any construction project, which include constraints on resources availability, weather conditions, government regulations, level of monitoring and controlling project execution, and price escalation of materials, labors, and equipment especially for long projects.

Sinesilassie et al.(2016)studied the critical success factors of scheduling public construction projects in Ethiopia using factorial analysis, the results of ANOVA analysis indicates that the following factors affect the scheduling:

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ISSN: 2186-8476, ISSN: 2186-8468 Print
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i. Project manager's knowledge and experience: a clear understanding of project scope, well-planning, and organizing of project execution at site facilitates monitoring, controlling the project progress easily, and anticipating any sudden problems before their occurring.
ii. Coordination and communication between project parties enhance completing the project within estimated time.
iii. Regular monitoring and feedback between site engineer and project manager improve project progress.
iv. Defining responsibilities of each party involved in the construction process prevent any conflicts in the future.
v. Clear plans and specifications help reducing change orders during construction and maintenance of the prepared schedule without any delay.
vi. A good prediction of weather conditions helps to organize the work at the site without any delay and improve resource management.

Aziz and Abdel-Hakim (2016) identified the top factors affecting the scheduling of road projects in Egypt as follows:

i. The financial ability of the owner (in road projects the Egyptian government is the owner of the project), any delays in progress payment to the contractor leads to project suspension which results in serious delays in project delivery.
ii. On time, delivering the materials and equipment required to commence the work.
iii. Strong site management and supervision of the contractor.
iv. Level of coordination between different parties of the construction process.
v. Change orders made by the owner.
vi. Government regulations and bureaucracy in obtaining permits and payment progress.
vii. Quality of materials and equipment used in the project.
viii. Lack of experience of consultants in dealing with extraordinary situations.

- Weather conditions.

Upadhyay et al. (2016) studied to determine the critical factors required for successful completion of the project at Gwalior in India. These factors include:

i. Effective planning and scheduling by a clear understanding of project scope and specifications.
ii. Detailed preparation of the contract, design documents, and drawings before starting the work at the site.
iii. Owner's commitment to pay the contractor on time.
iv. Clear definition of responsibilities of each party.
v. Availability of labors and equipment necessary for the project.
vi. On time delivery of required materials.
vii. Selecting qualified contractors.
viii. Selecting qualified subcontractors.
ix. Selecting qualified project manager and site engineer.

Wambui et al. (2015) studied to identify the main factors that should be considered in urban road construction projects in Nairobi, which include:

i. Project management experience.
ii. Project information technology used to control the progress of the project, which includes the database and software used by the management team.
iii. Availability of funds for the project.

iv. Quality of equipment used in road construction projects.
v. Availability of skilled labors.

In addition, the study recommends more study of mobilization methods of equipment to increase the productivity and reducing waiting times.

Ravisankar et al. (2014) studied the main causes of schedule delays in a construction project in India. A detailed questionnaire was prepared and distributed among contractors to gather required data. The data analysis reveals that the main reasons for delays are:

i. change orders made by the owner of the project.
ii. Bad weather conditions such as floods, and earthquakes.
iii. Unforeseen problems during construction.
iv. Shortage of skilled labors which increases the reworking items due to errors.
v. High changing in materials and equipment's prices.
vi. Ineffective site management and supervision.
vii. High idle times for equipment's maintenance.
viii. Delays in paying the contractors.
ix. Inaccurate time estimation and wrong selection of equipment.

Culfik and Alton (2014) focused on scheduling failure in Turkey's construction industry, the top reasons behind this failure are:

i. Underestimation of project duration due to lack of experience and unforeseen conditions.
ii. Slow in taking critical decisions.
iii. The financial ability of the contractor to continue working with owner's delay in payment.
iv. Inaccurate planning of the project.
v. Lack of resources.
vi. Bureaucracy in obtaining government permits.
vii. Delays in materials delivered to the site.
viii. Change orders made by the owner during construction.
ix. Project suspension by the owner.
x. Delays in contractor's payment.

Wong and Vimonsatit (2012) stated that the schedule of construction projects in Australia is affected by many factors, which include:

i. Availability of local skilled engineers: the government focuses on training and developing local site engineers instead of depending on foreigners who solve the problem for a short period.
ii. Financial resources of owners and contractors: the shortage of owners in paying the contractors for each progress in construction process will make the contractors unable to continue working in the project cause serious delays in the schedule and consequently cost overrun. Therefore, it is very important for the contractors to have reliable financial resources to support themselves in case of any delay from the owners.
iii. Availability of skilled workers: this can be done by providing training, good wage rates, incentives, and bonuses to make them continue working effectively in the construction industry.
iv. The accurate anticipation of project completion: predicting a realistic deadline to complete the project is a critical aspect of scheduling to avoid paying any liquidated

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damages. This necessitates including the risk and uncertainty in scheduling to avoid any critical conditions during construction.

v. Well-planned site investigation: will help the contractors to put a realistic schedule and manage any unforeseen ground problems.
vi. Accurate definition and organization of the construction process to minimize change orders, which result in a reliable schedule.
vii. Strong communication systems between different parties involved in the project will support quick decision-making and adjust the schedule quickly without any delay.

Mahamid et al. (2012) conducted a study on the factors affecting the scheduling of road construction projects in Palestine and identified five factors:

i. The political situation of the country, which limits the movement of available resources between different areas of the country.
ii. The rapid increase in material prices due to unstable conditions.
iii. Shortage in the availability of resources especially labors and equipment.
iv. Management skills and experience of project manager.
v. Low quality of materials and equipment available in Palestine due to the siege.

NEW DEVELOPMENTS IN SCHEDULING TECHNIQUES

Many models and improvements in scheduling methods were proposed to cope with the limitations of the traditional methods. In this section, a wide review of many articles published in this field was reviewed and presented.

HarithaMahalakshmi et al. (2017) presented a new method called location-based management system (LBMS) to schedule a residential building and compare the duration obtained from this method with the duration estimated using critical path method (CPM). The CPM was obtained using CANDY software while the LBMS was done using the VICO planner software. The concept behind LBMS is to ensure the continuous working of available resources without devoting different crews to different locations. So it's an integration between Line of Balance method (LOB) and critical path method (CPM). LBMS is suitable for repetitive projects whether it is vertical or horizontal projects. It was found from the case study presented in the article that LBMS provide short duration than CPM.

Biruk and Jaskowski (2017) proposed a mathematical model to schedule repetitive projects where the main objective function is to reduce project duration and find the best solution for resource allocation. The model uses permutations to arrange the working sequence id different sections of the project.

Gurcanli et al. (2017) studied to schedule the use of heavy equipment in Turkish construction industry using Monte Carlo simulation technique. The technique uses a random number generator to select the values of specific variables and based on these values the model calculates the productivity of the equipment. The developed model help project managers and engineers at the site to estimate daily production rate, adjusting bid price, monitoring the daily schedule of equipment and their costs.

Golizadeh et al. (2016) developed four artificial neural networks to predict the duration of reinforcement and concreting activities for beams and columns.

Salama et al. (2016) proposed a new scheduling method for hybrid offsite construction projects. The method depends on modeling the project using the BIM software; this software generates a database containing the list of different components of the building and the sequence of erection. Then integrating the data obtained from BIM with the linear scheduling

method (LSM) and the buffering method of critical chain project management (CCPM) to consider uncertainty in the calculations of activities durations. This method allows producing the schedule at different confidence levels, the basic schedule is produced with 50% confidence level, the proposed confidence levels that can be used to generate the schedule is 25%, 50%, and 75%.

Maghrebi et al. (2014) presented an artificial neural network to predict the duration of concrete casting activity for different parts of the building. The input layer represents the factors affecting this task as follows:

i. The travel time of concrete mixer during a specific day.
ii. The arrival time of concrete mixer at the site.
iii. The total number of concrete mixers ordered.
iv. Location of the project.
v. The total number of received orders by RMC.
vi. The total number of assigned deliveries from the source.
vii. Productivity, which can be calculated by dividing the total number of orders by the total duration taken to reach to the site.

The output layer represents the productivity in cubic meters per hour. The dataset was gathered for 4 months in Sydney metropolitan area and 1673 projects were used to train and validate the model. The mean squared errors (MSE) obtained from validating the model indicates high prediction accuracy.

Petruseva et al. (2013) developed a supervised learning algorithm with the name of support vector machine (VSM) to predict the project duration. 75 building projects were obtained from a survey conducted in Bosnia. The data were analyzed using the regression analysis and VSM to increase the prediction accuracy of project duration.

Wang et al. (2012) developed two models, the first model uses the support vector machines (SVM) to predict the project cost success with an accuracy of 92%. The second model uses an ensemble of artificial neural networks (ANN) to predict the project schedule success with an accuracy of 80%. These two models were trained and tested the data from 92 different projects including houses, hospitals, schools, hotels, offices, stores, and resorts.

Liu and Wang (2012) used the constraint programming (CP) to find the optimum minimum duration when scheduling linear projects. The two constraints considered here is the crew type where there are two types of crews, a single skilled crew hired for one activity, and multiple skilled crews. The second constraint is the interruption allowed during work, the first option is to keep the interruption as minimum as possible while the second option is no interruption is allowed. The proposed model also considers other factors such as the dependency relationship between activities and the cost to find the optimum schedule for horizontal projects.

El-kholy (2012) presented a new model to schedule repetitive projects using multi-objective linear programming to find the minimum project duration, minimum total cost and the minimum interruption time simultaneously. This objective was achieved using LINDO software to find the upper and lower bound for multi-objective function analysis. The results of fuzzy linear programming indicate that the project duration, total cost, and interruption deviated by small amounts from the values obtained from linear programming, which indicate the high accuracy of the model.

Jha and Chockalingam (2011) presented an artificial neural network (ANN) to predict the schedule performance of construction projects in India. The network consists of three layers: input layer represents the factors affecting schedule performance, which include:

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i. Project manager competency.
ii. Feedback from project participants.
iii. The commitment of project participants.
iv. Owner's experience in construction industry.
v. The interaction between project participants.
vi. Organization and coordination between involved parties.

The output layer is the schedule performance, which represents the possibility of time overrun beyond estimated deadlines. The hidden layer represents the processing unit of the artificial neural networks. 91 datasets were used to train and test the validation of the model where two-thirds of this dataset was used for training while the rest were used to test the model.

Yahia et al. (2011) presented an artificial neural network to predict time contingency that should be added to project duration to consider uncertainty in project scheduling. The dataset was collected from Egyptian construction industry and the important factors affecting time contingency were identified using a questionnaire which includes change orders, payment delays, late changes in the project specifications, High number of critical activities, missing items of project scope, inaccurate feedback, efficiency of planning, inadequate information provided by the designer, and unexpected requirements by owner's representative. These factors represent the inputs to the network while the output is the time contingency in days. The dataset consists of 40 projects used to train and test the performance of the proposed model. The root mean squared error indicates a high percentage of prediction of time contingency.

CONCLUSION

It is very clear from the documents available in the literature that the most important factors affecting scheduling process for any project are the financial situation of the owners and contractors, resources availability, weather conditions, change orders, clear understanding of the project scope, communication between involved parties, prices escalation, and the delays in contractors' payment as well as the managers, and engineer's experience. Other factors such as government regulations, bureaucracy, and lack of experience of the owners depend on the political and economic situation of the country. During the last years, many models were developed to improve the scheduling of vertical and horizontal projects by considering many constraints. These models include the artificial neural networks (ANN), linear programming and fuzzy linear programming, location-based management system (LBMS) and support vector machines (SVM).

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