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A MODEL FOR AUTOMATED GENERATION OF RESOURCE-DRIVEN CONSTRUCTION SCHEDULE FOR HOUSING INDUSTRY

A. Cindrela Devi
M.S Scholar
Department of Civil Engineering,
Indian Institute of Technology, Madras
Chennai – 600 036, India
cindrela@iitm.ac.in

K. Ananthanarayanan
Associate Professor
Department of Civil Engineering,
Indian Institute of Technology, Madras
Chennai – 600 036, India
kananth@iitm.ac.in

ABSTRACT

The efficacy of managing a construction project mainly depends on proper planning and scheduling. Mass housing projects are highly repetitive in nature, as the methods used for construction are often repetitive or cyclic. Resources are therefore being deployed repeatedly for the similar or identical tasks in these projects. In order to eradicate delays in mobilizing resources, an efficient resource schedule is required. Traditional scheduling tools like Critical Path Method (CPM), Programme Evaluation and Review Technique (PERT) are less effective in scheduling repetitive construction projects, as they consider availability of resources are unlimited. The main challenge in preparing construction schedule for repetitive projects is synchronizing the precedence logic and the allocation of resources as per requirements for all the activities. Consequently, activity scheduling and resource planning are prepared in parallel and this will facilitate in eliminating delays and idle resources across the projects thereby, controls the chain-reaction management (ripple effects). Nevertheless, almost all the repetitive scheduling methods developed so far have been giving focus on continuous repetitive projects, whereas in the present study, the emphasis is on discrete (non-linear) repetitive projects. This paper presents a model that uses genetic algorithms to optimally assign resources to repetitive activities, which aimed to minimize the total project cost & duration, idle cost & time and to maximize resource utilization. In the present study, an attempt is made to generate a resource-driven construction schedule automatically, with which resources can optimally be allocated to the activities. This schedule can be very useful in improving productivity and saving construction time and cost and also in decision-making. In addition, a case study is delineated to check the efficiency and effectiveness of the resource-driven construction schedule which is automated.

KEYWORDS

Resource Scheduling, Optimization, Genetic Algorithm, Repetitive Project

1. INTRODUCTION

Mass housing construction projects are highly repetitive in nature; since they have lots of repetitive activities which involve repetition of a unit throughout the project. This practice is similar to manufacturing assembly lines. However, in repetitive projects, it is labour and equipment that flow through the product (construction site) while in manufacturing assembly lines, it is the product flowing across stationary labour and equipment [1]. In other words, the products are stationary, whereas resources move from location to location and perform the same work. So the resources will be expertise in their tasks and the effect of learning curve will be more. The repetitiveness of these works is based on the activities involved, the relationships between the activities within a particular unit and the resource required to carry out the tasks. The traditional scheduling methods like bar chart, CPM, PERT focus on the project duration and give little consideration for effective use of resources. However, the site managers and contractors are more concerned about the effective use of resources rather than critical paths or early completion of the project [2]. The main concern is that these techniques do not consider the availability of resources while calculating the completion time of the project. Moreover, these techniques produce large and complex schedules when applied in the repetitive activities and the complexity increases with the increase in repetition. Hence it is highly impractical for projects that give more importance to resources allotment like mass housing projects. Another limitation is its inability to maintain crew work continuity [3]. Therefore, a schedule for smooth movement of resources is needed for minimizing the idle time, thereby maximizing the resource utilization.

1.1. Challenges in Scheduling Housing Projects

The development of an effective plan for scheduling and control of the mass housing construction involves a number of challenging tasks mainly repetitive activities as in our case. On the other hand, repetitive activities have to be scheduled by a technique that can provide resource-driven scheduling. This can be achieved by integrating traditional network scheduling and resource-driven scheduling techniques in an effective environment [4]. To achieve this, an algorithm has to be developed that incorporates utilization of resources. The resource includes both labours and sub-contractors apart from the tools and equipments. The algorithm should also consider the practical aspects that commonly encountered in this kind of projects.

The objective of this study is to develop a scheduling algorithm for repetitive projects that minimize the project duration and maximize the resource utilization. This algorithm should satisfy the three main constraints: i) precedence logic ii) resource availability iii) continuous deployment of resources. It should also consider the impact of a number of practical factors namely, typical activities, crew availability period on site, utilization of crews, activity interruption, sequence of construction operations, impact of weather and learning curve. To deal with this, the algorithm is developed in two phases: the first phase is to select the appropriate resource/crew option to deploy the resources continuously in optimal way thereby maintaining crew work continuity and the second is to prepare the schedule considering the precedence logic and resource/crew availability constraints.

2. KEY FACTORS IN SCHEDULING PROBLEM

To achieve success in a project, resource planning is a key issue. The main factors listed below are internally interlinked with each other in the resource scheduling.

2.1. Repetitive Projects

A repetitive project involves repetition of a unit network throughout the project. The unit network consists of the activities and their relationships that represent the work to be performed in each unit. The resources (labours and equipments) will perform same job in all the units. Hence the quality of the construction and learning curve will be more and also construction work speeds up [5].

2.2. Idleness

Format for A4 size paper (21cm X 29.7cm) It is common that in repetitive projects the resources are idle and waiting because the resources of precedence activity have not finished the jobs (in other words, the resources are not released from the previous activity). The idleness is due to unbalanced production rates and variation during execution. On the other hand, the jobs are pending and waiting for the crew. It is due to the shortage of labours and can be avoided by proper resource planning [6]. Both the resource idle time and the job waiting time are internally controllable and different from the forced causes like bad weather, labour accidents, etc. This results in higher costs and possible delay.

2.3. Continuous Resource Deployment

In the repetitive projects, the same set of resources will perform same kind of jobs. If these resources (labour and equipment) are not properly allocated among all activities, the continuity of work will get affected. Hence the deployment of resources is significant [7]. By planning the resources with continuous deployment, idleness can be reduced.

2.4. Work Continuity

Even if the resources deployed continuously, the job cannot be started because of the work in progress of the preceding activity. So the crew allotted for that particular activity is forced to wait till the space vacated by the crew allocated for the preceding activities [8]. This idle time turns to the excess of project cost. Hence it needs to be minimized to have the project in control. Here, the idleness is due to the varying production rates and the delay is because of the inspection, rework, etc.

2.5. Limited Resource

Because of the limited resources, there is the probability of project getting extended. In order to complete the project in minimum duration, resources have to be managed effectively. In the repetitive project, each unit composed of various repetitive activities which will be performed by different types of resources. Consequently various combinations of available resources are produced and optimized using genetic algorithm to get a schedule of reasonable duration [9].

The findings of this literature review have been effectively used in the development of the proposed model for scheduling repetitive projects. Fig.1. shows the job movement from one activity to other as well as one unit to the other and also shows the resource movement from one place to another in a typical repetitive network.

3. MODEL DEVELOPMENT

The model is designed considering various practical factors commonly encountered in the housing projects. In order to identify these practical factors, a series of discussions were conducted with the site engineers and managers. The findings of these discussions and the literature reviews were considered in the development of the algorithm.

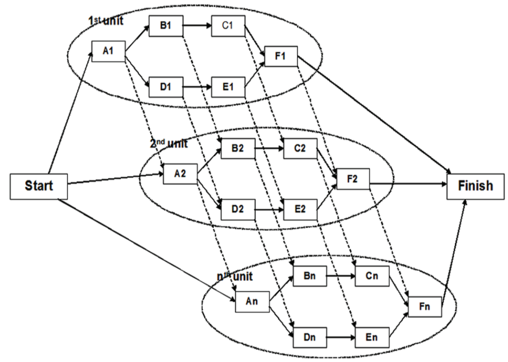

Figure 1 Typical Repetitive Network

A software tool was developed to generate the automated resource-driven schedule. It was intended for getting the information from user, combining genetic algorithm with the schedule. It was developed by integrating Visual Basic, spread sheet and commercial GA based tool for optimization. Fig.2 illustrates the conceptual idea behind the scheduling algorithm.

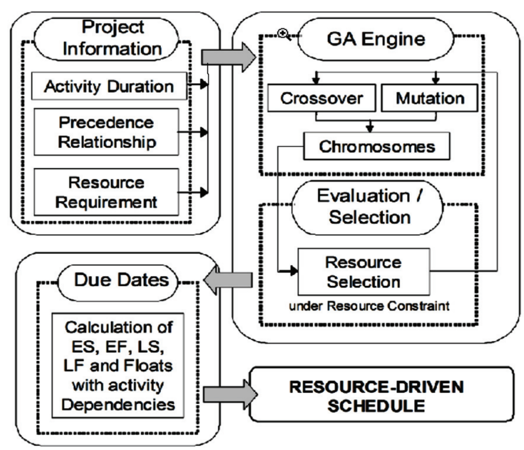

Figure 2 Proposed System of Scheduling with GA

3.1. Model Description

- Variables: Allocation of resources / crew to each of the activity, sequence of the activity according to the resource availability.
- Objective function: To minimize the project duration and maximizes the resource utilization.
- Constraints: a) Precedence logic b)Limitedly

available resources (crew) c)Continuous deployment of resources

- Assumptions: a) The duration is deterministic. b) The availability of materials and equipments are unlimited.c) The activities will be completed in time as per the productivity mentioned. d) No splitting of activity is employed.

3.2. Model Explanation

This research primarily focuses on the planning aspects of housing projects, considering associated constraints like resource availability, precedence logic, and the idle time of resources and the work continuity. The planning process entails

1. Selecting the optimum resource/crew for each of the activity.
2. Developing the schedule for all the activities of all the units in the entire project

The proposed model is designed to automate the schedule according to the precedence logic and resource requirement. The project implementation and the controlling system are outside the scope of this work.

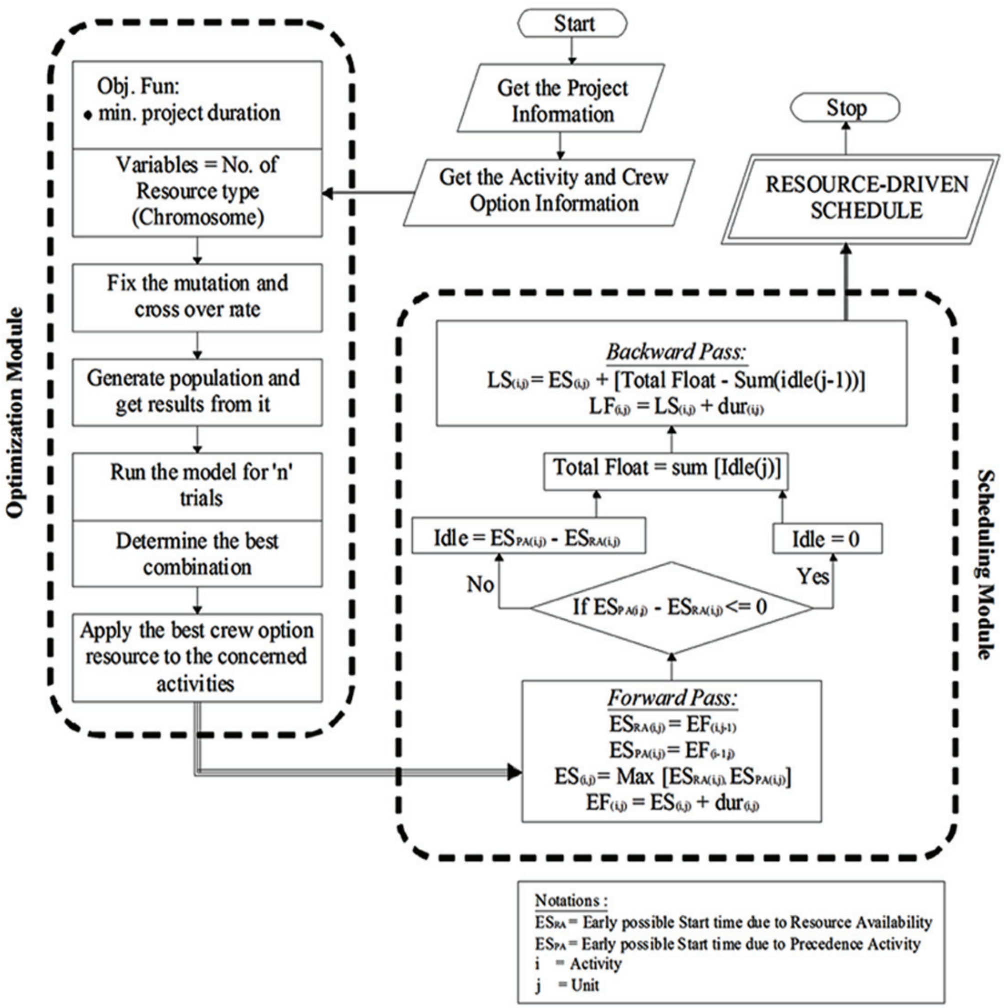

Figure.3 Flowchart of the Scheduling Algorithm

3.2.1 Phase One

The objective of the research is to acquire the appropriate resource/crew combination that minimize the project duration and to select the best crew option for each of the activities. In order to get the best resource/crew combination, the genetic optimization starts with the generation of population (chromosome). The number of chromosome or the population size is the number of the resource/crew type. In the present application, user is given the flexibility to input the mutation and cross over rate. Then, generations are created for the resource/crew combination and checked for the optimal solution. It is to be noted that the crew options are the variables to be optimized in order to get the minimum duration with maximum resource utilization.

3.2.2 Phase Two

In this phase, the schedule is developed by integrating the tasks and the resource availability. The optimum resource/crew option that obtained as output from the phase one is the primary information to control the duration of the each activity. It involves determining the commencement and completion times of each of the activities, work in progress and the resource/crew availabilities and also in allocation of the given resources to various activities in the units. Here the allocation is based on the location of each unit's site in order to avoid wastage of time and cost of mobilizing the resources/crew. The precedence logic among succeeding activities is 'finish to start' and with or without lag time.

4. CASE STUDY

4.1. Description

A Tsunami housing project at Nagapatinam, Tamil Nadu, India is delineated to illustrate the use of the developed resource-driven scheduling model and to demonstrate its capabilities. This project basically a calamity (Tsunami) relief project carrying out by the Government of Tamilnadu associated with other Non Government Organizations. After the Tsunami hit in Dec 2004, there is an immediate need for permanent accommodation for the people in the coastal area since the many of the coastal villages are totally washed away. Here one of the villages is demarcated which consists of 451 houses and construction of each house involves 13 activities. The resource (crew) availability is limited and therefore there is a need for allocating the available resources/crew to each of the activity as per the requirement. The management of the crew is found to be a major problem after regular discussion and meeting with the site and project managers. For the sake of making this paper concise, we have delineated the developed model with a set of fifteen units. The priority of construction is given according to the location of the each unit's site for easy mobilization and sharing of resources. The houses were named in consistent with their position (matrix form) of the entire project site. Each activity is performed by a crew that progresses from the first unit to the last unit sequentially. The precedence logic is 'finish to start' and without lag time. The various crew options are provided with the labour composition and their productivity rate. The concerned input of the housing project is shown in Table 1. The model can be executed even for a project having different types of construction units. It can also comprise of different crew compositions among the resource/crew options.

Table 1 Input Statement of the Housing Construction

S.No	Activity Name	Resource Composition			Resource Option		
		Skilled	Semi skilled	Unskilled	1	2	3
1	Excavation	1	6	5	1	1.5	1.25
2	Foundation	2	8	5	1	1.5	1.25
3	Column	2	7	4	3	3.5	3.25
4	Grade Beam	2	7	3	5	5.5	5.25
5	Brickwork I	6	12	6	5	5.5	5.25
6	Concreting	4	15	6	9	9.5	9.25
7	Curing	0	0	2	9	9.5	9.25
8	Dummy col &Decentering	1	1	1	3	3.5	3.25
9	BrickworkII	8	4	2	3	3.5	3.25
10	Plastering	12	6	3	6	6.5	6.25
11	Flooring	9	6	3	1	1.5	1.25
12	Painting	3	3	2	7	7.5	7.25
13	Finishes	0	0	3	2	2.5	2.25
	Total	50	75	45			

4.2. Validation of the Model

The GA optimization model is executed with the population of 50, mutation rate of 0.1 and the crossover rate of 0.5. The total optimization time taken for simulation is 9.43 minutes and the output is shown in fig.4. It gives the overall detail about the resource used and the time taken for completing each activity as well the project. The detailed graph of resource/crew distribution and the activity timings can also be extracted from the schedule. It also gives us a clear idea about the crew idle time and the job waiting time. So we can mobilize external resources or slow down some of the activities according to the budgeted cost of the project. In short, it also acts as a decision making tool. The auto-generated schedule shows the project duration as 99.5 days. The varying duration in each of the unit denotes the varying productivity of crew options and their availability.

The actual construction on site is in process from October'05 and lagging behind the planned construction schedule as resource planning is not given importance. Hence, this optimization model can be used for further scheduling of resources and activities and for improving the construction. It can be tracked and compared for future research.

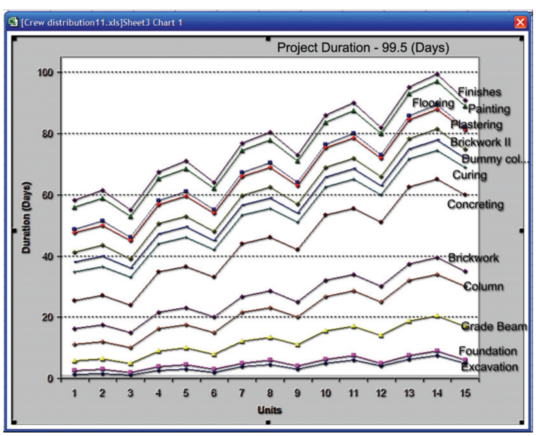

Figure 4 Activity and Resource Schedule of the Housing Construction

The generated resource options are the best crew combination to obtain minimum project duration with maximum crew utilization. External resources can be mobilized for the activities grade beam, column and for concreting to lessen duration. Each unit is completed in varying duration because of the ripple effect.

5. CONCLUSION

The resource-driven scheduling model was developed as a generic model that can be applied to schedule all types of repetitive construction projects such as: housing projects, high-rise buildings, highway construction, pipeline networks and segmental bridge construction. Due to its generic nature, the model considers even the special characteristics and unique requirements if its productivity is defined properly. The model employs resource-driven scheduling, accounts for the impact on crew productivity and considers the beneficial effect of the learning curve. It also facilitates the allocation of resources to activities in process. A case study is delineated to demonstrate the features of the developed model and to illustrate its applicability to planning the mass housing projects.

The proposed algorithm is applied, only for the crew that is being utilized in this project. However it can be expanded to the equipment and materials also. The construction schedule and optimum allocation of resources are the direct output. The priorities, extra mobilization of external resources and the forecasted results are the indirect outputs that help in decision making for the site manager or project manager. This tool can be used by the top management level and can be easily transferred to the low level.

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