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Project Scheduling Analysis in Major Construction Project using Intelligent Scheduling System

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Abstract— During practicing the planning process, scheduling and controlling mega construction projects, there are varieties of procedures and methods that should be taken into consideration during project life cycle. Accordingly, it is important to consider the different modes that may beselected for an activity in the scheduling, for controlling mega construction projects. Critical PathMethod ‘‘CPM’’ is useful for scheduling, controlling and improving mega construction projects;hence this paper presents the development of a model which incorporates the basic concepts of CriticalPath Method ‘‘CPM’’ with a multi-objective Genetic Algorithm ‘‘GA’’ simultaneously. Themain objective of this model is to suggest a practical support for compound horizontally and verticallymega construction planners who need to optimize resource utilization in order to minimizeproject duration and its cost with maximizing its quality simultaneously. Proposed software isnamed Smart Critical Path Method System, ‘‘SCPMS’’ which uses features of Critical PathMethod ‘‘CPM’’ and multi-objective Genetic Algorithms ‘‘GAs’’. The main inputs and outputsof the proposed software are demonstrated and outlined; also the main subroutines and the inferencewizards are detailed. The application of this research is focused on planning and schedulingmega construction projects that hold a good promise to: (1) Increase resource use efficiency; (2)Reduce construction total time; (3) Minimize construction total cost; and (4) Measure and improveconstruction total quality. In addition, the verification and validation of the proposed software aretested using a real case study.

Keywords: Scheduling; Critical Path Method; Programme Evaluation Review Technique; Genetic algorithms, Gene hunters excel interface.

I. Introduction

Techniques that are used for project scheduling will vary depending on project’s duration, size, complexity, personnel, and owner requirements. the construction projects divided into two main groups. The first one is the projects with non-repetitive activities. The second group has multiple numbers of stages. Projects with non-repetitive activities are divided into two main groups. The first one is the bar chartthat is one of the oldest methods used in construction planningand developed by Henry L. Gantt during the World War I; thesecond one is network-based methods which are two widelyknown network based techniques, namely, the Critical PathMethod ‘‘CPM’’ and the program evaluation and review technique‘‘PERT’’. Both methods were developed simultaneouslyand independently during the late 1950s.the construction projects divided with repetitive activities into two categories:linear and non-linear projects. Linear projects arecomposed of number of typical stages with identical activitiesof the same duration that are repeated consecutively from oneunit to the next. Several techniques were developed for projectswith discrete units, such as floors, houses, and offices. Thenames used have included the following: (1) Line Of Balance,‘‘LOB’’ according to O’Brien ; (2) construction planningtechniques according to Peer ; (3) Vertical ProductionMethod, ‘‘VPM’’ according to O’Brien ; (4) time spacescheduling method according to Stradal and Cacha ; and(5) time-location matrix model according to Carr . Severaltechniques were proposed for projects with continuous unitsas highways, pipelines, tunnels, bridges, etc. The progress ismeasured in terms of horizontal length. The names used haveincluded the following: (1) Velocity Diagrams, ‘‘VD’’ accordingto Harris and McCaffer; and (2) Linear SchedulingMethod, ‘‘LSM’’ according to Chrzanowski and Johnston. Line-Of-Balance ‘‘LOB’’ is one production schedulingand control technique, which tries to surpass the CPM difficultiesfor the mega construction scheduling. It is developed intomanufacturing environment by the US Navy, originated at thetime of World War II, according to Burke . Activities thatrepeat from unit to unit create a very important need for a constructionschedule that facilitates the uninterrupted flow ofresources from one unit to the next. It establishes activity-statingtimes and determines the overall project duration. Hence,uninterrupted resource utilization becomes an extremelyimportant issue, according todevelopeda tool for time and resource scheduling for mega constructionprojects; this has been done in three stages. This model called modified repetitive project model ‘‘MRPM’’ depends on theintegration between the principles of ‘‘LOB’’ method and CriticalPath Method. surveyed the different issues,which related to schedule repetitive construction process. Itcan be used in the development of a computerized schedulingsystem. The time-cost tradeoff ‘‘TCTO’’ problem has beenstudied since the 1960s and is considered as a

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particularlydifficult combinatorial problem. All methods in time-costtradeoff branch can be classified into the following categories:linear, integer, or dynamic programming, other methods approximate,heuristic or decomposition approaches, and lately algorithmsto reduce the computational effort.mentioned the relationships between time and cost as shownin the following steps: (1) Linear Relationship; (2) Multi-linearRelationship; (3) Discrete Function; and (4) Curvilinear ContinuousRelationship. proposed a mathematicalmodel for time-cost tradeoff based on the integrationbetween the principles of LOB and CPM. The output of thismodel is to determine the crashed duration for each activitywhich is corresponding to minimum project total cost.

A. Genetic Algorithm

Genetic Algorithms (GA) are inspired by Darwin'stheory about evolution. The GA is a global searchprocedure that searches from one population ofsolutions to another, focusing on the area of the bestsolution. It models with a set of solutions (representedby chromosomes) called initial population,computation is performed through the creation of aninitial population of individuals and modifying thecharacteristics of a population of solutions(individuals) over a large number of generationsfollowed by the evolution, a satisfactory solution isfound. This process is designed to produce successivepopulations that mean the solutions from onepopulation are taken and used to form a new .Basic outline of genetic algorithm is shown in Fig. 1

B. Basic outline of geneticalgorithms steps are as follows

1. Start: generate random populationof n chromosomes (suitable solutions for the problem)

*2.Fitness:*evaluate the fitness f(x) of each chromosome x in the population

3.New population: create a new population byrepeating following steps until the new population is complete

4.Selection: select two parent chromosomes from a populationaccording to their fitness (the better fitness, the biggerchance to be selected). The idea is to choose the better parents.Examples of well-known selection approaches are the following:(a) roulette wheel selection; (b) rank selection; (c) tournamentselection; and (d) elitism.

5.Crossover: allowspromising solutions to share their success by swapping thearrangement of parents' chromosomes genes to new offspring(children) with a crossover probability. If no crossover wasperformed, offspring is an exact copy of parents.

*6.Mutation:*allows random changes in the local search space of a givensolution, mutate new offspring at each locus (position in chromosome) with a mutation probability.

7.Accepting: placenew offspring in a new population.

8.Replace: use new generatedpopulation for further run of algorithm.

9.Test: if theend condition is satisfied, stop, and return the best solution in current population.

*10.Loop:*go to step no

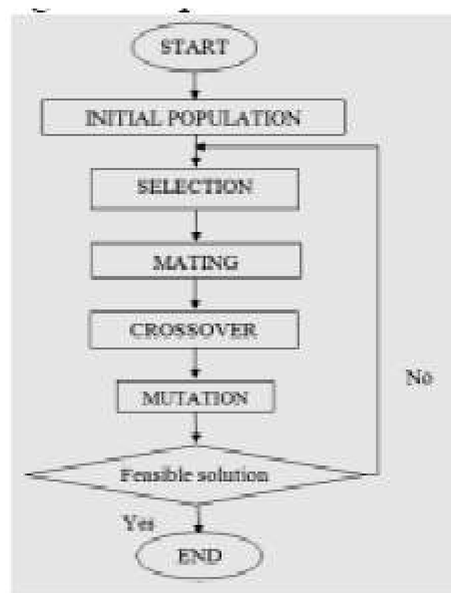

Fig. 1 Flowchart showing The Basic outline of Genetic Algorithm

C. Importance of GA

Genetic algorithm technique provides best solutions in comparison with the other classic approach. Because

Traditional techniques like Microsoft project and Primavera scheduling software do not consider resource constraints, actual cost and duration may vary from the estimated one. An effective GA representation and meaningful fitness evaluation are the keys to the success in GA applications.

The method of solving resource constraint problem using the software Gene Hunter which uses GAoptimization technique is presented in this paper. Gene Hunter is a Powerful software solution for optimization problems which utilizes a state-of-the-art genetic algorithm methodology.Gene Hunter includes an Excel Add-In which allows the user to run an optimization problem from Microsoft Excel, as well as a Dynamic Link Library of genetic algorithm functions that may be called from programming languages such as Microsoft Visual Basic orC.

II. PROBLEM FORMULATION

In order to solve a project scheduling problem involving resource constraint, activities involved in a real-time construction project has been considered. The resource constraint in the form of number of skilled and unskilled labourers available per day is taken.

A. Gene Hunter's Excel Interface

Creating a problem solving model in Gene Hunterrequires that the relevant data is entered into aMicrosoft Excel spreadsheet and specify problemsolving parameters.GeneHunter actually solves the problem by

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allowingthe less fit individuals in the population to die, andselectively breeding the fit individuals. The process iscalled selection, as in selection of the fittest. Twoindividuals are taken and mated (crossover), theoffspring of the mated pair will receive some of thecharacteristics of the mother and some of the father. In nature, offspring often have some slight abnormalities,called mutations. Usually, these mutations aredisabling and inhibit the ability of the offspring tosurvive, but once in a while, they improve the fitnessof the individual. GeneHunter occasionally causesmutations to occur. As Gene Hunter mates fitindividuals and mutates some, the population Undergoes a generation change.The population will then consist of offspring plus afew of the older individuals which Gene Hunter allowsto survive to the next generation. These are the mostfit in the population, and we will want to keep thembreeding. These most fit individuals are called eliteindividuals. After dozens or even hundreds of"generations," a population eventually emergeswherein the individuals will solve the problem verywell. In fact, the fit individual will be an optimum orclose to optimum solution

Fig.2 GeneHunter dialog Screen

The Gene Hunter Dialog screen shown in Figure 2 to identify the cells in the spreadsheet involved in solving the problem. The list of constraints that should be met by the solution can also be listed.

B. Fitness Function Cell

The Fitness Function box tells Gene Hunter the location of the cell which contains the formula that measures Gene Hunter’s success in finding a solution to the problem. The formula may be created using any of the Excel functions that are available from the Insert menu, such as average, sum, percentage, etc.,.Use of Excel macros or Visual Basic functions to create a formula that allows solving very complex problems. A neural net may even be used to model the process if an appropriate mathematical formula is not available.

C. Chromosomes

Chromosomes are the variables whose values are adjusted in order to solve the problem. Their value is related in some way to the fitness function. Gene Hunter uses two types of chromosomes to solve the problems. Continuous Chromosomes are used when the adjustable cell can take on a value that may be withina continuous range, such as the value 1.5 with therange 0 to 2. Continuous chromosomes may also beintegers if the search space is to be restricted.Enumerated Chromosomes are used when theproblem involves finding an optimal combination oftasks, resources, duties, etc.

Table 1 Resource Limit

Resource		Unit	Limit	
			Max	Min
R1	Client	No	3600	3500
R2	Mason	No	101300	101200
R3	Unskilled	No	244300	244100
R4	Crawler	No	680	600
R5	Carpenter	No	28314	28200
R6	Bar bender	No	5850	5700
R7	Plumber	No	12850	12600
R8	Electrician	No	12200	11900
R9	Painter	No	23100	22900
R10	Dewatering pump	No	620	550
R11	Sand	Cum	627100	62700
R12	Brick	1000 No’s	30465	30465
R13	Steel,kg	kg	25079000	25079000
R14	Cement bag(50kg)	Bag	4082000	4082100
R15	Project manager	No	3550	3400
R16	Site In charge-Block based	No	8000	7800
R17	Site engineer	No	16000	15800
R18	Foremen	No	39300	39100
R19	Supervisor	No	31950	31750

Table 2 shows the Resource Limit and Actual usage

Solution	Total duration(days)	No. of generation
MSP	504	-
Primavera	504	-
Gene Hunter	760	200

III. CONSTRAINTS

The constraint portion of the GeneHunter dialog boxallows doing the following:

Limit the range of values that GeneHunter will searchfor a solution, thus limiting the time taken to find an optimal solution. This is called hard constraint.Add restrictions or sub-goals to the original fitnessfunction. This is called a soft constraint. Solutions areattempted to be found that meet the soft constraints, aswell as optimize the fitness function.

A. Smart Critical Path Method System

‘‘SCPMS’’Smart Critical Path Method System ‘‘SCPMS’’ software isdesigned by C++ programming code system to provide a numberof new and unique capabilities, including: (1) ranking theobtained optimal plans according to a set of planner specifiedweights that represent the relative importance of time, cost,and quality in the analyzed project; (2) visualizing and viewingthe generated optimal tradeoff between construction duration,cost, and quality according to planner ranking relative weightsto facilitate the selection of an optimal plan that considers thespecific project needs; and (3) providing seamless integrationwith available project management calculations to benefit fromtheir practical project scheduling and control features. In orderto provide the aforementioned capabilities of SCPMS software,the system is implemented as shown in and developedin four main modules, (1) databasemodule to facilitate the storage and retrieval of constructionscheduling, resource utilization, and optimal tradeoff data;(2) running module to provide a seamless integration of theproject database with processing module and smart optimizationmodel and responsible for all calculations runs; (3) processingmodule to do all calculations; and (4) user interfacemodule to facilitate the input of project data and the visualization of the three-dimensional time-cost-quality tradeoff generated by the system.

IV. CASE STUDY

A. Objective function

The objective function is tofind the best schedule that gives minimum totalproject duration (T)

Minimize (T)

Where,

T depends on start date (Si) of activity and its duration (Di), i.e.,

T=Maximum (Si+Di) subjected to resource constraint

B. Resource limit

The table 1 shows the range of resource limits. Requirements of resources per day and duration in shown in table1. This data are input in GeneHunter, software

V. RESULTS

A. Comparison between two solutions

Intended goal of achieving the best schedule withresource constraints gives optimized duration of theproject is T = 760 days. Solution obtained from MSP is practically notpossible for tracking process and for execution. Henceoptimized duration is 760 days.

Input can be real values or variables in Gene Hunterwhereas it is only variables in MSP. Both GeneHunterand MSP undertake time and Predecessor constraint,but resource constraint can be incorporated inGeneHunter software.

VI. CONCLUSION

This paper presents the development of smart optimizationmodel in order to support the balance between time, costand quality simultaneously for major construction projects.The model was designed to search for the optimal resource utilizationPlans that minimize construction time and cost whilemaximizing its quality, and also to make development in threemain tasks. First task, the model is formulated to incorporateall major decision variables and to enable the optimization ofthe three major objectives in this resource utilization problem. Second task, the model is formulated to enable quantifyingconstruction quality in the optimization process, and thenthe model is implemented as an advanced multi-objective evolutionaryalgorithm in third task.User interfacemodule to facilitate the input of project data and genetic algorithmparameters, as well as the visualization and ranking ofthe obtained optimal solutions. An implementation of the GA developed model for in resource-constrained project scheduling hasresultedin optimized output with reduced cost. A real timeproject solved using this optimization software showsthat best converging result can be obtained.

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