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Optimization of Construction Projects Scheduling Using Primavera and Genetic Algorithm

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ABSTRACT
Resource allocation and leveling are among the top challenges in project management, due to the complexity of projects. The main objective of this project is to optimize the schedule of construction project activities in order to minimize the total cost with resource constraints using Genetic Algorithm (GA optimization technique). This work describes a genetic algorithm approach to Resource Constraint Project Scheduling Problems (RCPSP) in construction industry. The GA procedure searches for an optimum set of tasks and priorities that produce shorter project duration and better-leveled resource profiles using Evolver software. Major advantage of the procedure is its simple applicability within commercial project management software systems to improve the performance.

KEYWORDS: Genetic Algorithm, Resource Scheduling, Resource constraint Scheduling, Construction management, Evolver.

1. Introduction

Resource management is one of the most Chan,et al., 1996, Cengiz 2002, Ahmed important aspects of construction project 2008). management in today's economy because the compared with traditional heuristic and construction industry is resource intensive and mathematical models, the genetic algorithm scheduler the costs of construction resources have steadily has several advantages as it can consider. Risen over the last several decades. the objectives of time/cost trade-off, Every project schedule has its own resource-constraints allocation, and precedence Constraints, which means that each resource leveling for traditional models activity can be processed when all its to have such a function. It has more predecessors are finished. In general, the flexibility to solve scheduling problems purpose of project scheduler is to minimize of different types, because no heuristic the completion time or make span, subject to rules are necessary. precedence constraints.

1.2 Genetic Algorithm

This paper brings out the drawback in existing Genetic Algorithm (GA) are inspired by Scheduling software and the method of using Darwin's theory about evolution. The GA for resource constraint scheduling by means is a global search procedure that searches of a case study. From one population of solutions to another Traditional scheduling methods using scheduling focusing on the area of the best solution. It rules specific to the project model or constraint models with a set of solutions (represented formulation, this method uses a direct by chromosomes) called initial population, representation of schedules and a search computation is performed through the algorithm that operates with no knowledge creation of an initial population of the problem space. The representation individuals and modifying the characteristic enforces precedence constraints, & the

objective of a population of solutions over a large function measures both resource constraint number of generations followed by the violations and overall performance. The evolution, a satisfactory solution is The advantages of using GA based optimization found. This process is designed to Technique for resource based scheduling has to produce successive populations.

1.2.1 Fitness Function

The fitness function is the function to be optimized. For standard optimization algorithms, this is known as the objective function.

1.2.2 Individuals

An individual is any point to which the function can be applied. The value of the fitness of an individual is its score; an individual is a single solution. A chromosome is a set of parameters which define a proposed solution to the problem that the genetic algorithm is trying to solve. The chromosome is often represented as a simple string.

1.2.3 Populations and Generations

A population is an array of individuals. At each iteration, the genetic algorithm performs a series of computations on the current population called parents to produce a new population called children. Each successive population is called a new generation. Typically, the algorithm is more likely to select parents that have better fitness values.

1.2.4 Encoding

A chromosome is subdivided into genes. A gene is the GA representation of a single factor for a control factor. The process of representing the solution in the form of a string that conveys the necessary information is called Encoding. Each gene controls a particular characteristic of the individual; similarly, each bit in the string represents a characteristic of the solution. Encoding Methods are Binary Encoding, Permutation Encoding (Real number encoding), and Value Encoding.

2. Basic Outline of Genetic Algorithm

Figure 1 shows the various steps involved in Genetic Algorithm process.

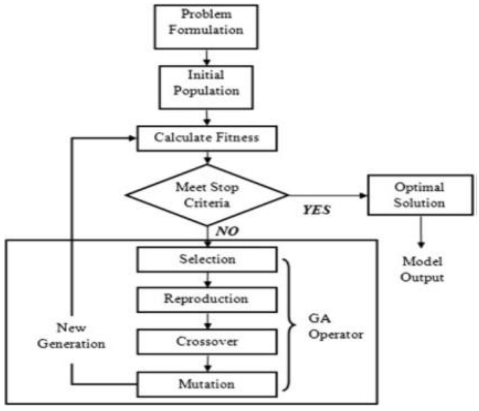


Fig. 1 Flowchart showing the Genetic Algorithm process

2.1 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 Evolver which uses GA optimization technique is presented in this paper.

Evolver is a powerful software solution for optimization problems which utilizes a state-of-the-art genetic algorithm methodology. Evolver 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 or C.

3. 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.

3.1.2 Evolver's Excel Interface

Creating a problem solving model in Evolver requires that the relevant data is entered into a Microsoft Excel spreadsheet and specify problem solving parameters.

Evolver actually solves the problem by allowing the less fit individuals in the population to die, and selectively breeding the fit individuals. The process is called selection, as in selection of the fittest. Two individuals are taken and mated (crossover), the offspring of the mated pair will receive some of the characteristics of the mother and some of the father. In nature, offspring often have some slight abnormalities, called mutations. Usually, these mutations are disabling and inhibit the ability of the offspring to survive, but once in a while, they improve the fitness of the individual. Evolver occasionally causes mutations to occur. As Evolver mates fit individuals and mutates some, the population undergoes a generation change. The population will then consist of offspring plus a few of the older individuals which Evolver allows to survive to the next generation. These are the most fit in the population, and we will want to keep them breeding. These most fit individuals are called elite individuals. After dozens or even hundreds of "generations," a population eventually emerges wherein the individuals will solve the problem very well. In fact, the fit individual will be an optimum or close to optimum solution.

3.1.3 Evolver Dialog Screen

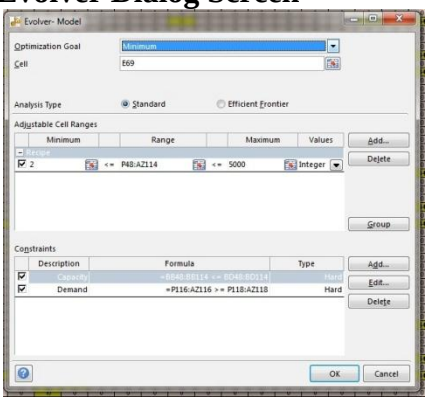


Fig.2 Evolver Dialog Screen

The Evolver 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.

3.1.4 Fitness Function Cell

The Fitness Function box tells Evolver the location of the cell which contains the formula that measures Evolver'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.

3.1.5 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. Evolver 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 within a continuous range, such as the value 1.5 with the range 0 to 2. Continuous chromosomes may also be integers if the search space is to be restricted. Enumerated Chromosomes are used when the problem involves finding an optimal combination of tasks, resources, duties, etc.

3.1.6 Constraints

The constraint portion of the Evolver dialog box allows doing the following: Limit the range of values that Evolver will search for 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 fitness function. This is called a soft constraint. Solutions are
attempted to be found that meet the soft constraints, as well as optimize the fitness function.

4. Case Study

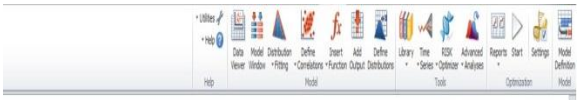
The project case study consists of construction of hospital building, which is located at Al-Diwaniya city in the middle part of Iraq and It is consists of three floors
(ground floor, first floor and second floor).
The Iraqi government planned to improve and construct the hospital buildings distributed all around the country due to the special political, security and the war conditions which are lasting in the country since 2003.
The project is implemented by Al-Andulos construction company. Total construction area is about 1300 m^2 (14000 $[\![ft]\!]$^2), and the total cost estimated for Al-Diwaniya general hospital is about (1,200,000 $).
Taking Al-Diwaniya General Hospital building as case study to realize the actual uses and benefits of using the genetic algorithm to solve the problem of optimization of recourses scheduling .

4.1 Objective function: The objective function is to find the best schedule that gives minimum total project 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

4.1.1 Resource Limit:

The following table shows the range of resource limits. This is input in Evolver,

Table 1 Resource Limit



	Resources		Resource Type	Unit of Measure	Limit Min / Day	Limit Max / Day	Price / Unit	Cost of Resources
R1	Land Scape crew	LS.L	Labor		1	3	400,000	1600000
R2	Excavation Crew	Ex.L	Labor		1	4	120,000	480000
R3	Back filling Crew	B.F.L	Labor		1	3	120,000	360000
R4	Shuttering Crew	SH.L	Labor		3	6	250,000	9500000
R5	DE shuttering Crew	DSH.L	Labor		3	6	110,000	4180000
R6	Isolation Crew	ISO.L	Labor		1	4	150,000	900000
R7	Steel fixer Crew	ST.L	Labor		3	6	300	11700
R8	Concrete Placing Crew	CON.L	Labor		1	3	470,000	2820000
R9	Bricks Crew	BR.L	Labor		2	4	165,000	1980000
R10	Sanitary Crew	SA.L	Labor		1	2	300,000	1800000
R11	Electrical Crew	ELE.L	Labor		4	10	150,000	8950000
R12	Carpenter's Crew	CAR.L	Labor		4	10	120,000	5760000
R13	Plastering Crew	PLS.L	Labor		3	10	150,000	3600000
R14	Painting Crew	PIN.L	Labor		5	8	100,000	1800000
R15	Finishing Crew	FIN.L	Labor		2	4	200,000	2400000
R16	Concrete ready mix Crew	CNR.L	Labor		3	6	300,000	10220000
R17	Loader	LO.E	Notlabor		4	10	150,000	3750000
R18	Scraper	SC.E	Notlabor		1	4	400,000	1600000
R19	Excavator	EX.E	Notlabor		4	7	400,000	2400000
R20	Truck	TRK.E	Notlabor		4	10	120,000	2040000
R21	Roller	RO.E	Notlabor		3	5	350,000	1400000
R22	Water tank truck	WTK.E	Notlabor		1	4	200,000	600000
R23	Vibrator	VB.E	Notlabor		3	6	300,000	6900000
R24	Concrete Mixer	MIX.E	Notlabor		1	3	450,000	10800000
R25	Fine Sand	SAN.M	Material	Cubic Meter	8	50	30,000	16080000
R26	Gravel	GAR.M	Material	Cubic Meter	8	50	20,000	6920000
R27	Portland Cement	CEM.M	Material	Ton	8	20	200,000	32000000
R28	Bitumen	BAR.M	Material	Each	1	10	90,000	900000
R29	Bricks (6 x 12 x 25)	BR.M	Material	Each	1000	5000	60000	864000000
R30	Reinforcement Steel	ST.M	Material	Ton	10	20	500,000	51000000
R31	Wood Forms	WO.M	Material	Square Meter	5	10	200,000	8600000
R32	Anchorage Wire	ANC.M	Material	Kilogram	5	10	7000	427000
R33	Water Tank crew	WTK.L	Labor		1	2	25000	50000
R34	Flooring Crew	FLR.L	Labor		3	5	200,000	4800000
R35	Fixing fence Crew	Fix.F.L	Labor		3	6	100,000	900000
R36	BRC Fence	BRC.M	Material	Square Meter	8	20	30,000	600000
R37	Office Erection crew	OFE.L	Labor		1	3	225,000	6750000

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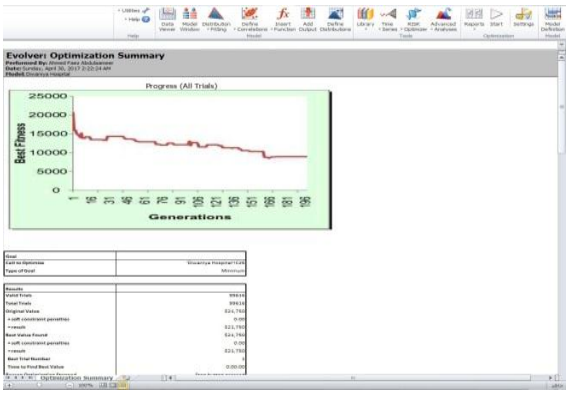


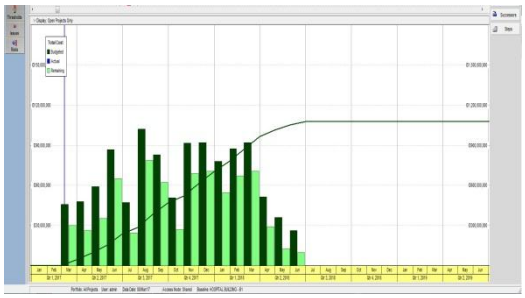
Solution obtained from Primavera is practically not possible for tracking process and for execution. Hence optimized duration is 317 days.

5. Results

5.1 Primavera Software

Implementation of this problem in Primavera with unlimited resources gives total project duration as 345 days. Resource Profile for a resource is shown in the Figure 3,

Fig: 3 Resource Profile



5.2 Evolver Solution

Problem is executed by using many generations. The converging result obtained was T = 317 days by applying resource constraints. Best fitness is obtained in 200 generations.

5.3 Comparison Between Two Solutions

Intended goal of achieving the best schedule with resource constraints gives optimized duration of the project is T = 317 days.

Table: 2 Comparison Actual Usage of Resources and Cost

Code	Primavera		Genetic Algorithim	
	Resource	Cost, ID	Resource	Cost, ID
R1	400,000	1600000	400,000	1500000
R2	320,000	1600000	320,000	1500000
R3	120,000	120000	120,000	110000
R4	250,000	1500000	250,000	1350000
R5	110,000	8800000	110,000	7800000
R6	250,000	12500000	250,000	10003000
R7	520000	26000000	520000	24000000
R8	470,000	1880000	470,000	320000
R9	165,000	8250000	165,000	7210000
R10	300,000	600000	300,000	400000
R11	150,000	1500000	150,000	1250000
R12	1,200,000	120000000	1,200,000	80000000
R13	150,000	1350000	150,000	1110000
R14	750,000	15000000	750,000	11500000
R15	200,000	400000	200,000	320000
R16	350,000	17500000	350,000	16500000
R17	320,000	3200000	320,000	2800000
R18	400,000	20000000	400,000	17500000
R19	400,000	2000000	400,000	1600000
R20	120,000	1200000	120,000	1100000
R21	350,000	3500000	350,000	2750001
R22	200,000	12000000	200,000	9000000
R23	300,000	15000000	300,000	14000000
R24	450,000	36000000	450,000	25560000
R25	120,000	6000000	120,000	5600000
R26	750,000	112500000	750,000	101200000
R27	200,000	4400000	200,000	4400000
R28	120,000	3000000	120,000	2700000
R29	120000	600000000	120000	590000000
R30	500,000	9500000	500,000	9400000
R31	630,000	12600000	630,000	12200000
R32	200000	2000000	200000	2000000
R33	250000	2500000	250000	2400000
R34	200,000	2600000	200,000	2500000
R35	180,000	3240000	180,000	3240700
R36	230,000	2990000	230,000	2982000
R37	225,000	4500000	225,000	4450000
Total		1077330000	Total	982255701
In Direct Cost		500,000,000		500,000,000
Total Cost		1577330000	Total Cost	1482255701

Input can be real values or variables in Evolver whereas it is only variables in Primavera. Both Evolver undertake time and Predecessor constraint, but resource constraint can be incorporated in Evolver alone.

6. Conclusion

An implementation of the GA developed model for resource-constrained project scheduling has resulted in optimized output with reduced cost. A real time project solved using this optimization software shows that best converging result can be obtained, the total cost of the project has been reduced by 6.4%, the total duration of the project has been reduced by one month.

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