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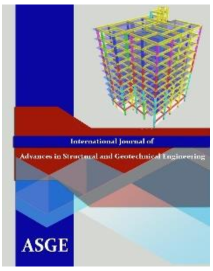

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ABSTRACT:

Time-cost trade off problem one of the most popular conflict multi objective optimization, which contain two conflict objectives function (time and cost). A set of optimal solutions (largely known as Pareto-optimal solutions) are arise, instead of a single optimal solution. This paper introduces multi-elitism techniques and multi selection processes to guide the genetic algorithm for finding multiple nondominated solutions Pareto front (time-cost trade off curve) that enjoy accuracy, a proximity to optimal Pareto front and diversity, which gives the project managers alternatives to help them make the right decision to implement the project more confidently. The VBA and Julia programming language has been used in writing code for these algorithms and show results.

Keywords: *Time-cost trade, Elitism, Julia programming, VBA programming, Optimal schedule, genetic Algorithm.*

1.Introduction:

Time and cost are two major factors in the construction industry; usually use in the project planning. Project planning is defined as "a process of choosing the one suitable method and order of activities from all the various ways and sequences in which it could be done, for completion of a project" [1]. the contractor has many decisions available that can provide for each activity that leads to an infinite number of schedule Making the choice of ideal construction methods that provide optimal balance more complex [2]. In scheduling the project duration can be compressed (crashed) by expediting some of its activities in several ways including; increasing crew size above the normal level, working overtime, or using alternative construction methods. The crashing alternatives come at an additional cost.**Fig.1** This trade-off between time and cost has been studied extensively as conflict multi objective Because maintaining both goals (time-cost) at the same time is not logical and impossible **.so**

The objective behind time–cost trade-off problem is to identify the set (or sets) of time–cost alternatives that will provide the optimal schedule [3]. this paper introduces multi elitism genetic algorithms techniques, which play great role to i) improve a time-cost trade-off curve, that deal with all direct cost in the project (martial-labours-equipment's subcontractors) showing the relationship between project duration and direct cost (time-cost curve). Also, by adding indirect cost curve, the optimal balance of time and total cost (optimal schedule) is determined. **Fig.2**. which provide the optimal selection of construction methods for project activities. ii) this approach is not limited to simple networks with finish-to-start relationships but has been developed to deal with all relationships (fs, ss , sf , ff) and delays .iii) Those algorithms applied on simple network consists of 18 activity with different selection mechanism.

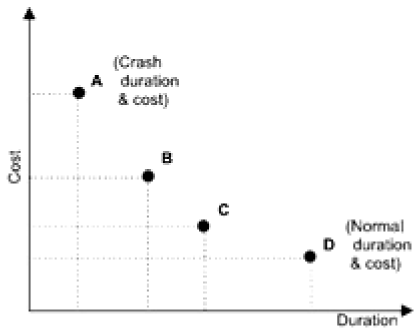


Fig. 1.
Typical relationship between time and cost of activity

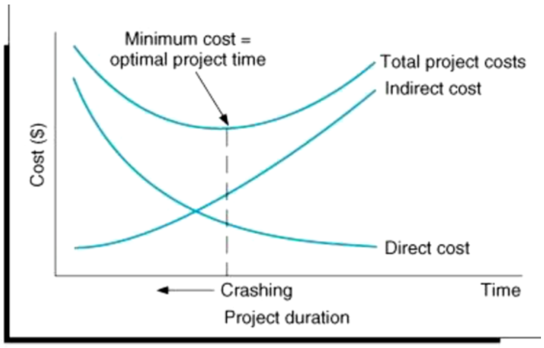


Fig. 2.
General relationship of project construction cost to duration

2.Litrutrue REVIEW:

Many research has been proposed to solve the problems related to time -cost in construction industry. This is due to the determination of the relationship between time and costs at the level of activity, whether continuous or discrete function etc. Time–cost tradeoff problems from the late 1950s mostly concentrated on shortening overall project duration by crashing the time required to complete individual activities.

2.1. mathematical models:

Mathematical programming method convert the Time-Cost Trade-Off problem (TCTP) to mathematical model and utilize linear programming, integer programming and dynamic programming to solve them. Such as linear programming models (Elmaghraby and Salem, 1982; Goyal, 1975; Kelley and Walker, 1959; Kelly,1961 ; Perera, 1980; Phillips and Dessouky, 1977; Siemens,1971) and nonlinear programming models (Deckro et al., 1987, 1995; Fulkerson, 1961; Meyer and Shaffer, 1963; Patterson and Huber, 1974). Under the assumption that time and cost tradeoffs for individual activities are linear, the relationship can be represented as a straight line on a graph depicting the relationship between activity time and cost (Wiest and Levy, 1997). The cost of completing the activity varies linearly between the normal time and the crash time (Fulkerson, 1961). Liu et al (1995) had developed a linear programming (LP) model for optimizing time-cost problem of construction project. Burns et al (1996) had proposed a hybrid optimization approach that is combination of linear programming and integer programming for determining the time-cost trade-off solution of construction scheduling problem. The method is applied in two stages: first stage is used to generate lower bound of the minimum direct curve and in second stage integer programming is used to find the exact solution. The limitation of this method is that it is time consuming and tedious.

2.2.A Heuristic method:

It based on the past experience of the project planner for problem solving. Examples of heuristic approaches include Fondahl's method (Fondahl 1961), Prager's structural model (Prager 1963), Siemens's effective cost slope model (Siemens 1971), and Moselhi's structural stiffness method (Moselhi 1993). These heuristic methods provide fairly good solutions, even though they may not be optimal

2.3. Meta-heuristic methods:

Different meta-heuristic methods had used for time-cost trade-off problem. These methods are: Genetic Algorithm (GA), Ant Colony, swarm method etc. Feng et al (1997) had used a GA to solve construction time-cost trade-off problem using Pareto. This model provides a number of solutions for particular project. The limitation of this approach is that it is only applicable to the finish to start relationship within the activities and it is also unable to deal with limited resources available for a completion of project. According to Li and Love (1997) had proposed a model to reduce the computational effort for optimization of problem. They had produced an improved GA model for optimizing time, cost and resources. The disadvantage of a proposed method is that
(1) They consider crash time as continuous variable which can be impractical.
(2) They did not consider resource constrained situation.

Hegazy (1999) had used a GA solver tool in MS project 4.1 to optimize the construction time-cost problem. An advantage of this method is that it considers project deadline, daily incentive, daily liquidated damage and daily indirect cost. Disadvantage of this method is that it is random in nature and require considerable amount of computation time for large network problem. Also, According to Daisy X. M. Zheng1; S. Thomas Ng 2; and Mohan M. Kumara swamy (2004) produced Multi objective approach that aims to optimize total time and total cost simultaneously by utilizing appropriate GAs concepts and tools. The model introduces a MAWA modified adaptive weight approach to replace traditional fixed MAWA.

3. CONICAL TIME - COST GENETIC ALGORITHM PROCEDURES:

Briefly, GA maintain many schedules in a generation. The number of schedules in the generation is the **population size** (pop size). Everyone has two features: Its location (**chromosome** consists of **genes**) and its strength or quality (**fitness** value) which determined form evaluation the objective function (time and cost). After obtaining the quality of all individuals, we use **selection** process to generate a mating pool. schedules with greater quality (fitness) must have a more probability of being chosen into the mating pool so that the best ones will have more chances to mating and the worst ones will not be chosen. schedules in the mating pools are called **parents**. Generally, two parents might be selected randomly from the mating pool to generate one or two offspring **Fig.3.** as following:

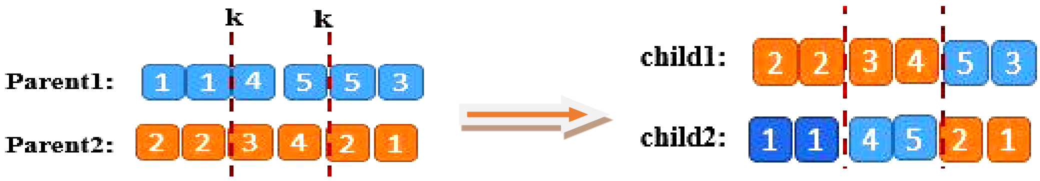


Fig.3. (parent-offspring)

4. PARETO FRONT (EFFICIENT SET OR INFERIOR SET) CONCEPT:

Introduced by Vilfredo Pareto in the 18 hundred years ago, the main idea of the Pareto optimum is the customarily accepted mean for examine the difference of two solutions in multi objective optimization. That have no unified criterion about optima [4]. Non-inferior solutions are the out put of multi objective optimization problem instead of a single optimal solution, In the lack of any additional data or information, Pareto-optimal points cannot be said to be better than the other. This demands a decision support to obtain multi Pareto-optimal solutions as possible, this is what we seek to achieve in this paper. If any schedule S1 is better than S2 in terms of all objective values (Time and cost), we say that the solution SI dominates S2 or the solution S2 is inferior to SI. Any member of the feasible region that is not dominated by any other member is said to be non-dominated or non-inferior **[3]**. The region defined by Pareto optimal solutions is called the Pareto front, and the objective of multi objective optimization is to establish the entire Pareto front for the problem instead of a single best solution.**Fig.4**

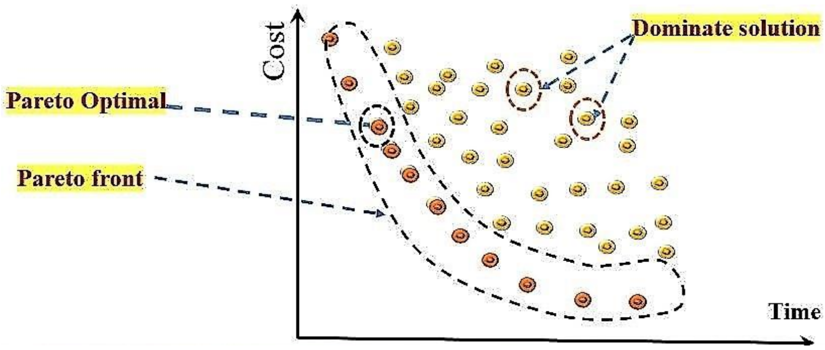


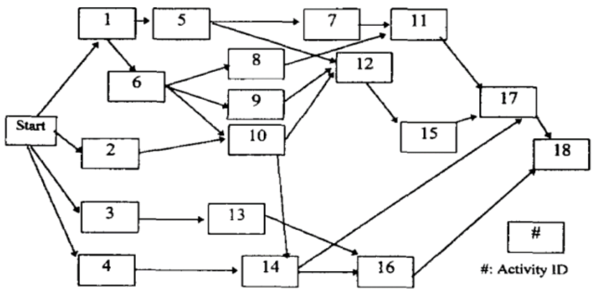
Fig. 4.
The concept of pareto

5. ELITISM MULTI OBJECTIVE EVOLUTIONARY ALGORITHMS:

Sometimes best parents can be miss when reproduction (cross-over or mutation) results in offspring that are lower fitness than the parents. Often the EA will re-discover these miss improvements in a next generation but there is no guarantee. To combat this, we can use a treat known as elitism. Elitism include copying a small ratio of the fittest parents, unchanged, to the. next generation. This can occasionally have a great effect on performance by ensuring that the EA does not spend time re-discovering before neglected partial solutions. Candidate individuals that are conserved unchanged within elitism keep eligible for chosen as parents when breeding the residue of the next generation. This is what has been to focus on the papers.

6. EXPERIMENTING WITH THE MODEL:

6.1. NETWORK CASE STUDY:



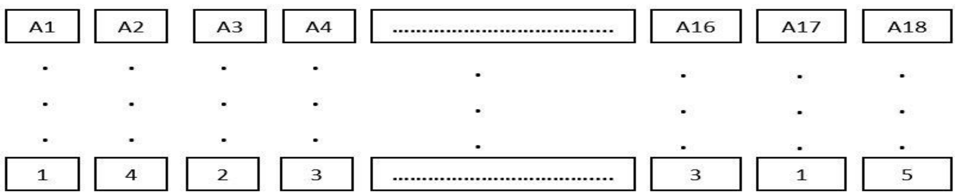
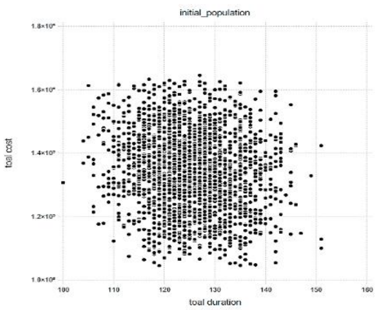


Fig.5
Chromosome structure and population for network

In this section an example construction project with eighteen 18-activities networks is used to illustrate genetic procedures in.**Fig.5** This network could be presented as string or array with has 18 element or bit, the value of each element or position within the string refer to which construction method is randomly selected from (1 to maximum number of options for activity) to complete the activity called (genetic material), and the index of element indicates activity ID. Because of the permutation produced by assigning different construction methods for each activity there are k^m number of random strings in decision space. each string represents a potential schedule to the problem where m is the project activities length and k refer to number of construction methods as. **Fig.5**. Julia programing is utilized to produce chromosomes and population with initial pop size length 2000 chromosome. **To evaluate** objective functions for each chromosome, Notice that when the user customizes construction method of each activity randomly find that each activity takes and different time and cost, which leads to change the total cost and total deadline of the project that are determined by calculation of forward path in CPM and by summing up the cost for each activity. Using VBA program and Julia algorithm which can produce an infinite number of schedule have different costs and time [4]. **Fig.6.**

Fig.6 evaluation



Fitness function value is determined by calculate the smallest distance from each schedule to convex hull boundary, the smaller this distance the more fit is the individual as. **Fig.7**.

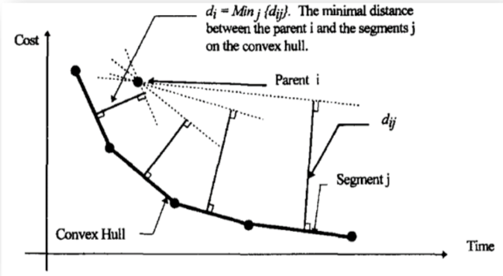


Fig.7. (determine the fitness value)

so, we find the offspring population move toward the boundary of convex hull and toward the optimal trade off curve by apply reproduction operators from selection (tournament, roulette wheel) -crossover – mutation as **Fig.8.**

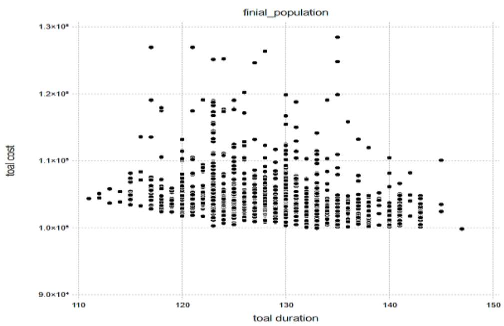


Fig.8. (Offspring population)

Then with the concept of pareto mentioned above we maintain the non-dominated schedule for each generation and apply different algorithms which guide the GA to generate schedules more converge and more diversity to provide the project manager with more alternatives to complete the project that help him to make right decision to implement the project more confidently. This is what we will illustrate in next section.

7. MULTI NON-DOMINATED ARCHIVE ALGORITHMS:

7.1. Algorithm1: (simple non-dominated archive):

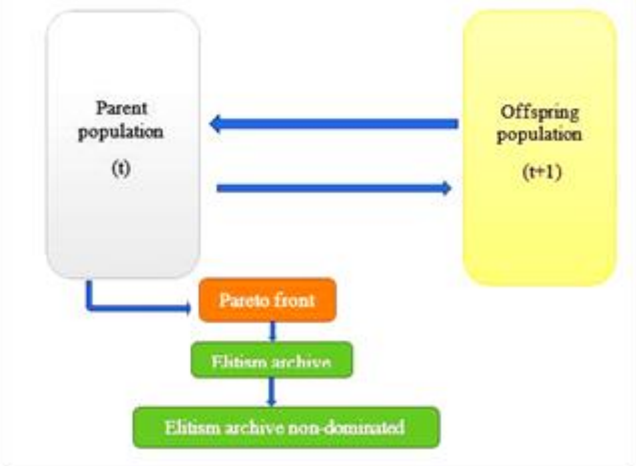


Fig.9. Nondominated Archive Algorithm

In this algorithm, the best schedules are maintained in the population at every generations inside the archive but the non-dominated schedules of the offspring population are compared with that of parent schedules to form an overall non dominated set of schedules only this set called Elitism in this Julia code but this set dose not participates in all genetic operations its only function is to assemble effective sets in each generation and compare them to other in order to be each schedule in the archive pareto optimal solution .the genetic algorithm operators still generate the efficient solutions until the length of Elitism remains constant then stop the repeat processes this mean that This means that there is no improvement in generations and this is an indicator to end the algorithm In this algorithm, the researcher has implemented two types of selection Roulette Wheel Selection and tournament selection and compare the results in order to show which is best to deal with the problem of study with the algorithm.

7.2. Algorithm 2: (non-dominated archive with elitism Pareto- restricted mating):

In this algorithm:

step1: combined population: the best schedules in the population are maintained in another variable called Pareto front then generate anew population, Crossover and mutation are then to the reproduced new individuals according to the specified crossover and mutation rates Pc and Pm to create a new generation this called Meta population then evaluate objectives time, cost and calculate the fitness values for each individual in meta population then sorting the generation according to its fitness values in other words, arrange the generation according to its proximity to the convex hull boundary, After that a number of individuals are replaced who have the worst fitness with the best solutions in the previous generation (Pareto front variable) this population is called combined-population.

step2: Restricted mating: During the process of selecting parents, the selection mechanism is forced to produce one of the parents from the best solutions in the previous generation and make any kind of selection process on the second parent this force new population to move toward the convex hull and pareto front.

Step 3: applying algorithm 1(**non-dominated archive**).

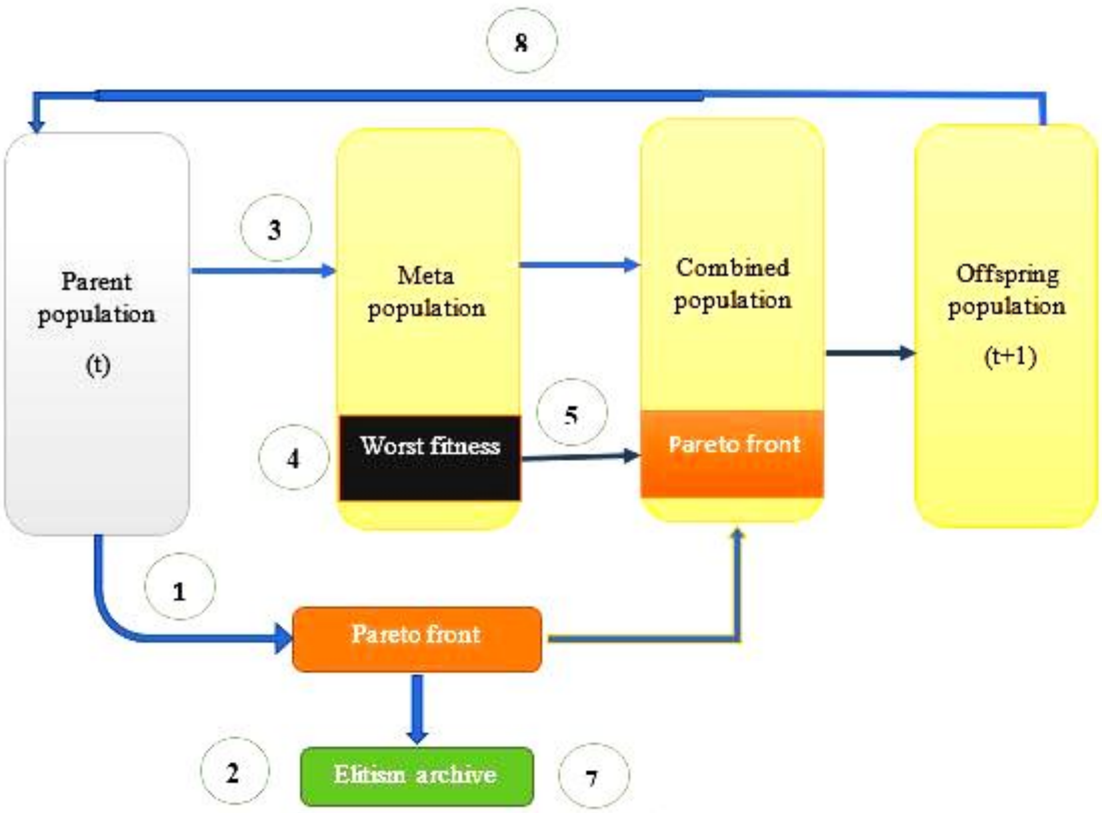


Fig.10. Nondominated Archive Algorithm with elitism Pareto

7.3. Algorithm 3: elitism non-dominated archive (total and percentage) with &without restricted mating:

In this algorithm, it is dealt with non-dominated archive not with pareto front as before where the best solutions are kept in every generation without repeating these solutions are the most important characteristic that these solutions are the most important characteristic is that more converge and more diversity, so it will be used on the two sides in the process of improving the generations during the selection process

Case1: total Elitism non-dominated archive:

In this case a number of bad solutions will be replaced that have worst fitness in the generation with all the elements of the non-dominated archive, which have the highest fitness, giving it a great opportunity for the process of selection in the next generation that leads the algorithm work to word the pareto optimal points through the type of selection process without restricted mating Thus, the process of selection is responsible for (convergence) in another hand at the same time maintain the diversity of solutions by push the non-dominated archive points in the next generation This is what is sought in this time-cost trade off problem=>Finding optimal alternatives to implement the project which is hoped to achieve.

Also, the above section can be applied but with restricted mating where the algorithm is forced to be mating with the new points that enter the generation each time from the non-dominated archive this method very affects to convergent and time-saving but in contrast does not greatly preserve diversity because the algorithm is forced to produce solutions in certain places, which makes it impossible to explore more places for solutions. This is logical, because any attempt to convergence, in turn, reduces diversity. So, the number of optimal solutions is found on the Pareto front results less than without restricted mating, but the number of generation is found in restricted mating is less than without restricted this mean that the stop condition achieved earlier than without restricted mating algorithm. These two types of mating implement by using the three type of selection (1) Roulette Wheel Selection, (2) tournament selection based on fitness, (3) Tournament selection with compare fitness for non-dominated solutions. **Case2: Percentage Elitism non-dominated archive:**

In this case the same first case will be applied but with a slight change, which is that only a percentage of the random number of the archive will be handled and replaced in the generation, which makes the algorithm enjoy more diversity, whether without restricted mating or restricted mating but takes a bit more time than before making the results somewhat satisfactory

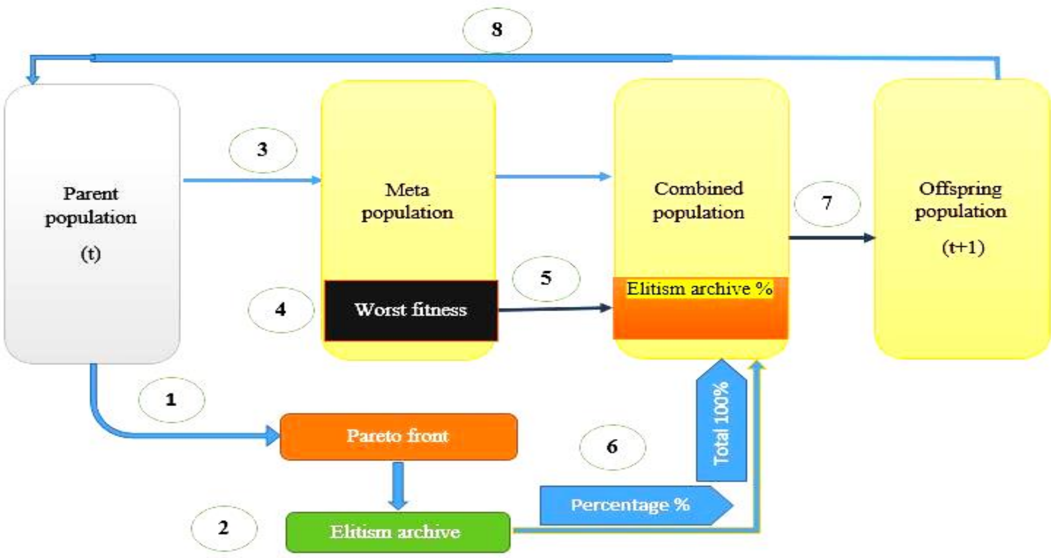


Fig.11. Nondominated Archive Algorithm with elitism archive.

RESULTS:

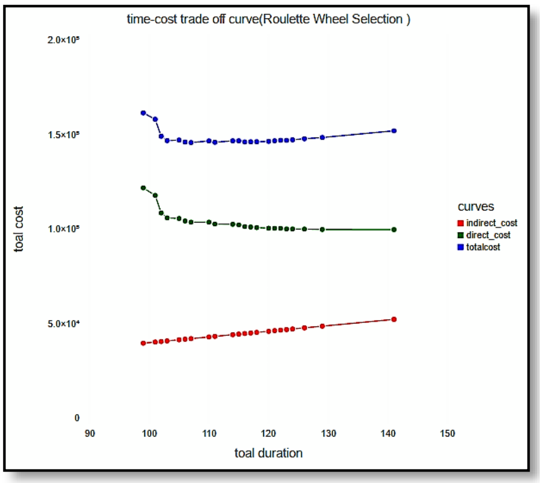


Fig.12.Algorithm (1) -Result

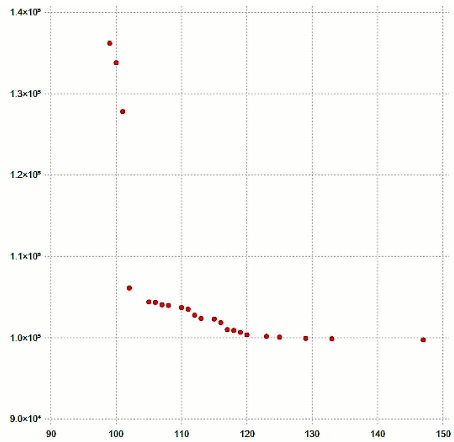
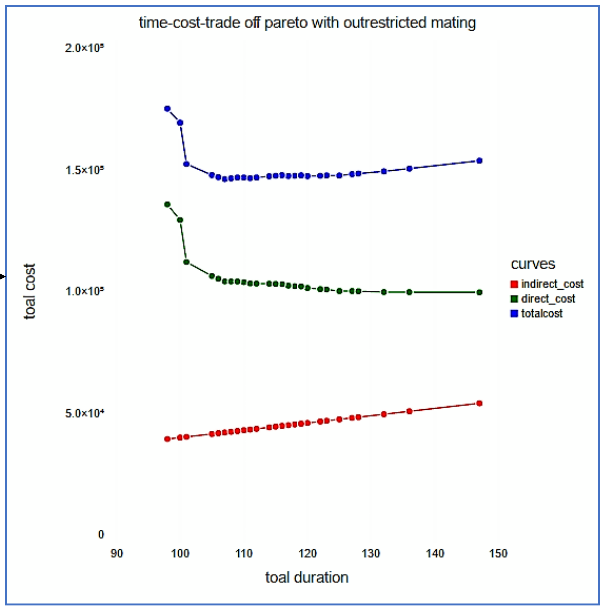


Fig.13.Algorithm (2) -Result



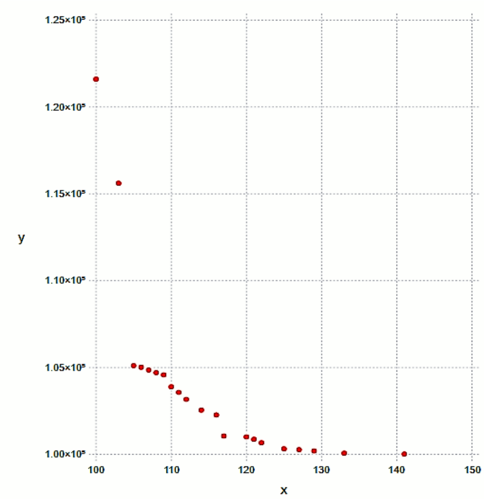
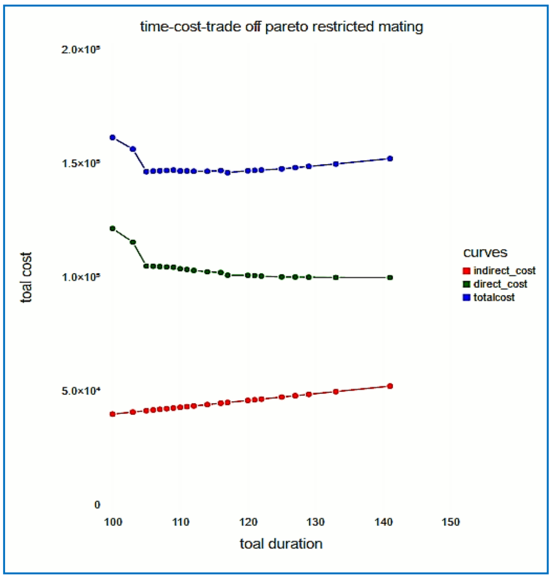


Fig.14.Algorithm (3) -Result



8.summary and Conclusion:

this paper introduce three algorithms for MOGA which apply the principle of Elitism to maintain the best individuals(schedules) of the current population and all old populations survive to the next generation for improving time-cost trade off curve (1) Algorithm 1- non-dominated archive, (2) Algorithm 2-non-dominated archive with elitism Pareto- restricted mating, (3) Algorithm Elitism non-dominated archive (total and percentage) and applying them to the problem for providing the optimal balance between time and cost .

9.REFRENCES:

[1] M.K.Trivedi and Sapan Namdev(2015)Use of optimization techniques in time-cost trade off (TCT) in civil construction: An Overview

[2] Hegazy, T.(Dec.1999.) Optimization of Construction Time-Cost Trade-Off Analysis using Genetic Algorithms. Canadian Journal of Civil Eng., CSCE, Canada.

[3] Feng, C., Liu, L., and Burns, S.(1997). Using genetic algorithms to solve construction time–cost trade-off problems. ASCE Journal of Computing in Civil Engineering, 11(3): 184–189.

[4] M, D.X., Ng, S.T.and Kumaraswamy, M. (. 2004)M.Applying a Genetic Algorithm-Based Multi-objective Approach for Time-Cost Optimization.Journal of Construction Eng. and Management, ASCE, 130(2),168-176.

[5] Kelley, J.E., (1961), “Critical path planning and scheduling: Mathematical basis”,

Operations Research, 9, pp. 296–320.

[6] Meyer, W.L., and Shaffer, L.R., (1965), “Expanding CPM for multiform project

time-cost curves”, Journal of the Construction Division, Proceedings of the ASCE.

[7] Chen, P.H., Weng, H.J. (July 2009) A Two-Phase GA Model for Resource-Constrained Project Scheduling. Automation in Construction, 18(4), (SCI, EI), 485-498.

[8] Sedigheh Nader Abadia,*, Emad Roghanianb, Hadi Aghassic. (2010). A Multi-Mode Resource-Constrained Optimization of Time-Cost Trade-off Problems in Project Scheduling Using a Genetic Algorithm.,Journal of Optimization in Industrial Engineering .

[9] Maryam Rahimi and Hossein Iranmanesh. 2008. Multi Objective Particle Swarm Optimization for a Discrete.

[10] Siemens, N. (1971). "A simple CPM time-cost tradeoff algorithm."Mgmt. Sci., 17(6), B-354-363.

[11] Srinivas, N., and Deb, K. (1995). "Multi-objective optimization using nondominated sorting in genetic algorithms ".Evolutionary Computation 2(3), 221-248.

[12] A Fast and Elitist Multiobjective Genetic Algorithm: NSGA-II Kalyanmoy Deb, Associate Member, IEEE, Amrit Pratap, Sameer Agarwal, and T. Meyarivan

[13] USING GENETIC ALGORITHMS TO SOLVE CONSTRUCTIONTIME - COST TRADE-OFFPROBLEMS By ChungWeiFeng ;LiangLiu/AssociateMember,ASCE,andScottA .Burns, 3Member,ASCE

[14] Applying a Genetic Algorithm-Based Multiobjective Approach for Time-Cost Optimization Daisy X. M. Zheng 1 S. Thomas Ng 2 and Mohan M. Kumaraswamy, M.ASCE

[15] Sedigheh Nader Abadia*,Emad Roghanianb ,Hadi(2010) A Multi-Mode Resource-Constrained Optimization of Time-Cost Trade-off Problems in Project Scheduling Using a Genetic Algorithm Aghassica Msc, Department of Industrial Engineering,

[16] A two-phase GA model for resource-constrained project scheduling Po-Han Chen⁎ , Haijie Weng School of Civil and Environmental Engineering, Nanyang Technological University, 639798, Singapore.

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