A State of Art Review on Metaheuristic Methods in Time-Cost Trade-off Problems

Gülçağ Albayrak and İlker Özdemir
Dept. of Civil Eng., Eskisehir Osmangazi University, Eskisehir, Turkey
Email: {galbayrak, iozdemir}@ogu.edu.tr

***Abstract*—The project managers encounter with difficult conditions with regard to fulfilling projects on time and within reserved resources. This sophisticated relationship among time and cost has been one of the challenging problems among project managers at all times. These types of problems were formerly defined and solved by traditional exact methods such as crashing method and linear programming. However, the complexity of the trade-off problem makes difficult to solve. Hence a number of methods called metaheuristics have evolved over the past few years. Although a few algorithms can be applied to time cost trade-off problem to make it more useful and valid with less computational time, some algorithms have not been studied adequately. This paper summarizes the existing metaheuristic methods and algorithms which are applied for solving time-cost trade-off problem, including genetic algorithm, swarm based algorithms, bio-inspired algorithms and etc. The potential contribution of this paper is to provide the current literature for researchers.**

***Index Terms*—metaheuristic methods, time-cost trade-off problem, project management, literature review**

I. Introduction

Time-cost trade-off (TCT) is one of the extremely substantial problems in project management. In the case of TCT problem (TCTP), the purpose is to minimize the project completion time with the minimum expenditure of resources [1]. It is apparent that when project duration is compressed, the project managers need more labour and equipment for meeting rising demand, and then the project cost increases inversely.

Construction projects are unique in nature and each has their own site characteristics, weather condition, crew of labour and fleet of equipment [2]. As a result, the accurate prediction of exact duration and cost for an activity is complicated.

Trade-off between project duration and project cost has comprehensively discussed in the literature and several searching methods including deterministic methods (e.g. linear programming, dynamic programming, branch and bound algorithms, simulation based method) and metaheuristic methods (e.g. genetic algorithm (GA), simulated annealing (SA), particle swarm optimization (PSO) and ant colony optimization (ACO)) were suggested to solve this problem with numerous different assumptions.

In accordance with the literature, the first work was done by Chau, Chan and Govindan in 1997 [4]. Their GA-based model which considers resource constraints while selecting appropriate project activities to expedite has been extended to deal with TCTP.

After that, Feng, Liu and Burns suggested a new computer program which automates the execution of the GA with Pareto Front Approach [5]. Thus they provided a tool for practitioners. Also, Li and Love improved GA with a number of modifications in the same year [6].

In 1999, some significant studies were performed by researchers. Hegazy was one of them with his GA model [7]. In according to the model, the total project cost can be minimized as objective function and considered for project-specific constraints on time and cost with its robust optimization search. The other early studies are as follows.

Leu and Yang proposed a multi-criteria optimal model for construction scheduling using GA which integrates the TCT model [8].

Li, Cao, and Love developed machine learning and GA based system which generates the quadratic time-cost curves automatically [9].

Leu, Chen and Yang suggested GA-based fuzzy construction TCT model which has been adopted to search for the optimal project TCT profiles under different risk levels [10].

Que presented a new time-cost optimization approach which can be used for practical application by integrating a project management system to the GA system [11].

Zheng, Ng and Kumaraswamy proposed a novel multi-objective approach MAWA (modified adaptive weight approach) which became very popular afterwards [12].

Azaron, Perkgoz and Sakawa developed a new multi-objective GA-based model for the TCTP in PERT networks [13].

TCT is known as NP-hard problem (including large number of variables and non-linear objective functions) therefore the difficulties related with using deterministic methods for solving large scale trade-off problems have contributed to the development of metaheuristic solutions. Simplicity and efficiency are the main advantages of metaheuristic methods. A general flow-chart of metaheuristic methods can be shown in Fig. 1.

Manuscript received January 21, 2016; revised August 1, 2016.

doi: 10.18178/ijscer.6.1.30-34

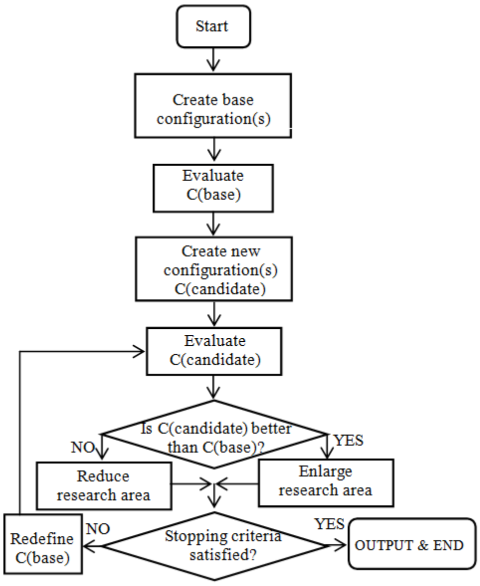

Figure 1. General flow-chart for metaheuristic methods [3]

TABLE I. LIST OF METAHEURISTIC METHODS USED TO SOLVE TCTP

Ref.	Year	Author(s)	Algorithm	Remarks
[14]	2006	Senouci and Naji	GA	The activity precedence relationships, multiple crew-strategies and TCT have been considered.
[15]	2007	Afshar, Kaveh and Shoghli	Multi-colony ant algorithm	A model which is capable of compromising between important aspects of construction projects while maximizing the quality has been developed.
[16]	2007	Kasaeian, Reza and Afshar	Improved multi-objective GA	A model has been implemented to optimize TCT and compared to the results of MAWA approach which validated the robust capabilities of the presented model.
[17]	2007	Pathak and Srivastava	Fuzzy-GA	A multi-objective TCTP under real life uncertainties has been solved using proposed algorithm
[18]	2007	Tareghian and Taheri	Electro-magnetic Scatter Search	Scatter search has been improved with electromagnetism mechanism.
[19]	2007	Yang	New elitist PSO	A new algorithm has been altered the selection of local and global bests in classical PSO and developed an elite archiving scheme.
[20]	2008	Eshtehardian Afshar and Abbasnia	GA and fuzzy sets	An appropriate GA has been used to develop a solution to the multi-objective fuzzy time-cost model.
[21]	2008	Hooshyar, Rahmani and Shenasa	GA	An algorithm with an intelligent mutation operator is presented to solve the TCTP.
[22]	2008	Iranmanesh, Skandari and Allahverdilo	FastPGA	A metaheuristic has been developed based on a version of GA specially adapted to solve multi-objective problems.
[23]	2008	Ng and Zhang	ACO	Ant Colony System (ACS) has been used for TCTP and compared with GA.
[24]	2008	Pathak, Srivastava and Srivastava	Neural network embedded multi-objective GA	A novel and robust procedure has been presented to produce optimal values of processing time and direct cost of activities.
[25]	2008	Rahimi and Iranmanesh	Multi-objective PSO	A metaheuristic algorithm for discrete time, cost and quality trade-off problem was applied and multiple alternative were considered for the activities of a project.
[26]	2008	Xiong and Kuang	ACO	Incorporating with the MAWA, ACO and GA solutions have been compared.
[27]	2009	Afshar, Ziaraty, Kaveh, and Sharifi	Nondominated Archiving ACO	A new multi-colony ant algorithm has been developed.
[28]	2009	Eshtehardian Afshar and Abbasnia	Fuzzy based multi-objective GA	A new approach for the solution of TCTP within the uncertain environment has been presented.
[29]	2009	Ezeldin and Soliman	GA with dynamic programming	A proposed technique has aimed at circumventing combinatorial explosion and NP-hard characteristics of the stochastic construction schedules optimization problem.
[30]	2009	Yang	Improved PSO	A new algorithm has been proposed to solve TCTP by avoiding local optimum.
[31]	2010	Abd El Razek, Diab, Hafez and Aziz	Simplified GA	In order to minimize project cost and duration while maximizing its quality simultaneously, the development of a practical software system named AMTCROS has been presented.
[32]	2010	Zhang and Xing	Fuzzy-multi-objective PSO	A proposed fuzzy multi-attribute utility methodology has been adopted to evaluate combinations.

[33]	2011	Abdel-Raheem and Khalafallah	Evolutionary algorithm	The new algorithm named Electimize has simulated the behaviour of electrons moving through electric circuit branches with the least resistance.
[34]	2011	Aladini, Afshar and Kalhor	Multi-objective ACO	A model for TCTP has been developed which minimizes project direct cost taking into account discounted cash flows.
[35]	2011	Mohammadi	Multi-objective GA	The presented approach has searched for locally Pareto-optimal or locally non-dominated frontier where simultaneously optimization of time-cost was aimed.
[36]	2011	Mokhtari, Bardaran and Salmasnia	Ant Colony System	The ACS algorithm has been employed for a new multi-mode discrete TCTP with discrete cost function and normal distribution of activity duration.
[37]	2011	Li, Hussein and Lei	Incentive GA	A methodological framework including optimization, sensitivity analysis, and improved (incentive) GA has been proposed.
[38]	2012	Haque and Hasin	GA with fuzzy environment	The aim was to develop a more realistic approach to solve project TCTP under uncertain conditions with fuzzy time periods.
[39]	2012	Shahsavari Pour, Modarres and TavakkoliMoghadam	New Hybrid GA	A new hybrid GA has been proposed using linguistic variables and compared with GA by the ANOVA method.
[40]	2012	Shrivastava, Singh and Dubey	Multi-Colony Ant Algorithm	A new metaheuristic algorithm has been developed for the optimization of two and three objectives as a trade-off problem.
[41]	2012	Sonmez and Bettemir	Hybrid algorithm	A hybrid algorithm has been developed with using GA, SA and Quantum SA.
[42]	2012	Zhang and Ng	Ant colony System	A TCO model based on the ACS techniques has been developed to optimize the time and cost simultaneously for construction projects using MAWA to combine the time and cost into a single objective function through the weight values on the objectives.
[43]	2013	Issa and Eid	GA	A model that deals with time-cost-quality trade-off in construction projects has been developed to find minimum cost for different quality levels at a certain time limit.
[44]	2013	Mungle, Benyoucef, Son and Tiwari	Fuzzy clustering-based GA	A novel approach has been implemented to solve trade-off problem.
[45]	2014	Zhang	Fuzzy based adaptive hybrid GA	A new algorithm with fuzzy variables has been proposed.
[46]	2015	Kaveh, Khanzadi, Alipour, Rajabi Naraky	Charged System Search and Colliding Body Optimization	The proposed metaheuristics have been introduced to solve TCTP.
[47]	2015	Pathak, Srivastava	Fuzzy-ANN-HMH	A new technique which provides to project planners the best plan that optimizes time and cost to complete a project under uncertain environment has been developed.
[48]	2015	Zareei, Hassan-Pour	NSGA-II, MOSA and MOPSO	A mathematical model has been developed using three evolutionary algorithms and applied to find the set of Pareto solutions for the multi-objective scheduling problem.

II. Method

The present study which focused on metaheuristics was limited to the TCTP because of the extent of the research field. Initially, TCTP was identified as the main area. Then the existing works were browsed in academic indices. Hence, an extensive literature was collected. When the mathematical and heuristic methods were removed, the studies were figured out by using metaheuristic methods have only been kept for consideration.

The reviewed papers were arranged with their publication year, author name and brief overview. All the considered works were shown chronological in Table I.

III. Conclusion

This paper summarized the existing works using a scheme of algorithms and techniques which have been conducted for solving TCTP in the last decade. Although the numerous methodologies are available to solve TCTP, only the metaheuristic methods have been focused. For this purpose, more than forty research papers have been comprehensively considered. These obtained publications have been represented in a table with brief information about their applications.

According to this review process, the usage of the metaheuristic method in solving TCTP is observed for nearly twenty years. The first study in this field belongs to Chau, Chan and Govindan who adopted the GA with their problem in 1997. GA had remained its popularity in subsequent studies for a long time. Among the researchers, GA is still preferred with major modifications and hybridization. Furthermore, ACO and PSO are well-known and frequently used methods. These methods have been usually adopted and improved with different modifications by researchers. Additionally, some effective and applicable new techniques based metaheuristic principles have been suggested in some works.

Despite time and cost are commonly considered objectives in the reviewed literature, some neglected factors such quality and risk were taken into account in specific researches.

Finally, this paper provides an up-to-date review of the literature on metaheuristic methods used to solve TCTP entirely.

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Mrs. Gülçağ Albayrak received her B.Sc (Civil Eng.) and M.Sc (Construction Management) from Eskisehir Osmangazi University (ESOGU) Dept. of Civil Engineering, Turkey. She is a PhD candidate in ESOGU Civil Eng. Dept., Construction Management program and presently working as a research assistant at the same department. Her research interests include value engineering applications, statistical evaluations, engineering management, mathematical modelling, metaheuristic methods and optimization techniques in civil engineering.

Dr. İlker Özdemir received his B.Sc (Civil Eng.) Karadeniz Technical Univ. (KTÜ), M.Sc (Transportation Eng.) İstanbul Technical Univ. (İTÜ) and PhD (Cons. Eng. And Management) from Eskisehir Osmangazi Univ. (ESOGU), Turkey. He is presently working as a lecturer (Prof. Dr.) ESOGU Civil Eng. Dept., Cons. Eng. Program. His research interests include civil engineering management, building cost control, construction law, graphical construction, scheduling and modelling, optimization techniques.