Novel Approach of Cost-Time Optimization for Construction Contractors using Hybrid Swarm Optimization Approach

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Abstract- construction industry is to directly and indirectly provide people's daily needs. Mostly, a construction project involves the use of different resources (e.g., machinery, materials, manpower, etc.) to produce the final product (e.g., a building, a bridge, a water distribution system, etc.) that serves the targeted users' needs. The difficulties that are met in construction projects include budget limitations, contractual time constraints, safety and health issues, sustainability ratings, local building codes, the desired level of quality, to name but a few. Consequently, a construction project has multiple objectives including maximum productivity, minimum cost, minimum duration, specified quality, safety, and sustainability. Making decisions is difficult when one wants to reach the optimal solution for a combination of objectives. GA model that involves 152 decision variables and 462 constraints. The model generated 361 optimal solutions. For equipment management problems, proposed dynamic programming-based GA because they believed it would be capable of solving this type of problem more efficiently than traditional methods. The goal of the method was to minimize the project's total cost and maximize equipment operations such that in case of equipment failure there would be an equipment available. Moreover, to make the method more reliable, the failure rate of the equipment was considered a fuzzy variable. An actual hydropower project in China was selected to test the model. Under the same environment, the proposed algorithm performed better in searching than the standard GA.

Keywords- project, multi objective, optimization

I. INTRODUCTION

Optimization is an important concept in science and engineering. The construction industry is one of the prominent areas benefiting from it for efficient and effective execution of projects, for instance. Optimization is applied in the design and scheduling of HVAC systems, the design of structural systems and components, building layout, acoustic design, and the design of construction site layout. With respect to HVAC systems optimization usually concerns the minimization of energy use. In structural design optimization usually concerns simultaneous minimization of material and construction cost and maximization of stability, stiffness and strength. With respect to building layout, optimization usually concerns maximization of accessibility and reach ability as well as satisfaction of perceptual requirements, such as visual openness and privacy. Simultaneously compactness of the shape of a building's perimeter may be subject to maximization due to energy loss considerations. In acoustic design optimization usually concerns minimization of reverb time. In the layout of construction sites reach ability is generally subject to maximization. Although optimization is a traditionally well-known concept, in many instances it is treated in single objective form, where the objective is known to be 'the cost function'. As an extension of this is the optimization where one or more constraints are simultaneously satisfied next to the minimization of the cost functions. In the construction industry the essential concern is to reach optimality with a number of objective functions, in place of only minimizing a cost function. In the former case the functions involved are simultaneously minimized (or maximized). The accomplishment of this task is due to the methodology known as multi-objective optimization (MO).

The MO is gaining gravity especially in the last decade due to the increasing technological demand of optimization in many diverse areas. For instance, in building design the building costs and the energy consumption of a building during its lifecycles are subject to minimization simultaneously. With respect to the construction industry, there are many instances where multi-objectivity is an important computational aid for effective project executions. This is easily understood considering that in building design many criteria are conflicting and subject to optimal satisfaction, such as cost, functionality, aesthetic appeal, and sustainability.

The main aim of this chapter is to understand the significance of project management and construction industry separately. Project management is an integral part of organizational management in almost all companies today irrespective of the industry to which company belongs. On the other hand, the construction sector is growing incessantly in all the countries of the world and is catering to basic and luxury needs of the people. Thus this thesis helps to implement the most required project management initiative in the most developing construction industry of the world. This chapter details about the types and styles of project management. The types of project management have been detailed on the basis of industry and on the basis of Complexity (Gentile, 2012). The traditional and modern approach as to project management and its growing scope has been discussed in detail whereby the project cycle is also identified. Waterfall, agile and cyclical styles of project management are discussed in detail in respect to the concept and basis of these styles, advantages and disadvantages of implementing the style and for which category of business the respective is suited the most. Further, considering that leadership is an integral component of project management, various leadership styles are discussed in reference to their application for efficient project management (Yousif et al., 2015). Also, this chapter analyses historical view of the construction industry in Abu Dhabi whereby the importance of oil is identified and the changes in the society are observed

Projects in the construction industry are mostly late, over the budget and saddled with creep due to poor protocols of communication and inadequate controlling system. It is pertinent for every project manager to implement a proactive approach for completion of the project (Loosemore, 2003). Project management in the industry helps in planning even for projects that are relatively modest and helps in exhibiting better level of methods that can ensure timely completion of the project as per the expected budget. Project management helps in dealing with practical on-site problems like miscommunication or poor communication, wrong pricing strategies during the state of schematic design, construction document development and risks related to unresolved issues. For implementation of project management in any construction project, the goal of the project must be set out straight (Sears et al., 2010). This should be followed by clearly writing a goal statement for the project. Then, the project scope should be identified and the scope must be different from the goal. Further, before examining the project life cycle, project management helps in breaking the project into various phases to ensure that each stage is individually looked upon for requirements. These stages can also be considered as various significant parameters for the construction project and might include the following: 1. Project Deliverables - these shall define the tangible products or services or results that are desired to be produced for the project. The project must identify these deliverables with specific dates on which these are accomplished (Toor & Ogunlana, 2008). 2. Important Dates - these would not merely include the end date of the project but also other dates relating to completion of small projects. 3. Criteria for Project Completion - it would help in identifying that the project is approaching towards its end. Also, it is test for the project manager to analyse the current stage of project and measure it with delays, if any. Setting the project criteria helps the entire team to aim for specific project goals and clearly identify various project phases. 4. Project Expectations - it helps in setting up expectations for employees so that they can identify tasks and other requirements of the project (Schwalbe, 2013). 5. Potential elements of risk - it helps in identifying areas related to potential problems and can help in building some factors for checks and balances so that the problems can be minimized (Lester, 2007).

Project Management in Construction Industry In the recent years, development in the construction industry has grabbed the attention of the world. Construction industry is the largest industry in the world in today’s scenario. It is growing rapidly in all the economies. It is mixture of service and manufacturing industry and interacts with the final consumers on daily basis. It being a part of manufacturing industry has components like that of service delivery timelines, high-quality product range, reduced rates of failure and reasonable cost of service (Bairi, 2012). However, in reality most project exhibit cost overruns, conflict between parties and undue extension of time. Project management is an integral requirement for the construction industry that can help in rectifying the current mismanagement.

There are eight factors which actively participate in the development of the construction industry. These are physical resources, financial resources, competition, government intervention, coordination, cooperation, policy and long term vision. In the development of the construction industry the role of project manager is very important. Project manager is responsible for the communication between the government and the industry. Project manager profile is a unique position. The project manager should have management skills to significantly influence and effectively promote the development in the construction industry. Project manager is responsible for managing the construction projects in order to optimize the capital investment. The interpretation of the role of project manager can be explained by these eight factors. These factors have been explained according to their strengths (Hills et al., 2008). Project management in construction industry helps in dealing with many challenges. These challenges may be related to construction cost, construction time and construction control. Project management is a proactive approach to deal with challenges like over budgeting, late and saddled with scope creep, poor communication and inadequate control (Guérin, 2012; Kendrick, 2011). India

II. RELATED WORK

Ibraheem Alothaimeen et.al. (2019) In this chapter, a review is presented of 16 multi-objective optimization approaches used in 55 research studies performed in the construction industry and that were published in the period 2012–2016. The discussion highlights the strengths and weaknesses of these approaches when used in different scenarios [6].

Chen Chen et.al. (2019) the research explores better workstation arrangements. An open queuing network (OQN) model was used to approximate the flow production system. Since the problem of workstation arrangement is a combinatorial optimisation problem, simulated annealing (SA) was applied to search for a good solution. The combination of an OQN model and SA provides a powerful tool to solve the facility layout problem for a stochastic flow production system. The experimental results show that the proposed approach has the potential to guide industrial layout design and practice [7].

Ibraheem Alothaimeen (2018) In the U.S., the building sector is responsible for 73% of electricity usage, 38% ofCO2 emissions, and 13.6% of potable water. These data indicate that the construction industry negatively impacts the global environment and natural resources. The concept of 'sustainability" was introduced to set guidelines for the construction industry to limit its negative environmental impact. To promote sustainability in the construction industry, many organizations have introduced guidelines and rating systems for buildings. One of these rating systems is Leadership in Energy and Environmental Design (LEED) which is the most globally acknowledged system. In this study, a multi-objective optimization framework, which uses Non-dominated Sorting Genetic Algorithm-II (NSGA-II), is proposed to find the optimal solution in terms of life-cycle cost and sustainability for a new construction project pursuing LEED v4 BD+ Certification. A BIM project of a 3-floor educational building was selected as a case study in the research. The study case is used to verify the efficiency and soundness of the proposed model [8].

Doddy Prayogo et.al. (2018) The present study proposes the Differential Big Bang - Big Crunch (DBB-BC) algorithm. This new hybrid metaheuristic is designed to enhance the performance of the Big Bang-Big Crunch (BB-BC) algorithm. DBB-BC uses collaborative-combination hybridization to combine the BB-BC algorithm, Differential Evolution algorithm, and Neighborhood Search in order to improve the exploration and exploitation capabilities of the original BB-BC in finding global solutions. Subsequently, a number of unconstrained mathematical benchmark problems and seven practical design problems from the construction-engineering field are used to investigate the effectiveness and efficiency of DBB-BC. The results of this investigation confirm that the DBB-BC performs significantly better than the other algorithms that were tested in terms of optimal solution (efficacy) and required function evaluations (efficiency) [9].

Shouyong Jiang et.al. (2017) In this paper, we revive an early developed and computationally expensive strength Pareto-based evolutionary algorithm by introducing an efficient reference direction-based density estimator, a new fitness assignment scheme, and a new environmental selection strategy, for handling both multi-objective and many-objective problems. The performance of the proposed algorithm is validated and compared with some state-of-the-art algorithms on a number of test problems. Experimental studies demonstrate that the proposed method shows very competitive performance on both multi-objective and many-objective problems considered in this paper. Besides, our extensive investigations and discussions reveal an interesting finding, that is, diversity-first-and-convergence-second selection strategies may have great potential to deal with many-objective optimization [10].

N.Delgarm et.al. (2016) This paper proposes an efficient methodology for the simulation-based multi-objective optimization problems, which addresses important limitations for the optimization of the building energy performance. In this work, a mono- and multi-objective particle swarm optimization (MOPSO) algorithm is coupled with EnergyPlus building energy simulation software to find a set of non-dominated solutions to enhance the building energy performance. In the optimization section, mono-criterion and multi-criteria optimization analyses of the annual cooling, heating, and lighting electricity consumption are examined to understand interactions between the objective functions and to minimize the annual total building energy demand. The achieved optimum solutions from the multi-objective optimization process are also reported as Pareto optimal fronts. Finally, the result of multi-criteria minimization is compared with the mono-criterion ones [11].

Germán Ramos Ruiz et.al. (2016) This paper presents a methodology to accurately perform automated envelope calibration under option D (calibrated simulation) of IPMVP – vol. 1. This is frequently ignored because of its complexity, despite being more flexible and accurate in assessing the energy performance of a building. A detailed baseline energy model is used, and by means of a metaheuristic technique achieves a highly reliable and accurate Building Energy Simulation (BES) model suitable for detailed analysis of saving strategies. In order to find this BES model a Genetic Algorithm (NSGA-II) is used, together with a highly efficient engine to stimulate the objective, thus permitting rapid achievement of the goal [12].

Kyungki Kim et.al. (2015) This paper presents an optimization approach that enables a simultaneous search for an optimal construction schedule in terms of three objectives: minimization of construction duration, cost, and resource fluctuation. A multi-objective optimization (MOO) approach was adopted to generate scheduling solutions considering all those objectives. To enable a simultaneous optimization, the researchers propose a new data structure that can compute the performances of solutions in terms of all the objectives at the same time. A Niched Pareto Genetic Algorithm (NPGA) is modified to facilitate the optimization procedure. Then the proposed optimization approach is implemented in an existing case study. The result indicates that the proposed approach has the capability to explore and generate a greater range of solutions compared to existing models [13].

Min-YuanCheng et.al. (2015) this paper develops a novel optimization algorithm, the Opposition-based Multiple Objective Differential Evolution (OMODE), to solve the time–cost-utilization work shift trade-off (TCUT) problem. This novel algorithm employs an opposition-based learning technique for population initialization and for generation jumping. Opposition numbers are used to improve the exploration and convergence performance of the optimization process. Two numerical case studies of construction projects demonstrate the ability of OMODE generated non-dominated solutions to assist project managers to select an appropriate plan to optimize TCUT, an operation that is otherwise difficult and time-consuming [14].

III. THE PROPOSED METHOD

Problem formulation

Proper cost control is also a vital ingredient for a successful project. The first step of cost control is to identify the factors that affect project costs. The existing factors can be divided into two major categories: quantitative factors and qualitative factors. Currently, the AEC industry researchers have given many efforts to develop techniques that only consider quantitative factors and ignore qualitative factors such as "client priority on construction time, contractor's planning capability, procurement methods and market conditions including level of construction activity". Due to a great number of factors that need to be considered, it is difficult to predict the exact cost to complete construction projects (Gould, 2004). It is common to see that the final project cost is higher than the budgeted cost. It was reported that a cost overrun is one of the main problems in the AEC industry. stated the biggest cause of cost overruns is inaccurate estimation at the beginning of a project. An estimate is a general evaluation of the future project cost, and the budget represents the amount of money that the stakeholders would like to invest. The more accurate the estimate is, the closer the budget is to the actual cost, which means the profit is closer to what the project participants expect

Problem statement

The improvement based on cost and time of construction enhances the budget and the activities-based deadline with its pollution factor. For balancing, the parameters of the system require an optimization approach wherein the proposed approach uses hybrid optimization. Hybrid optimization helps to improve the convergence of threshold and effectively balances the parameters of the system.

Proposed Methodology

Step 1: Input the construction scenario.

Step 2: Pre-processed the activities.

Step 3: Apply convolution Process on image.

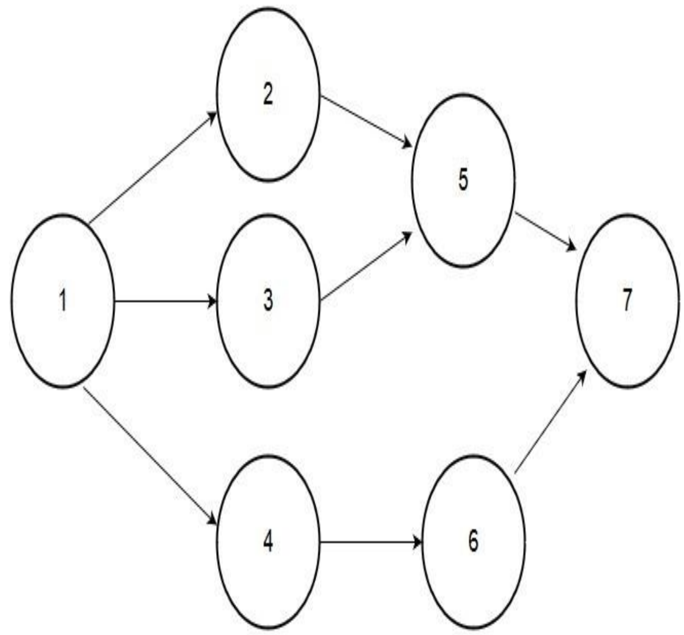
Step 4: After convolution low dimension matrix is produced.

Step 5: Initialize the PSO.

Step 6: Search local and global best by water cycle.

Step 7: Check the output is optimized or not if optimized the go to step 8 otherwise go to step 4.

Fig.1: Activity Precedence Diagram



Activity Precendence Diagram

Step 8: Calculate the total variation.

Step 9: Analyse the PSO time and cost of the Image

IV. RESULT ANALYSIS

4.1 Result Analysis

Also during the construction there is an order in which the events take place. For eg, Excavation (2) cannot be performed before the Survey (1) is over. The precedence diagram for the activities are shown below−

As we can see there are three paths for the construction sequence− 1. 1−2−5−7

2. 1−3−5−7
3. 1−4−6−7

The time duration required for the construction project will not be the sum of time duration of all activities, it would rather be the maximum time required for one of the above three paths (critical path). Hence, there is a constraint to follow the above paths and we need to minimize the time required for the critical path.

Flow chart for the optimization problem:

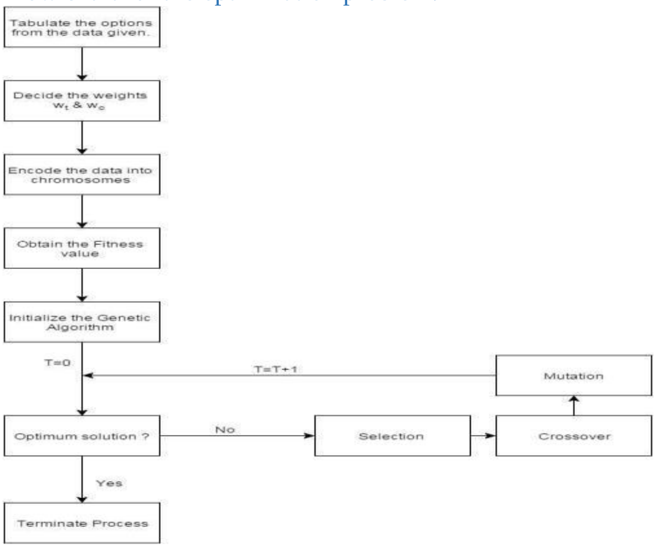
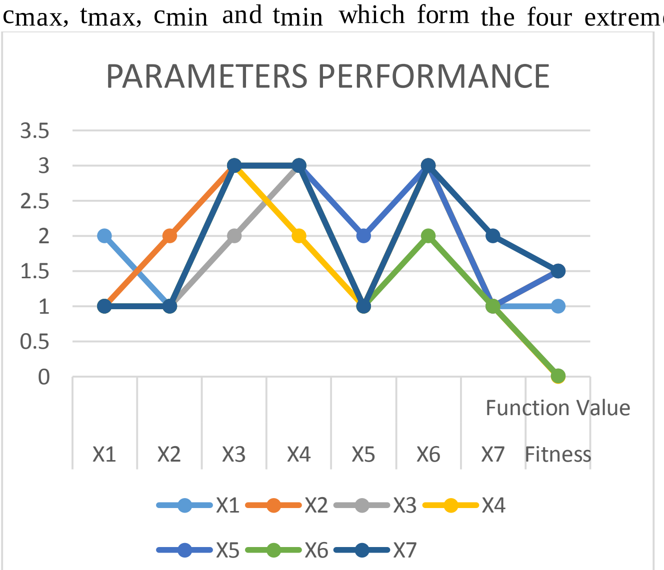


Fig.2: Optimized Flow chart

Optimization technique and statistical tool to be used:
The given optimization problem is a multi-objective optimization problem. The given problem is discontinuous and has discrete values. Classical methods cannot be used and hence, we will use Genetic Algorithms for the same. All the calculations will be done in the Matlab software.

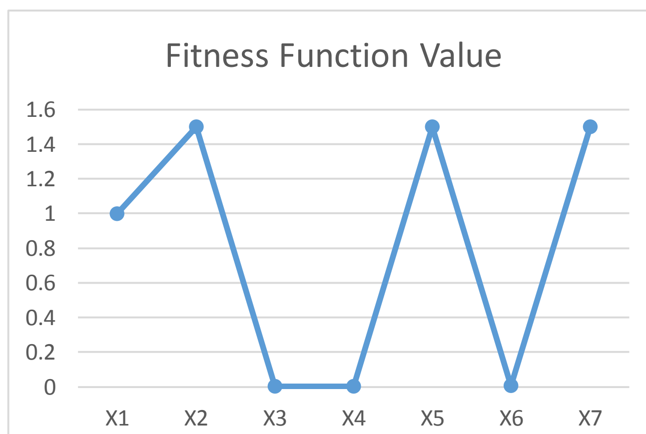
Implementation of PSO-WCA Algorithm
For a particular population there are four points namely, cmax, tmax, cmin and tmin which form the four extreme



oints of a quadrilateral. In the subsequent generations, these extreme points are renewed to reach an ideal minimum point. Hence, the constants in the fitness function change with every new population to reduce the size of the quadrilateral formed and reach the optimal point.

The whole data is stored in a Matrix B(5x2x5) in which the duration and time of respective activities are stored. Two functions are created in Matlab.First one (Func(x) to calculate the fitness value of population. The Genetic alogirthm inbuilt function in matlab is used in vectorized case on,which means the whole population of one generation is passed in the fitness function (func(x)) .Here x is a (populationsizeX7) matrix.which contain random value generated by PSO-WCA function.PSO-WCA function is used in the vectorized form to calculate the maximum value of decision variables in a set of populations, which is later used to calculate the fitness in fitness function.

To calculate the min and maximum value of decision variable a new function is defined called function calling(x) which is called in the fitness function definition.In this way for every set of populations, fitness function is called and the whole population is passed.The maximum and minimum values of the variables are calculated and fitness values are returned.In our case PSO-WCA function is called for integer value solution with lower and upper limit of variables as [1,1,1,1,1,1,1] and [3,5,3,3,4,3,4] respectively.



V. CONCLUSION

used in these studies in which some of the authors justify their picks on multiple factors (e.g., construction project type, project size, number of objectives, number of constraints, convergence rate, problem complexity such as constraints' nonlinearity with discontinuity and continuity, etc.). Moreover, some methods were found to be more efficient than others in some studies. For example, in water network planning, Creaco et al. [30] showed that their NSGA-II using a probabilistic approach was superior to NSGA-II used by Creaco et al. [29] in an earlier study in which they used a deterministic approach. The GA proposed by Aziz et al. [6] in a scheduling problem outperformed the GA utilized by Feng et al. [7] for the same case study. Fallah-Mehdipour et al. [26] concluded that NSGA-II has performed better than multi-objective PSO in solving a scheduling problem. Most of the time, it is difficult to guarantee the performance of a method until it is compared with another method. The most common number of objectives used in the literature is two and three. As expected, cost and duration were the most targeted objectives as cost and duration are important objectives for all construction practitioners. The quality objective has also drawn the interest of researchers as they sometimes include it.

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