Nigerian Journal of Technology (NIJOTECH)
Vol. 41, No. 5, September, 2022, pp.862 - 869
www.nijotech.com

Print ISSN: 0331-8443
Electronic ISSN: 2467-8821
http://dx.doi.org/10.4314/njt.v41i5.6

GOAL PROGRAMMING AND GENETIC ALGORITHM IN MULTIPLE OBJECTIVE OPTIMIZATION MODEL FOR PROJECT PORTFOLIO SELECTION: A REVIEW

A. O. Mogbojuri[1,*] and O. A. Olanrewaju[1]

[1]Department of Industrial Engineering, Durban University of Technology

*corresponding author (Phone Number: +234-802-782-8336. Email: akinlo.mogbojuri@gmail.com)

Article history: Received 06 April, 2022. Revised 25 July, 2022. Accepted 26 July, 2022

Abstract
Many scientific fields, such as engineering, data analytics, and deep learning, focus on optimization. Optimization problems are classified into two types based on the number of optimized objective functions: single objective and multi objective optimization problems. In this paper, a comparative review since 2000 using one of the deterministic and stochastic modelling approaches called goal programming (GP) and genetic algorithm (GA) in multi-objective optimization problem is discussed. This study gives a prime review of the application of GP and GA in various criteria of project portfolio selection problem. GP is a method for solving large-scale multi-objective optimization problems to assist decision makers in finding solutions that satisfy several competing goals. GA on the other hand are global meta-heuristic search algorithms that are used to provide approximation or optimal solutions to large-scale optimization problems. Of the 23 articles considered in this review showed that, from more than 100 projects, GA proved near optimal, feasible solution and efficient frontier in projects ranking, projects interaction and a preferred decision support tool of project portfolio selection. In addition, the two models select projects on risk-based approach, but GA proved to be more effective in terms of number of projects proposed, central processing unit (CPU) time and accuracy. The review concludes that, in multi-objective optimization model for project portfolio selection problems on a large-scale, very large or complex problems and less CPU time, GA is more effective than GP in multi-objective optimization problems. The review also showed gaps in previous studies of GP and GA application on project portfolio selection problem (PPSP). This review will aid scholars and demanding practitioners in gaining a broader understanding of goal programming and genetic algorithms in the context of project portfolio selection problems.

Keywords: Genetic algorithm, Goal programming, Multi-objective, Optimization, Project portfolio selection.

1.0 INTRODUCTION

A project is a one of a kind undertaking circumscribed by schedules, budgets, and resources [1]. Virtually every project has three essential features in the traditional approach: budget, schedule, and performance criteria. Interested readers can refer to [2] on more details of the features. A portfolio is also a collection of projects or programs (whether or not they are interdependent) and other work that are grouped to facilitate the effective management of the grouped work to meet the strategic business objectives. As a result, project portfolio selection can be characterized as a dynamic decision-making process for analysing, choosing, and prioritizing a project or a set of projects for implementation given restricted resources and the existing organisational strategies[3]. Project selection is a complicated decision-making process that is influenced by a wide range of objectives, many of which are at variance with one another. The vast number of projects from which a subset (portfolio) must be chosen illustrates the difficulty of the project selection problem [4]. Every organization's project selection process is critical because selecting the appropriate projects helps the organization achieve its objectives. Because projects in general necessitate finite financial and resource investment, it is critical that the projects selected by an organization produce a high return on the resources and capital committed [5]. The goal of project portfolio selection (PPS) is to choose the best set of projects to achieve the given goals or needs while staying within the set of constraints (e.g., resource, time, risk) [6].

PPS is an iterative process in which managers choose projects from a pool of proposals and ongoing projects to achieve the company's objectives. This approach is necessary for the company to maintain its competitive edge by allowing it to concentrate on the most important and strategic projects [7]. Project selection approaches are necessary because they assist organizations in selecting the most appropriate projects in order to be successful and efficient in their resource allocation. They also give the organization with a list of prioritized projects, which increases the likelihood of success because such techniques include the company's strategic goals as well as the interests of stakeholders [8]. One of the most important aspects of managerial decision making is project selection. The decision maker has a wide selection of criteria to choose from when evaluating projects, many of which are intangible or contradictory [9]. Project selection is the first and most important step in project portfolio management. Multiple criteria are frequently used in project selection, and it is critical to employ multiple criteria decision making (MCDM) model to discover a suitable assessment. There have been numerous attempts in recent years to use MCDM approaches for project selection [10].

Optimization is the process of achieving the best possible result under given conditions. This can be expressed as the process of determining the conditions that yield a function's maximum or minimum value [11]. An objective function (often referred to as fitness, cost, etc.) is used to evaluate the merit of each solution. There are two types of optimization problems based on the number of optimized objective functions. These are single-objective optimization problems and multi-objective optimization problems.

The problem is single objective when only one objective function is used, and the solutions can be compared using relational operators. When optimizing multiple objective functions, however, the result cannot be compared using relational operators. In multi-objective optimization problems (MOPs), two or more objective functions must be approximated at the same time [12]; in some instances, just one objective/criterion is examined, resulting in a single optimal solution. This optimal solution achieves the best results based on the specified objective while also satisfying all the problem's constraints/limitations. As a result, instead of a single best solution, multi-objective problems have numerous, usually infinitely many, Pareto optimum (or non-dominated) solutions with variable trade-offs across objectives [13]. Because there are so many possibilities, it's crucial to select one out of the collection. The informed expert or decision-maker (DM) makes the decision based on their preferences. As a result, there are two crucial components to multi-objective optimisation problems: (a) determining the Pareto optimal solutions (optimisation part), and (b) identifying the most favoured solution (decision-making part) [13].

The best solution or optimal value can be discovered through the optimization process. The optimization problems include maximum or minimum value or using one objective or multi-objective. Multi-objective optimization (MOO) refers to problems that have more than one goal. This type of challenge can be encountered in a variety of fields, including mathematics, engineering, science, deep learning, data analytics, social studies, economics, agriculture, aviation, and automotive. These areas are rapidly expanding, and their concepts are used for a variety of objectives, including as extracting insights from large sets of data or constructing precise prediction models. An efficient implementation in a suitable programming language is critical whenever an algorithm must manage large amounts of data [14][15].

This paper presents a study between goal programming and genetic algorithm models used to solve multi-objective optimization in project portfolio selection problem (PPSP) for the purpose of review and comparison. The review focuses on number of projects proposed, accuracy of the models and criteria for project selection. The following section detail's goal programming in its application to multi-objective optimization with its gaps and section 3 on genetic algorithm application. Section 4 compares the two methods and section 5 concludes.

2.0 GOAL PROGRAMMING MODEL FOR MULTI-OBJECTIVE OPTIMIZATION IN PPSP AND ITS GAPS

Goal programming is a well- known technique for solving specific types of multi-objective optimization problems [11]. Goal programming is the most powerful multi-objective decision-making method that has been used to handle a variety of decision-making problems [16]. It is a technique with the purpose of being able to solve multi-objective decision situations. The approach enables the decision maker to specify the level of multi-choice desire for each objective that can be avoided, ensuring that no one undervalues the decision [16]. For problems with conflicting objective functions, goal-programming is more beneficial. The goal of goal-programming is to minimize deviations from the specified targets to a minimum [17].

Goal programming method has been used to solve multi-objective optimization in project portfolio selection problems. Kim and Emery [18] presented a paper which dealt with a project for aircraft control for specific engine component but their model is applicable to all companies that have multiple projects to select from, with limited resources. A goal programming model was established to identify which programs to pursue over a four-year period in order to optimize profit, as well as machine procurement plans and projected man-power requirements. The model reflected the situation in the short term and with a small number of programs, but it also showed a lot of capacity for growth to handle 12-15 programs over a longer period of time. The study had limitations in number of decision variables that GP software could handle, hence, management decided to setup the planning horizon up to four years.

According to Badri et al.,[19], healthcare management are always confronted with the problem of allocating money among competing projects. A goal programming model was formulated to overcome the challenges of providing an integrated framework for selecting projects that are aligned with the organization's goals. An evaluation analysis technique could be used to determine the preference scores of decision-makers and users in the study.

A zero-one linear goal-programming approach was introduced by Rabbani et al.,[20] for the selection and scheduling of research and development (R & D) project portfolios. The proposed model focused on the most significant aspects to consider while choosing a project portfolio. It provided decision-makers with a tool to comprehend the nature of compromise among the numerous factors that influence the portfolio of R&D projects. The study for R & D project problem could have focused on either project selection or scheduling project.

A two-phase fuzzy goal programming (FGP) method, according to Liang [21] was developed to tackle project management (PM) choice problems with multiple goals in uncertain environments. The study developed a systematic decision-making framework that allows the decision maker to change the search direction interactively until the most efficient solution is identified and revealed. When dealing with complicated dependency and relationship of project activities, decision-makers require the identification of all contradicting goals in a single model. The proposed model for the two-phase fuzzy goal programming (FGP) developed need to be remodified to make it better suitable for real-life project selection problem data.

Sahebi et al. [22] formulated a multi-criteria mathematical model to select the best partners to form an optimal joint venture (JV) in oil field projects using goal programming approach. Through the strategic objectives and prospects of the venture party, their approach conceded numerous objectives and priority levels. As a result, instead of one single answer, a collection of solutions was created by altering the priority level rankings for the decision-maker. The study could have administered multi-criteria decision-making approach like analytic network process (ANP) or analytical hierarchy process (AHP) to present the criteria and priority levels of objectives.

The government-guaranteed project selection criteria in Build-Operate-Transfer (BOT) and Public Private Partnership (PPP) project funding were examined by [23]. The study discovered that the government's decision to undertake a BOT/PPP infrastructure guarantee project is a multi-objective problem, and it built a goal programming model to help the government make that decision.The proposed study could have been tested in a real-life situation to show its validity.

3.0 GENETIC ALGORITHM MODEL FOR MULTI-OBJECTIVES OPTIMIZATION IN (PPSP) AND ITS GAPS

Genetic Algorithm, also known as a meta-heuristic search algorithm for optimization problems, starts with a random initial solution and attempts to discover the best solution under certain criteria and parameters [24]. Because it finds the best solution by emulating the evaluation principle and chromosome processing work in classical genetics, it outperforms all other approaches for solving discrete, non-linear, and non-convex global optimization problems [25].

In operations research, industrial engineering, and management science, GA has been used as an optimization technique to solve difficult and non-linear problems. When dealing with non-smooth and multimodal search spaces, the GA method is an effective optimization tool [26]. GA has several advantages over other optimization solution approaches, including the ability to work with both discrete and continuous variables, a large search space, flexibility in constraint management, and the ability to use parallel computing techniques. It's also worth noting that a GA is just a general search principle; there's no approved GA for every optimization problem [27]. The genetic algorithm (GA) is a natural selection-based optimization technique. It's a population-based search method based on the survival of the fittest principle. It is a well-known algorithm that is based on the process of biological evolution. Chromosome representation, fitness function, selection, crossover, and mutation are all crucial elements of GA [28]. A mimetic technique for solving optimization issues is a genetic algorithm [29]. It employs population search technology to depict a set of problem-solving options. A new generation of population is formed by performing a sequence of genetic operations on the existing population, such as selection, crossover, and mutation, and the population eventually increases to a state with the optimal or approximation acceptable solution [30]. Genetic algorithms have found to be a strong and versatile optimisation technique that can quickly provide optimal or near-optimal solutions [31]. It is used to solved multi-objective optimization in project portfolio selection problems (PPSP).

Bastiani et al., [32] proposed an evolutionary algorithm for solving the public portfolio problem from Ranking Information (ESPRI) based on the Non-Dominated Sorting Genetic Algorithm-II (NSGA-II) that seems to be capable of obtaining solutions near to the Pareto frontier. The proposed algorithm helped the decision makers in finding a rational compromise between the quality of the projects in the portfolio and the number of projects approved. But the NSGA-II could not maintain the diversity in Pareto-front.

Huang and Zhao [33] developed a genetic algorithm (GA) for selecting and scheduling R&D projects in the absence of historical data on project parameter values. Their findings revealed that the proposed algorithm is robust to the parameters provided and successful in addressing investment cost and net income challenges. The approach was tested for a small number of projects if tested with a large number, there might be a change in the numerical result. Also, when the project number and the length of the deadline of the whole projects become large, efficiency of enumeration could decrease greatly. Project selection and scheduling problems should also be separated.

Kumar and Pushkar [34] studied a Genetic Algorithm-based strategy to solving the problem of multi-criteria project selection to improve the performance of analogy-based software cost estimation. They developed a multi project selection problem based on decision-makers' criteria, with and without interaction effects among projects. The Genetic Algorithm in the study was not able to find the exact global optimum but experimenting with some more or integrated methods for project selection can help to overcome the limitation.

Polat et al., [35] applied a genetic algorithm to choose subcontractors for all work packages in a construction project, considering time, cost, and quality. There commended model enables the general contractor to select the optimal subcontractor combination for all work packages by considering the interactions between the subcontractors and their influence on overall project performance. The non-dominated Sorting Genetic Algorithm (NSGA-II) was used to provide non-dominated optimal solutions for general contractors to choose the best compromise option that covered all work packages and project performance values of time (day), cost, and quality (%). In the study, cost was affected based on the quality performance result and the higher the quality percentage, the increase in the cost of the project.

Zhao and Huang [36] developed an improved genetic algorithm (GA) of project selection problem from the perspective of complex resource constraints. It was determined that projects chosen using the improved genetic algorithm yielded significantly more benefits than those that did not consider all resource characteristics and constraints. The improved genetic algorithm in the study could be tested for non-resources project selection problem.

Guo et al., [37] Developed a fuzzy multi-objective model termed the multi-objective genetic algorithm (MOGA) for project portfolio selection (PPS) in the face of uncertainty, balancing strategic contributions and financial benefits. Their model aided in the selection of project portfolios and boosted the efficiency of decision-making. The modifications designed for the next generation after crossover and mutation with MOGA, could not satisfy the risk and resources constraints except the technological constraint.

Dewi and Sawaluddin [38] explored project selection in the context of two objective functions: profit maximization and cost minimization, as well as the availability of limited resources including human, machine, and raw material resources. The project selection process was aided by a multi-objective combinatorial optimization technique that uses a genetic algorithm to develop optimal solutions for selected projects. The Genetic Algorithm method steps were not explicit for both readers and project selection practitioners in the study.

Table 1: Comparison of Goal Programming (GP) and Genetic Algorithm (GA)

Approach	No of Projects	Time (S)	Accuracy	Author	Project Selection Criteria
GP	4		Optimal Solution	[40]	Railway projects for economic & revenue benefits
	6		Optimal Solution	[41]	Product development process planning
	8		Optimal Solution	[42]	Marketing activities project
	8		Pareto Solution	[22]	Joint venture and partner selection
	9		Optimal Solution	[18]	Aircraft control for specific engine component
	10	1	Optimal Solution	[20]	Research and Development Project
	16	6480	Not Optimal	[43]	Risk-based approach
	28		Optimal Solution	[19]	Information system
	43		Optimal Solution	[44]	Marine renewable energy
GA	10		Optimal Solution	[33]	Net income and investment
	12		Optimal Pareto	[45]	Sustainability
	20		Optimal Pareto	[46]	Risk and ranking project
	20	1.274	Optimal Solution	[36]	Resource constraints.
	21	22	Optimal Solution	[34]	Projects interaction effect
	30		Optimal pareto	[37]	Strategic contribution and financial returns
	30	354	Near Optimal	[43]	Risk-based approach
	100		Near Optimal	[32]	Ranking of projects
	200	102.25	Feasible Solution	[24]	Projects interaction effect
	36000	86400	Efficient Frontier	[47]	Decision support tool framework

4.0 COMPARISON OF METHODS

Table 1 shows the comparison of both the reviewed and new studies in goal programming model and genetic algorithm under project portfolio selection problems for number of projects proposed, time, accuracy, including the criteria of projects selected. The GP and GA methods selected projects on risk-based approach criteria proved that, GA was better than GP as indicated as follows: the number of projects proposed was 30 for GA and 16 for GP; in CPU time, 354 seconds for GA and 6480 seconds for GP; accuracy was near optimal for GA and not optimal for GP.

Furthermore, both in the reviewed and new studies, GA proved better or effective when the number of projects proposed increased from 100 and above indicating near optimal, feasible and efficient frontier under the accuracy of the algorithm in the areas of projects ranking, projects interaction and decision support tool in project selection criteria section. The study also shows, the CPU time to find optimal solution for GA and GP on number of candidates projects proposed. In GA, 20 projects were solved in 1.274 seconds, 21 projects in 22 seconds, 30 projects in 354 seconds, 200 projects in 102.5 seconds and 36000 in 86400 seconds, while in GP, 10 projects were solved in 1 second and 16 projects in 6480 seconds. The reviewed proved that GA generates objective functions for each project portfolio selection problem, whereas the GP generates some objective functions but does not provide objective functions as the number of projects in the portfolio grows. When solving large-scale multi-objective optimization problems, the goal programming model is an analytical structure that can be used by a decision maker to determine optimal solutions to various conflicting goals. When a problem gets too entangled for a goal programming model to handle, the genetic algorithm (GA) approach is a good approach for handling complicated issues including a large number of decision variables and non-smooth and multimodal search spaces.

Therefore, genetic algorithm (GA)-based problem-solving approach is more effective than some standard programming methods in terms of obtaining good solutions promptly. The genetic algorithm (GA) is a method for solving constrained and unconstrained optimization problems that is based on a natural selection process similar to biological evolution [26], [36], [39]. Though, in section 3.0 and table 1, GA seems better with all the evidence given, but it also has some gaps likes, the non-dominated Sorting Genetic

Algorithm (NSGA-II) could not maintain the diversity in Pareto-front, efficiency of enumeration could decrease greatly when the project number and the length of the deadline of the whole projects become large and also could not be able to find the exact global optimum. The modifications designed for the next generation after crossover and mutation with multi-objective genetic algorithm (MOGA), could not satisfy risk and resources constraints. Therefore, project selection and scheduling problems should also be separated and hence, integrated methods for project selection can help to overcome these limitations.

5.0 CONCLUSION

This study presents a review on goal programming and genetic algorithm on multi-objective optimization for project portfolio selection problems (PPSP) in various criteria. The review highlights the following:

1. The two models selected projects on risk-based approach and GA performed better than GP in terms of number of projects proposed, CPU time and accuracy.
2. GA more advantageous in dealing with more projects as evidenced from literature.
3. The gaps identified from the reviewed and new studies of both goal programming and genetic algorithm on project portfolio selection problem (PPSP).

The study reviewed that goal programming, as one of the multi-objective approaches, has been useful in obtaining solutions that satisfy several conflicting goals. It's used to solve large-scale multi-objective optimization problems, with decision makers (DM) presenting a set of goals (or targets) and genetic algorithms, on the other hand, are global search heuristics used to solved huge or complex project selection problems to identify approximation or optimal results or analytic solutions. GA is better compared to GP, however, the limitations found in GA should be taken into consideration if practitioners decided to use GA in their application. Therefore, project selection and scheduling problems should also be separated and integrated methods for project selection can help to overcome the limitations and gaps identified.

This review will be helpful to researchers or practitioners for their initial level studies in goal programming and genetic algorithm for multi-objective optimization on project portfolio selection problems.

REFERENCES

[1] Asadujjaman, M., Rahman, H. F., Chakrabortty, R. K., and Ryan, M. J. “An Immune Genetic Algorithm for Solving NPV-Based Resource Constrained Project Scheduling Problem”, IEEE Access, vol. 9, pp. 26177–26195, 2021, doi: 10.1109/ACCESS.2021.3057366.

[2] Nicholas, J., and Steyn, H. "Project Management for Business, Engineering and Technology", Sixth. Routledge, 2012.

[3] Project Management, I. "A guide to the project management body of knowledge (PMBOK guide)", Sixth edit. NewTown Square: Project Management Institute, Inc., 2017.

[4] Khalili-Damghani, K., Sadi-Nezhad, S., Lotfi, F. H., and Tavana, M. “A hybrid fuzzy rule-based multi-criteria framework for sustainable project portfolio selection”, Inf. Sci. (Ny)., vol. 220, pp. 442–462, 2013, doi: 10.1016/j.ins.2012.07.024.

[5] Ahmad, B., and ul Haq, I. “Project Selection Techniques, Relevance & Applications in Pakistan”, Int. J. Technol. Res., vol. 4, no. 2, pp. 52–60, 2016.

[6] Zhang, X., Fang, L., Hipel, K. W., Ding, S., and Tan, Y. “A hybrid project portfolio selection procedure with historical performance consideration”, Expert Syst. Appl., vol. 142, 2020, doi: 10.1016/j.eswa.2019.113003.

[7] Chaparro, X. A. F., Gomes, L. A. V., and Nascimento, P. T. S. “The evolution of project portfolio selection methods: from incremental to radical innovation”, Rev. Gestão, vol. 26, no. 3, pp. 212–236, 2019, doi: 10.1108/rege-10-2018-0096.

[8] Chávez, R. “IT Project Portfolio Selection using Analytic Hierarchy Process”, Ind. Data, vol. 11, no. 2, pp. 59–62, 2008.

[9] Khalilzadeh, M., and Salehi, K. “A multi-objective fuzzy project selection problem considering social responsibility and risk”, Procedia Comput. Sci., vol. 121, pp. 646–655, 2017, doi: 10.1016/j.procs.2017.11.085.

[10] Sadi-Nezhad, S. “A state-of-art survey on project selection using MCDM techniques”, J. Proj. Manag., vol. 2, pp. 1–10, 2017, doi: 10.5267/j.jpm.2017.6.001.

[11] Rao, S. S. "Engineering Optimization: Theory and Practice", Fifth edit. Hoboken, NY: John Wiley & Sons, Inc., 2020.

[12] Cui, Y., Geng, Z., Zhu, Q., and Han, Y. “Review: Multi-objective optimization methods and application in energy saving”,

Energy, vol. 125, pp. 681–704, 2017, doi: 10.1016/j.energy.2017.02.174.

[13] Shavazipour, B., and Stewart, T. J. "Multi-objective optimisation under deep uncertainty", Oper. Res., no. 0123456789, 2019, doi: 10.1007/s12351-019-00512-1.

[14] Gunantara, N. "A review of multi-objective optimization: Methods and its applications", Cogent Eng., vol. 5, no. 1, pp. 1–16, 2018, doi: 10.1080/23311916.2018.1502242.

[15] Blank, J., and Deb, K. "Pymoo: Multi-Objective Optimization in Python", IEEE Access, vol. 8, pp. 89497–89509, 2020, doi: 10.1109/ACCESS.2020.2990567.

[16] Wiguna, P. A. P., and Sudiartha, M. M. "Determination of Optimal Warehouse Location at PT . Sumber Alfaria TrijayaTbk (Bali Branch)", Am. J. Humanit. Soc. Sci. Res., vol. 5, no. 1, pp. 664–671, 2021.

[17] Hussain, A., and Kim, H. M. "Goal-programming-based multi-objective optimization in off-grid microgrids", Sustain., vol. 12, no. 19, pp. 1–18, 2020, doi: 10.3390/su121981 19.

[18] Kim, G. C., and Emery, J. "An application of zero-one goal programming in project selection and resource planning - a case study from the Woodward Governor Company", Comput. Oper. Res., vol. 27, no. 14, pp. 1389–1408, 2000, doi: 10.1016/S0305-0548(99)000 80-5.

[19] Badri, M. A., Davis, D., and Davis, D. "A comprehensive 0–1 goal programming model for project selection", Int. J. Proj. Manag., vol. 19, no. 4, pp. 243–252, 2001, doi: 10.1016/s02 63-7863(99)00078-2.

[20] Rabbani, M., Tavakkoli-Moghaddam, Jolai, F., and Ghorbani, H. R. "A Comprehensive Model for R and D Project Portfolio Selection with Zero-One Linear Goal-Programming", IJE Trans. a Basics, vol. 19, no. 1, pp. 55–66, 2006.

[21] Liang, T. F. "Applying fuzzy goal programming to project management decisions with multiple goals in uncertain environments", Expert Syst. Appl., vol. 37, no. 12, pp. 8499–8507, 2010, doi: 10.1016/j.eswa.2010.05.026.

[22] Sahebi, H., Nickel, S., and Ashayeri, J. "Joint venture formation and partner selection in upstream crude oil section: goal programming application", Int. J. Prod. Res., vol. 53, no. 10, pp. 3047–3061, May 2015, doi: 10.1080/0020 7543.2014.970708.

[23] Li, P. "Project Selection of Government Guarantee in BOT/PPP Project Finance", Am. J. Ind. Bus. Manag., vol. 10, no. 06, pp. 1107–1120, 2020, doi: 10.4236/ajibm.2020.106073.

[24] Yu, L., Wang, S., Wen, F., and Lai, K. K. "Genetic algorithm-based multi-criteria project portfolio selection", *Ann. Oper. Res.*, vol. 197, no. 1, pp. 71–86, 2012, doi: 10.1007/ s10479-010-0819-6.

[25] Tailor, A. R., and Dhodiya, J. M. "Multi-objective Assignment Problems and Their Solutions by Genetic Algorithm.", in Computational Management Applications of Computational Intelligence in Business Management, 2nd ed., Patnaik, S., Tajeddini, K., and Jain, V., Eds. Gewerbestrasse: Springer Nature, 2021, pp. 409–428.

[26] Jin, W., Hu, Z., and Chan, C, W. "A genetic-algorithms-based approach for programming linear and quadratic optimization problems with uncertainty", Math. Probl. Eng., vol. 2013, pp. 1–12, 2013, doi: 10.1155/2013/2724 91.

[27] Dutta, B., Dao, S. D., Martínez, L., and Goh, M. "An evolutionary strategic weight manipulation approach for multi-attribute decision making: TOPSIS method", Int. J. Approx. Reason., vol. 129, pp. 64–83, 2021, doi: 10.1016/j.ijar.2020.11.004.

[28] Katoch, S., Chauhan, S. S., and Kumar, V. "A review on genetic algorithm: past, present, and future", Multimed. Tools Appl., vol. 80, no. 5, pp. 8091–8126, 2021, doi: 10.1007/s11042-020-10139-6.

[29] Maghawry, A., Hodhod, R., Omar, Y., and Kholief, M. "An approach for optimizing multi-objective problems using hybrid genetic algorithms", Soft Comput., vol. 25, no. 1, pp. 389–405, 2021, doi: 10.1007/s00500-020-05149-3.

[30] Yin, L., and Zhao, P. "User preference intelligent information recommendation system based on chaos genetic algorithm", J. Ambient Intell. Humaniz. Comput., 2021, doi: 10.1007/s12652-020-02611-w.

[31] Qi, J. G., Burns, G. R., and Harrison, D. K. "Application of parallel multipopulation genetic algorithms to dynamic job-shop scheduling", Int. J. Adv. Manuf. Technol., vol. 16, no. 8, pp. 609–615, 2000, doi: 10.1007/s00 1700070052.

[32] Bastiani, S. S., Cruz, L., Fernandez, E., Gomez, C., and Ruiz, V. "Project Ranking-

Based Portfolio Selection Using Evolutionary Multiobjective Optimization of a Vector Proxy Impact Measure", in Eureka-2013. Fourth International Workshop Proceedings Project, 2013, no. January, pp. 232–240, doi: 10.2991/. 2013.28.

[33] Huang, X., and Zhao, T. "Project selection and scheduling with uncertain net income and investment cost", Appl. Math. Comput., vol. 247, pp. 61–71, 2014, doi: 10.1016/j.amc.2014 .08.082.

[34] Kumar & Pushkar, "A Genetic Algorithm Approach for Multi-criteria Project Selection for Analogy-Based Software Cost Estimation", in Computational Intelligence in Data Mining, 2015, vol. 3, no. 1, pp. 13–24, doi: 10.1109/icsmc.2001.973492.

[35] Polat, G., Kaplan, B., and Bingol, B. N. "Subcontractor Selection using Genetic Algorithm", Procedia Eng., vol. 123, pp. 432–440, 2015, doi: 10.1016/j.proeng.2015.10.081.

[36] Zhao, T. and Huang, X. "Optimizing project selection: a perspective from resource constraints", Optimization, vol. 66, no. 11, pp. 1863–1878, 2017, doi: 10.1080/02331934.201 7.1317777.

[37] Guo, Y., Wang, L., Li, S., Chen, Z., and Cheng, Y. "Balancing strategic contributions and financial returns: a project portfolio selection model under uncertainty", Soft Comput., vol. 22, no. 16, pp. 5547–5559, 2018, doi: 10.1007/s00500-018-3294-7.

[38] Dewi, S., and Sawaluddin, "Combinatorial Optimization in Project Selection Using Genetic Algorithm", in IOP Conference Series: Materials Science and Engineering, 2018, vol. 300, no. 1, pp. 1–5, doi: 10.1088/17 57-899X/300/1/012020.

[39] Lee, A. H. I., Kang, H. Y., and Chen, C. L. "Multi-objective assembly line balancing problem with setup times using fuzzy goal programming and genetic algorithm", Symmetry (Basel)., vol. 13, no. 2, pp. 1–28, 2021, doi: 10.3390/sym13020333.

[40] Ahern, A., and Anandarajah, G. "Railway projects prioritisation for investment: Application of goal programming", Transp. Policy, vol. 14, no. 1, pp. 70–80, 2007, doi: 10.1016/j.tranpol.2006.10.003.

[41] Tripathy, B. B., and Biswal, M. P. "A zero-one goal programming approach for project selection", J. Inf. Optim. Sci., vol. 28, no. 4, pp. 619–626, 2007, doi: 10.1080/02522667.20 07.10699763.

[42] Liao, C. "A Zero-one Goal Programming Model for Marketing Project Selection", J. China Inst. Technol., vol. 40, pp. 77–88, 2009.

[43] Namazian, A., Yakhchali, S. H., and Rabbani, M. "Integrated bi-objective project selection and scheduling using Bayesian networks: A risk-based approach", Sci. Iran., vol. 26, no. 6, pp. 3695–3711, 2019, doi: 10.24200/sci.2019. 21387.

[44] Akbari, N., Jones, D., and Arabikhan, F. "Goal programming models with interval coefficients for the sustainable selection of marine renewable energy projects in the UK", Eur. J. Oper. Res., vol. 293, no. 2, pp. 748–760, 2021, doi: 10.1016/j.ejor.2020.12.038.

[45] Wu, Y., Xu, C., Ke, Y., Li, X., and Li, L. "Portfolio selection of distributed energy generation projects considering uncertainty and project interaction under different enterprise strategic scenarios", Appl. Energy, vol. 236, no. October 2018, pp. 444–464, 2019, doi: 10.1016/j.apenergy.2018.12.009.

[46] Razi, F. F. "A hybrid grey relational analysis and nondominated sorting genetic algorithm-II for project portfolio selection", Adv. Oper. Res., vol. 2014, 2014, doi: 10.1155/2014/9542 19.

[47] Sampath, S., Gel, E. S., Kempf, K. G., and Fowler, J. W. "A generalized decision support framework for large-scale project portfolio decisions", Decis. Sci., no. January 2019, pp. 1–24, 2021, doi: 10.1111/deci.12507.