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A priority based genetic algorithm for nonlinear transportation costs problems ☆

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ABSTRACT

In this manuscript, a vehicle allocation problem involving a heterogeneous fleet of vehicles for delivering products from a manufacturing firm to a set of depots is considered. Each depot has a specific order quantity and transportation costs consist of fixed and variable transportation cost. The objective is to assign the proper type and number of vehicle to each depot route to minimize the total transportation costs. It is assumed that the number of chartering vehicle types is limited. It is also assumed that a discount mechanism is applied to the vehicles renting cost. The discount mechanism is applied to the fixed cost, based on the number of vehicles to be rented. A mathematical programming model is proposed which is then converted to a mixed 0–1 integer programming model. Due to the computational complexity of the proposed mathematical model, a priority based genetic algorithm capable of solving the real world size problems was proposed. A computational experiment is conducted through which, the performance of the proposed algorithm is evaluated. The results reveal that the proposed algorithm is capable of providing the astonishing solutions with minimal computational effort, comparing with the CPLEX solutions.

1. Introduction

Transportation system is one of the most important fields of supply chain management. Optimization of transportation systems comprises a great potential to reduce costs and to improve service quality. To be successful in today's fast growing business competition, enterprises need to design and build a productive and a cost effective logistics model. In this manuscript a priority based encoding genetic algorithm is proposed for the problem of vehicle depot assignment in an existing distribution network. The distribution network encompasses the following aspects:

- a heterogeneous fleet of vehicles having various capacities,
- the transportation costs, consists of a variable cost which incurred proportionately to the travel distance, and a fixed cost,
- a manufacturing firm and a number of depots acting as the distribution centers of this manufacturing firm,
- each depot has a known demand,
- the number of available vehicles of each type is limited,
- a discount mechanism is applied to the fix cost depending on the number of vehicles to be rented.

Motivation of this study came from the vehicle depot assignment problem of a food industrial group in a developing country. Keeping the major aspects of this real-world problem, we propose a more generalized version of this problem in order to create a more applicable model which may later be used by similar worldwide firms.

Based on the above discussion, in this work, the problem of distributing products from a manufacturing firm to a set of distinct depots and allocating of the appropriate vehicles to the depots routes will be considered. A mathematical model, in the form of a nonlinear mixed integer programming is constructed for the proposed model. The objective function is defined as the minimization of total transportation costs. Due to the computational complexity of the proposed problem, any solution approach for handling a real world case is expected to suffer from the computer time and memory requirements. Based on this fact, we proposed a prioritized encoding genetic algorithm as the solution approach. For evaluating the efficiency of the proposed genetic algorithms, we first convert the proposed nonlinear model to a linear zero-one mathematical programming model. By this conversion, the mathematical model could be solved by a conventional optimization software by which we can evaluate the robustness of the solutions obtained by the proposed algorithm. We then randomly generated

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a vast number of test problems and solve them by the proposed algorithm as well as the CEPLEX software. The results are compared and will be reported in Section 6.2.

2. Literature review

Discounted fixed cost transportation can be considered as a version of fixed cost transportation problem. This is considered to be an NP-hard problem since the cost structure causes the value of the objective function to behave like a step function (Altassan, El-Sherbiny, & Sasidhar, 2013). Recently, research on logistics caught more and more attention. One of the important issues on logistic systems is to find the least cost processes for products delivery. Numerous models have been developed to overcome this issue. However, due to the diversity and complexity of practical problem, the existing models are usually not very satisfying to find the solution efficiently and conveniently. Zegordi, Abadi, and Nia (2010) considered the scheduling of products and vehicles in a two-stage supply chain. In this study, it was assumed that the various output products occupy different percentages of each vehicle's capacity. They modeled their proposed problem as a mixed integer programming problem, and, presented a "gendered genetic algorithm" as the solution approach. Xie and Jia (2012) proposed an efficient method to solve nonlinear fixed charge transportation problem, on condition that any route has a fixed cost irrelative to its shipping amount, and a variable cost directly proportional to the quadratic of its shipping amount. Cheng and Gen (1994) also considered the problem of fixed charge capacitated in a non-linear transportation model. They then developed an algorithm for solving this transportation problem and conducted a computational experiment. A discounted generalized transportation problem in which cost of transportation depends upon the amount of transported commodity was explored in work of Acharya, Basu, and Das (2013a). In this article, they developed a new algorithm for obtaining the optimum solution of this problem. They also proposed a modified method for fixed charge transportation problem (Acharya, Basu, & Das, 2013b). Osuji, Ogbonna-Chukwudi, and JUDE (2014) focused on the application of transportation algorithm with volume discount on distribution cost using Nigerian Bottling Company Plc Owerri Plant. The proposed problem can also be considered as the vehicles utilization problem. The work conducted by Sarkar and Mohapatra (2008) addressed this problem. In this paper they considered the problem of a steel plant which is haired a third-party for their maintenance, repair and operations. The problem was formulated as a mathematical programming model to maximize the utilization of vehicle capacity.

Due to the fact that the logistics networks design is an NP hard problem (Das, Basu, & Acharya, 2013), several heuristics and meta-heuristic approaches have also been proposed. Among these approaches, the use of the genetic algorithms seems to be very promising (Pandey, Chaudhary, & Mehoretra, 2014). Hwang, Katayama, and Gen (2008) presented a priority – based encoding genetic algorithm to solve the multi-objective U-shaped assembly line balancing problem. Lee, Gen, and Rhee (2008) considered a reverse logistics network problem with two objectives of minimizing total cost of transportation and minimizing cost of inventory. For applying an evolutionary approach, a priority-based encoding method and adaptive weight approach were proposed. Later Lee, Gen, and Rhee (2009) proposed a genetic algorithm with priority-based encoding method consisting of two stages, and combines a new crossover operator called weight mapping crossover for solving multistage reverse logistics network problem with minimizing the total of costs to reverse logistics shipping cost.

Lotfi and Tavakkoli-Moghaddam (2013) proposed a genetic algorithm using priority-based encoding for linear and nonlinear fixed charge transportation problems. They modified a priority-based decoding procedure proposed by Das et al. (2013) to adapt to the proposed problem structure. BozorgiRad, Desa, and Firoozi (2014) employed a genetic algorithm with penalty method, called P-GA, to solve the multi-source single product flexible multi stage logistic network. It is shown however that the P-GA requires unreasonable elapsed time to obtain an acceptable solution. Roghanian and Pazhoheshfar (2014), proposed a probabilistic mixed integer linear programming model for the design of a reverse logistics network. This probabilistic model is first converted into an equivalent deterministic model. They then proposed multi-product, multi-stage reverse logistics network problem for the return products in order to determine the establishment of disassembly and processing centers as well as the transportation strategy and recycling centers with minimum fixed opening cost and total shipping cost. A priority based genetic algorithm was proposed and a numerical example was presented.

There are several other works applying genetic algorithm for solving combinatorial optimization problems. Among them are work of Gen, Altiparmak, and Lin (2006) who proposed a modification of traditional order-based crossover operators for solving a resource constrained project scheduling problem. The augmentation of the evolution program with domain-specific knowledge is adopted for generation of the feasible schedules. They also implemented a designed crossover to perform blind search for exploring the entire search are, and a designed mutation for performing intensive search to produce an improved solution. The proposed approach has been tested on two standard test problems and the results showed the superiority of their approach comparing to the existing heuristic techniques. Cheng, Gen, and Tsujimura (1996) implemented a genetic algorithm based method for solving job-shop scheduling problem (JSP). They proposed a new procedure for representation of the schedules, as an individuals, and designing the genetic operators for obtaining better results. By conducting a computational experiment they demonstrated the efficiency of their approach through a set of standard benchmark of JSPs. The application of multi-objective genetic algorithm approach on solving the combinatorial optimization problems presented in the book by Gen et al. (1994). In this book combinatorial problems such as shortest path, min cost-max flow, minimum spanning tree, travelling salesman, location–allocation, project scheduling, logistics network, airline fleet assignment, and assembly line balancing problems, are explored.

Although genetic algorithms have been successfully applied in many hard combinatorial optimization problems, but no efficient solution algorithm has been found yet for one of the hardest problems (JSP) optimality in polynomial time. Gen, Cheng, and Lin (2008) presented a tutorial survey of recent works on solving classical JSPs using genetic algorithms. Their survey consist of two parts, In Part I, they focused on the representation schemes of JSPs. In Part II, they discussed the efficiency of hybrid genetic algorithms and other conventional heuristics. The novelty of their work is the fact that exploration of the techniques developed for JSP may be useful for other scheduling problems and other combinatorial optimization problems.

There are several other attempts using genetic algorithm in design of transportation systems such as (Mehdizadeh, Afrabandpei, & Afshar Najafi, 2013; Lee, Chung, Lee, & Gen, 2013; Kamiyama & Katoh, 2014; Krzysztof Kowalski, Lev, Shen, & Tu, 2014; Maity & Roy, 2015).

The scope of the proposed problem will be described in the following section.

3. Scope of the problem

Consider a directed graph $G = (N, A)$ with the set A of directed arcs, and the set N of nodes representing a manufacturer and