Expert Systems with Applications 38 (2011) 12730–12738

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

A distribution network optimization problem for third party logistics service providers

Hüseyin Başligil, Selin Soner Kara *, Pelin Alcan, Betül Özkan, E. Gözde Çağlar

Department of Industrial Engineering, Mechanical Faculty, Yildiz Technical University, 34349 Istanbul, Turkey

ARTICLE INFO

Keywords:
3PL
Distribution network optimization
Mixed integer programming
Genetic algorithm

ABSTRACT

Third party logistics service providers (3PLs) have an important role in supply chain management. Increasing cooperation with 3PLs is expanding in today's business environment. Hence, 3PLs need to have an efficient distribution network to meet customer demands. Nevertheless, few researches have tried to propose a solution for distribution network problems of 3PLs. The optimization problem which is discussing in our study is solved in two stages. At the first stage, the assignment problem which includes assigning the order of the vehicles is solved with mixed integer programming by using GAMS 21.6/CPLEX. The output of the first stage is used as an input in the second stage. In this stage routes are determined for vehicles by developing a genetic algorithm by using C#.

1. Introduction

Third party logistic (3PL) has become more important for logistic sector in recent years. Companies want to reduce the costs and provide customer satisfaction exactly. They don't want to deal with logistics problems, so they prefer special firms for some or all of their logistics operations. Therefore, a third party logistics (3PL) business is emerging and developing rapidly to fulfill the demands for advanced logistics services, in such fields as, transportation, warehousing, freight consolidation and distribution, product marking, labeling and packaging, inventory management, cross docking, product returns, order management, and logistics information systems (Rabinovich, Windle, Dresner, & Corsi, 1999).

There are different definitions for 3PL in the literature. Some broad definition for 3PL are "the use of external companies to perform logistics functions that have traditionally been performed within an organization" (Lieb, 1992) and "an external organization that performs all or part of a company's logistics functions" (Coyle, Bardi, & Langley, 2003). Bask (2001) describes 3PL as "relationships between interfaces in the supply chains and third-party logistics providers, where logistics services are offered, from basic to customized ones, in a shorter or long term relationship, with the aim of effectiveness and efficiency".

The vehicle routing problem (VRP) can be described as the problem of designing optimal delivery or collection routes from one or several depots to a number of geographically scattered cities or customers, subject to side constraints. The VRP plays a central role in the fields of physical distribution and logistics. The vehicle routing problem lies at the heart of distribution management (Laporte, 1992). A vehicle routing problem (VRP) is one of visiting a set of customers using a fleet of vehicles, respecting constraints on the vehicles, customers, drivers, and so on. The goal is to produce a low cost routing plan specifying for each vehicle, the order of the customer visits they make. Industrial VRPs tend to be large, and so local search techniques are used extensively as they scale well and can produce reliably good solutions (Shaw, 1998).

Genetic Algorithms (GAs) have seen widespread application to various combinatorial optimization problems, including certain types of vehicle routing problem, especially where time windows are included (Baker & Ayechew, 2003). GAs employ search procedures based on the mechanics of natural selection and survival of the fittest. In the GAs, which use multiple point search instead of single point search and work with the coded structure of variables instead of actual variables themselves, the only information required is the objective function thereby making the searching for global optimum simpler (Das, 2002).

Many researchers have conducted studies to solve vehicle routing problems using mathematical models and heuristic algorithms. These are some examples of recent studies: Hadjar and Soumis (2009) used a branch-and-price approach price approach to solve the multiple depot vehicle scheduling problem with time windows (MDVSPTW). They developed a dynamic time window reduction technique. This technique is used at every node of the branch-and-price tree to tighten the time window. Chen, Hsueh, and Chang (2009) proposed a nonlinear mathematical model to consider production scheduling and vehicle routing with time windows for perishable food products. They used a constrained Nelder–Mead method and a heuristic method for the vehicle routing with time

* Corresponding author. Tel.: +90 212 383 2902.
E-mail addresses: basligil@yildiz.edu.tr (H. Başligil), ssoner@yildiz.edu.tr (S.S. Kara), palcan@yildiz.edu.tr (P. Alcan), bozkan@yildiz.edu.tr (B. Özkan).

0957-4174/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2011.04.061

window to solve the problem. Zachariadis et al. (2009a) proposed a metaheuristic methodology for the capacitated vehicle routing problem with two-dimensional loading constraints. Tabu search and Guided local search are used together in this methodology. The aim of the paper is to find the minimum cost routes, starting and terminating at a central depot. Hemmelmayr et al. (2009) developed a new heuristic for the periodic vehicle routing problem without time window. The method is based on variable neighborhood search. In the periodic vehicle routing problem there is a planning horizon of several days and the customers must be visited more than once. Fleszar, Osman, and Hindi (2009) proposed a variable neighborhood search heuristic for open vehicle problem. Proposed solution is based on reversing segments of sub-routes and exchanging segments between routes. Li et al. (2009) proposed a Lagrangian relaxation based-heuristic for the real-time vehicle rerouting problems with time windows. In real-time vehicle rerouting problems there are service disruption because of vehicle breakdowns. So some vehicles must be rerouted. Fuellerer et al. (2009) developed an effective heuristic based on ant colony optimization for the two-dimensional loading vehicle routing problem. There is a combination of two problems: Loading of the freight into the vehicles and routing the vehicles successfully. Zachariadis et al. (2009b) tried to propose an effective hybrid metaheuristic algorithm. The algorithm is a combination of tabu search and guided local search methodologies. There is simultaneous delivery and pick-up service in this type of vehicle routing problem.

Genetic Algorithm (GA) is a popular algorithm for solving vehicle routing problems. Some of the studies are as follows: The study of Wang and Lu (2009) primarily focused on solving a capacitated vehicle routing problem (CVRP) by applying a novel hybrid genetic algorithm (HGA) capable of practical use for manufacturers. The search mechanism embedded in the GA focuses on the breeding process in evolution on crossover and mutation operators that are applied using probability setting to approach a close-to-optimal solution. Liu et al. (2009) studied the fleet size and mix vehicle routing problem (FSMVRP), in which the fleet is heterogeneous and its composition to be determined. They design and implement a genetic algorithm (GA) based heuristic. On a set of twenty benchmark problems it reaches the best-known solution 14 times and finds one new best solution. It also provides a competitive performance in terms of average solution. The paper of Prins (2009) presented two memetic algorithms (genetic algorithms hybridized with a local search) able to solve both the VFMP (The vehicle fleet mix problem) and the HVRP (The heterogeneous fleet VRP). They are based on chromosomes encoded as giant tours, without trip delimiters, and on an optimal evaluation procedure which splits these tours into feasible trips and assigns vehicles to them. Ho et al. (2008) studied the MDVRP (multi-depot vehicle routing problem) because the number of depots is not limited to one in many real-world situations. Besides routing and scheduling, the grouping problem is also considered in the MDVRP. Because the MDVRP integrates three hard optimization problems, a Hybrid genetic algorithm (HGA) rather than a simple GA was developed. The paper of Prins (2004) bridged the gap by presenting a relatively simple but effective hybrid GA. The framework of this research is the development of effective metaheuristics for hard combinatorial optimization problems met in vehicle routing. It is surprising to notice in the literature the absence of effective genetic algorithms (GA) for the vehicle routing problem contrary to node routing problems with time windows or arc routing problems. The study of Baker and Ayechew (2003) considers the application of a genetic algorithm (GA) to the basic vehicle routing problem (VRP), in which customers of known demand are supplied from a single depot.

There are limited numbers of papers about vehicle routing problems of 3PLs. Some examples can be given as follows: Krajewska and Kopfer (2009) used a tabu search algorithm for solving the integrated transportation planning problem. Zäpfel and Bögl (2008) consider short-range weekly planning on the part of postal companies that must decide about pickup tours and delivery tours for fluctuating volume (number of shipments), with time windows for the demand points, in consideration of variable vehicle capacities and personnel planning, and including outsourcing decisions for tours and drivers for 3PLs. Tan et al. (2006) developed a hybrid multi-objective evolutionary algorithm for truck and trailer vehicle routing problem. The purpose of this study is to minimize the routing distance and the number of trucks.

The remainder of this paper is organized as follows. The theoretic descriptions for genetic algorithms are presented in Section 2. The proposed methodology is described in Section 3. Section 3 also, explains a numerical example in Istanbul. Finally, the results and the conclusion are presented in Section 4.

2. Genetic Algorithm

Genetic Algorithms (GAs) are adaptive heuristic search algorithm premised on the evolutionary ideas of natural selection and genetic (De Jong, Spears, & Gordon, 1993). Genetic Algorithms are a family of computational models inspired by evolution. These algorithms encode a potential solution to a specific problem on a simple chromosome like data structure and apply recombination operators to these structures so as to preserve critical information (Whitley, 1994).

The basic concept of GAs is designed to simulate processes in natural system necessary for evolution. As such they represent an intelligent exploitation of a random search within a defined search space to solve a problem. First pioneered by John Holland in the 60s, Genetic Algorithms has been widely studied, experimented and applied in many fields in engineering worlds. Not only does GAs provide an alternative method to solve problem, it consistently outperforms other traditional methods in most of the problems link (De Jong et al., 1993).

Genetic algorithms have shown great advantages in solving the combinatorial optimization problem in view of its characteristic that has high efficiency and that is fit for practical application (Chiu, Fang, & Lee, 1999). Genetic Algorithms are search algorithms which are based on natural selection and natural genetic mechanism (Cheng, 1999). From the view point of the working principle, genetic algorithms firstly needs the coding of the problem with the condition that it should be fitting with the GA (Çakar, Koker, & Demir, 2008). After coding stage, GA operators are applied on chromosomes. It is not guaranteed that the obtained new offsprings are good solutions by the working of crossover and mutation operators. Feasible solutions are evaluated, and others are left out of evaluation. The feasible ones of the obtained offsprings are taken and new populations are formed by reproduction process using these offsprings (Damodaran, 2006).

During each iteration step genetic operations, that is, crossover, mutation and natural selection are applied in order to search potential better solutions. Crossover combines two chromosomes to generate next-generation chromosomes preserving their characteristics. Mutation reorganizes the structure of genes in a chromosome randomly so that a new combination of genes may appear in the next generation. Reproduction is to copy a chromosome to the next generation directly so that chromosomes from various generations could cooperate in the evolution and the "quality" of the population may be improved after each generation (Hop & Nagarur, 2004).

An implementation of a genetic algorithm begins with a population of (typically random) chromosomes. One then evaluates these structures and allocates reproductive opportunities in such a way that those chromosomes which represent a better solution