Socio-Economic Planning Sciences 47 (2013) 309–317

Contents lists available at SciVerse ScienceDirect

Socio-Economic Planning Sciences

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

Location-allocation problem for intra-transportation system in a big company by using meta-heuristic algorithm

Ali Zeinal Hamadani [a], Mostafa Abouei Ardakan [a], Taghi Rezvan [a,*], Mohammad Mehran Honarmandian [b]

[a] Department of Industrial Engineering, Isfahan University of Technology, Isfahan 84156-83111, Iran
[b] Mobarakeh Steel Company, Isfahan 98311-3327327, Iran

ARTICLE INFO

Article history:
Available online 26 March 2013

Keywords:
Transportation
Location-allocation problem
Meta-heuristic algorithm

ABSTRACT

This paper presents the location-allocation problem of parking facilities in Mobarakeh Steel Company. The aim is to find the optimal location for the parking facilities and allocate travels between departments to each parking facility. To optimize the cost and facing the transportation demands of all departments, a mathematical model is designed and solved by a commercial software package. Also, the number of vehicles allocated to each parking facility is determined. A hybrid meta-heuristic algorithm combining a genetic algorithm with parallel simulated annealing is developed which can be used even in more complicated structure of the problem. The results show that this hybrid algorithm is highly efficient in solving this kind of problems.

1. Introduction

The distributing of facilities in each system is a strategic decision for every company. The facility location and customer allocation problem constitutes the core of distribution systems. Factories and industrial companies need proper location for their machinery and warehouses. Wholesalers also need to find proper locations for their warehouses. Similarly, local government agencies need to decide where to locate buildings such as offices, schools, hospitals, park and ride sites and fire stations. The quality of the provided services in each facility depends on the location of that facility and the relationship between other facilities. Many applications of location models such as hospitals and fuel supply centers in cities can be found in a book by Drezner and Hamacher or Heragu [12,13].

The effective use of transportation resources and facilities is an important task for a proper management. Goals such as increasing efficiency, reducing environmental pollutions, fair distribution of transportation facilities and increasing employee satisfaction have made transportation planning as an important scope for managers. Choosing appropriate locations for transportation facilities could be of great importance in big companies. In these companies, parking facilities are equipped with vehicles used as transportation equipment for moving employees from one department to another one.

Location-allocation models include diverse sets of models such as simple linear, single-phase, single-commodity, capacity, no capacity, deterministic models, dynamic and probabilistic models, non-linear, multiphase models, etc. These models include discrete placement, continuous placement, and network placement such as P-median, P-center and so on [12,19].

The theoretical framework for location was first introduced by Weber [25]. Location models are divided to many categories based on the constraints of the problem. In the Uncapacitated Facility Location Problem (UCFLP), capacity of each facility is infinite so that each customer is served by a single facility. When each facility has a limited capacity the problem is called the Capacitated Facility Location Problem (CFLP). The CFLP consists of locating a set of facilities with capacity constraints to satisfy the demands of a set of customers at the minimum cost. In this problem each customer can receive its demand from several facilities [6]. In Single Source Capacitated Facility Location Problem (SSCFLP), as the special case of CFLP, it is assumed that each customer is supplied by only one facility. In this paper, a modified version of SSCFLP is proposed for the location-allocation problem and adapted for intra-transportation of a big company. This adaption has increased the dimension of variables from 2 to 3 which affects the complexity of the problem solving. Therefore, for tackling this problem, a meta-heuristic algorithm is presented and used.

Few researches have focused on solving SSCFLP and most of them used various types of Lagrangian heuristic. Klincewicz and Luss [17] introduced a modified version of Lagrangian heuristic for the SSCFLP, where the capacity constraint is dualized. Beasley [3] proposed a Lagrangian heuristic, which relaxes the capacity and the customer assignment constraints. For the SSCFLP, an allocation

* Corresponding author. Tel.: +98 3113912550; fax: +98 3113915526.
E-mail address: taghi_rezvan@in.iut.ac.ir (T. Rezvan).

0038-0121/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.seps.2013.03.001

cost procedure is used by Beasley to calculate the cost of open facilities. Hindi and Pienkosz [14] presented an efficient approach for large SSCFLP. They developed a Lagrangian relaxation with subgradient optimization method by relaxing customer assignment constraint to calculate a lower bound and generated configurations of chosen facilities.

Cortinhal and Captivo [11] applied Lagrangian relaxation to obtain the lower bounds for the SSCFLP, and the upper bounds were given by local search and tabu search (TS), respectively. Ahuja et al. [1] developed a very large scale neighborhood (VLSN) search algorithm, which involved customer exchanges and facility moves, to solve the SSCFLP. Customer exchanges were applied to change the customer assignment among selected facilities, while the facility moves were to find improving configurations of the open facilities. The results revealed that the VLSN is an effective method to solve the SSCFLP. Chen and Ting applied a multiple ant colony system and also developed a hybrid ant colony and lagrangian heuristic for the SSCFLP. Their computational results show that the performance of hybrid algorithm is better than other proposed algorithms [5,6].

Some real world applications of facility location models are studied by different authors such as the study of placement of emergency fire stations [7], distribution centers for humanitarian relief [2], health care centers [4,9,20], ecological reserves [8] and etc.

In this paper we review some of the real world studies which are closed to our problem, in more details. These papers manifest the novelty and contribution of the presented model and the solutions.

Hongzhong et al. [16] considered a large-scale facility location of medical services. Their aim was to determine the optimal emergency medical service (EMS) facility locations to address the needs generated by large-scale emergencies such as house fires and regular health care needs. To determine the number and location of facilities, they used mixed integer programming (MIP) and solved the MIP model with CPLEX software. Verter and Lapierre [23] investigated the problem of locating preventive health care facilities in the United State and Canada. Their aim was to determine the number of facilities to be established and the location of each facility in order to maximize the participation for prevention programs. For the solution of the problem they presented a MIP model and solved by the CPLEX software.

Wang and Wang [24] proposed a placement model with a double objective of minimizing cost and maximizing demand coverage. They determined the number and locations of fuel supply centers in the Taiwan's road network using mixed integer programming. They used the LINGO software for solving the proposed MIP model and found non-inferior solutions. Since a real large-size location problem includes many constraints, they relaxed the constraint by considering uncapacitated stations in order to greatly reduce the number of constraints. However, they suggested using meta-heuristic algorithms to tackle the large-size problems.

Chevalier et al. [7] developed a decision-support system for Belgium fire stations. Their objective was determination of optimal location for fire stations and assigning staff and equipments to them. In order to determine these objectives they introduced a location-allocation problem. The location problem was modeled as a mixed integer programming (MIP) and the allocation problem was solved by hypercube queuing model. Authors showed that solving the proposed model is not easy by using any commercial MIP solver in a reasonable time limit. Therefore, they implemented a mean field-feedback neural network approach and showed the capability of this heuristic approach.

Tong et al. [22] investigated the problem of locating farmers' markets, in Tucson, Arizona state. They considered the limitations of service hours and spaces in farmers' market and used P-median problem for the establishment of their MIP model. For more realizations they classified farmers' markets into weekday morning–noon markets, weekday afternoon–evening markets, and weekend markets and also customers were divided into workers and non-workers groups. In order to solve the real problem of Tucson farmers' markets CPLEX software was implemented and results showed that afternoon–evening markets are preferred in providing the optimal solution for minimizes the overall travel.

In this paper the problem of selecting appropriate parking facilities, among the candidate parking locations, with limited capacity and allocation of department-to-department travels is considered. In addition, the number of vehicles that could be allocated to each selected parking facility is determined. Therefore the problem under consideration is a location-allocation problem which will be considered in two stages. In the first stage, the optimal number of parking facilities, their locations for covering the transportation demands and the allocation of travel demands to the selected parking will be obtained using an integer programming (IP) model. In the second stage the allocation of vehicles to the selected parking facilities will be obtained using a simple algorithm.

CPLEX solver of the General Algebraic Modeling System (GAMS) software is used to obtain the optimal solution of IP model. Furthermore, for more complex aspects of the problem such as the large dimensions or certain structures of data, a hybrid parallel simulated annealing-genetic algorithm is implemented. Final results will prove the effectiveness of proposed meta-heuristic algorithm.

The rest of the paper is organized as follows. In Section 2, the developed model is introduced. The solution by using CPLEX solver of GAMS software and the meta-heuristic algorithm are discussed in Section 3. Section 4 investigates efficiency of meta-heuristic algorithm for this problem. Section 5 introduces the case study in Mobarakeh Steel Company. Conclusion remarks are presented in Section 6.

2. The problem structure

Mobarakeh Steel Company is using a central non-equipped parking facility and the intra-transportation services are given by this parking. As this system has an unsuitable performance, the transportation management of the company is interested on objectives such as monitoring transportation system, increasing efficiency, finding the proper distribution of transportation services, decreasing consumption of fuel and consequently reducing costs and environmental pollutions and increasing employee satisfaction. The following questions are raised from the above objectives: How the transportation system could be monitored? Is a parking facility adequate to satisfy the transportation demands? Should new parking facilities be created? And finally how many parking facilities should be created and how many vehicles should be allocated to each parking facility? In this paper the answers to the above questions will be provided.

For monitoring the transportation system it is recommended to use the proper technology such as GPS, E-cards with RFID technology, etc. Employees that use this transportation system will be provided an E-cards with RFID technology. When an employee uses transportation service, the card reader devices and GPS will record the information of employee and its driver, origin–destination (O–D) of travel, start and end time of travel, and other useful information. The equipments of parking facility have mobility properties and in future the transportation system can be optimized using the new recorded information. The rest of above questions can be answered by solving a location-allocation problem. The problem will be tackled in two stages; in the first stage we find the best locations for parking facilities and the optimal allocation of traveling demands. In the second stage the vehicle allocation to the