Computers & Industrial Engineering 98 (2016) 462–469

Contents lists available at ScienceDirect

Computers & Industrial Engineering

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

A Benders based rolling horizon algorithm for a dynamic facility location problem

Mohammad Marufuzzaman[a], Ridvan Gedik[b,*], Mohammad S. Roni[c]

[a] Department of Industrial and Systems Engineering, Mississippi State University, Starkville, MS 39759, USA
[b] Department of Mechanical and Industrial Engineering, University of New Haven, 300 Boston Post Rd, West Haven, CT 06516, USA
[c] Biofuels & Renewable Energy Technologies, Idaho National Laboratory, Idaho Falls, ID 83415, USA

ARTICLE INFO

Article history:
Received 25 September 2015
Received in revised form 26 June 2016
Accepted 27 June 2016
Available online 28 June 2016

Keywords:
Dynamic facility location problem
Benders decomposition algorithm
Rolling horizon heuristics
Hybrid Benders based rolling horizon algorithm

ABSTRACT

This study presents a well-known capacitated dynamic facility location problem (DFLP) that satisfies the customer demand at a minimum cost by determining the time period for opening, closing, or retaining an existing facility in a given location. To solve this challenging $\mathcal{NP}$-hard problem, this paper develops a unique hybrid solution algorithm that combines a rolling horizon algorithm with an accelerated Benders decomposition algorithm. Extensive computational experiments are performed on benchmark test instances to evaluate the hybrid algorithm's efficiency and robustness in solving the DFLP problem. Computational results indicate that the hybrid Benders based rolling horizon algorithm consistently offers high quality feasible solutions in a much shorter computational time period than the stand-alone rolling horizon and accelerated Benders decomposition algorithms in the experimental range.
© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

The problem of locating a set of facilities to serve customers has received extensive attention from researchers, managers, and practitioners due to the problem's presence in almost any supply chain. Therefore, various types of facility location problems have been investigated in order to determine which facilities should be opened, closed or relocated to serve select customers to minimize the total cost (Melo et al., 2009). This paper examines a version of the capacitated facility location problem (CFLP) in which facilities are assumed to provide a finite amount of goods to meet time-dependent and deterministic customer demand subject to time-dependent cost parameters in a multi-period planning horizon. This problem is referred to as the capacitated *Dynamic Facility Location Problem* (DFLP) (Arabani and Farahani, 2012; Torres-Soto and Uster, 2011). In order to be able to respond to varying demand, the decision maker must determine whether to open new facilities, keep the existing facilities open or closed, or relocate them at any time period. In addition, the portion of customer demand needs to be satisfied by each operating facility must be decided. The ultimate objective is to minimize the total cost, which may include transportation and operating costs, facilities opening and closing expenses, or other costs during all planning periods.

Arabani and Farahani (2012) categorize the facility location problem into two main groups based on whether the (re)location decisions vary by time. The static facility location problem is referred to as single-period facility location problem in which the facility location decisions and their parameters are independent of time. Since the dynamic counterpart relaxes this assumption, dynamic model variants are more suitable to reflect the impacts of vital factors that cannot be represented by static models, such as incentives, energy prices, and market growth. Thus, dynamic model variants have many application areas, including, but not limited to, combat logistics (Gue, 2003), electronics logistics (Manzini and Gebennini, 2008), and healthcare (Ghaderi and Jabalameli, 2013). Current et al. (1998) further apply another classification criteria for the DFLP based on facility (re)location decisions. The *explicitly* DFLP controls the opening and closing of a facility in a planning horizon, whereas the parameters may change over time, but the (re)location decisions can be made only at the beginning of the time horizon in the *implicitly* DFLP. Mirchandani and Odoni (1979) study a version of the implicitly DFLP in which the travel times are treated as random variables with known discrete probability distributions. Drezner and Wesolowsky (1991) demonstrate an optimal solution method for the single facility location problem with a single (re)location option with known demand of each serving point and a continuous linear function of time. Farahani et al. (2009) extend this work by including multiple relocation opportunities and proposing an exact algorithm to make optimal relocation decisions. The implicitly DFLP proposed by

* Corresponding author.
E-mail addresses: maruf@ise.msstate.edu (M. Marufuzzaman), rgedik@newhaven.edu (R. Gedik), mohammad.roni@inl.go (M.S. Roni).

http://dx.doi.org/10.1016/j.cie.2016.06.029
0360-8352/© 2016 Elsevier Ltd. All rights reserved.

Drezner (1995) develops a progressive p-median problem that does not consider (re)location of the existing facilities but time periods are known when new facilities are added to the network. The common property of these studies is, although the demand is assumed to be dynamic and deterministic as a function of time, facilities can only be opened at the beginning of the planning period.

This study limits attention to the explicitly DFLP that represents the impacts of time-dependent parameters on time-dependent (re) location decisions. Even in this subgroup of facility location problems, differences exist due to several assumptions, or limitations, on the ways facility capacities can be dynamically adjusted to correspond to the dynamic structure of demand. Thus, some researchers assume that once a facility is located during a time period, it will remain open until the end of the planning horizon (Scott, 1971). Some others consider the case that opening new facilities or expanding current capacities and closing existing ones can occur throughout the entire planning horizon (Canel et al., 2001; Lim and Kim, 1999; Melo et al., 2006; Roy and Erlenkotter, 1982). Klose and Drexl (2005) underline the exponentially increasing complexity of the dynamic models over time. We also show that this problem is $\mathcal{NP}$-hard. Despite these facts, the DFLP has received extensive attention due to recent computational advancements and in the problems applicability to real -life applications. Researchers have presented numerous intelligent solution ways for different versions of this problem. Jena et al. (2015) develop several valid inequalities to strengthen the DFLPs formulations separately with decisions about capacity expansion or reduction and facility closing and reopening. Scott (1971) proposes a near optimal dynamic programming approach for the DFLP in which multiple facilities can be located over equally distributed discrete time periods. Roy and Erlenkotter (1982) propose an exact dual ascent method embedded in a branch-and-bound search for the uncapacitated DFLP that solves the problem instances within one second and considers 25 facility and 50 customer locations, as well as 10 time periods. Later on, Lim and Kim (1999) consider the capacitated facilities for the same problem and develop a Lagrangian relaxation based branch-and-bound approach supported by Gomory cuts. Their technique finds good quality lower bounds by employing a subgradient optimization method. Canel et al. (2001) further extend this work by considering multi-commodity items. In the first two stages of their algorithm, a branch-and-bound procedure is adopted to make the facility opening and closing decisions for each time period. At the final stage, the optimal configuration of facilities is identified by dynamic programming. Melo et al. (2006) introduce modular capacity concept that enables facilities to exchange capacities. In addition, their capacitated multi-commodity DFLP problem considers inventory activities and external supply of goods. They investigate the complexity of each DFLP attribute by reporting the solution quality of the mathematical models solved by a commercial branch-and-bound solver. Jena et al. (2014) study the multi-commodity DFLP with generalized modular capacities in which facility closing, reopening, capacity reductions, and expansions are taken into account. They present a Langrangian based algorithm that finds good quality solutions within reasonable CPU times. Their technique consistently obtains solutions within 4% from the best known lower bound, even for the problem instances the commercial solver fails to report any solution due to memory limitation.

The multi-period international facility location problem (IFLP), introduced to the literature by Canel and Khumawala (1996), is a variant of the DFLP and seeks either to minimize the total cost of dynamically opening facilities in domestic/foreign countries or maximize the after-tax profits. Opening new facilities is the only facility related decision in the IFLP. However, the optimal time of the location decisions, the total quantities that need to be produced in each location and the shipment amounts from facilities to customers are taken into account. Canel and Khumawala (1996) further develop few mixed integer programs (MIP) for both the capacitated and uncapacitated IFLP, and by solving these problems in a commercial solver, they demonstrate how sensitive the location decisions are for specific problem parameters, such as with/without demand shortages. In a follow-up study, Canel and Khumawala (1997) tackle the uncapacitated IFLP with a branch-and-bound algorithm that is shown to be faster than the MIP formulation by a factor of 50 on some problem instances. Finally, a heuristic proposed by Canel and Khumawala (2001) demonstrates significant computational time gains for a similar IFLP problem.

Torres-Soto and Uster (2011) study two versions of the DFLP. In the first variant, they allow the facility opening and closing decisions throughout each period, whereas the second variant assumes located facilities are open during the entire planning period. After presenting a MIP for each, they develop only the Benders decomposition algorithm for the second problem and a Benders and a Lagrangian relaxation based algorithm for the first problem. This study presents the same problem as the first DFLP variant in (Torres-Soto and Uster, 2011). No assumption is made on the demand structures, and the facility opening/closing decisions can be made during any time period. The major contribution of this study is twofold. First, it proposes three main solution approaches: (i) a rolling horizon (RH) heuristic, (ii) an accelerated Benders decomposition algorithm, and (iii) a hybrid (RH- Benders) decomposition algorithm. Second, in addition to the largest set of problem instances introduced by Torres-Soto and Uster (2011), we introduce larger problem sets and compare both their methods with our novel algorithms in terms of solution quality and time.

The rest of this paper is organized as follows: Section 2 introduces the mathematical model formulation of the DFLP and discusses some basic properties. The proposed solution methods including rolling horizon approximation, accelerated, and hybrid Benders decomposition algorithms are presented in Section 3. A comparative discussion of these algorithms over some benchmark instances from the literature is demonstrated in Section 4. Finally, Section 5 concludes this paper by providing possible future research directions.

2. Problem formulation

This section introduces the mathematical formulation of the [**DFLP**] that was proposed by Torres-Soto and Uster (2011). Let $\mathcal{G} = (\mathcal{N}, \mathcal{A})$ be a complete directed graph where $\mathcal{N}$ denotes the set of nodes and $\mathcal{A}$ denotes the set of arcs. Set $\mathcal{N}$ consists of set of customers $\mathcal{I}$ and set of facilities $\mathcal{J}$ i.e., $\mathcal{N} = \mathcal{I} \cup \mathcal{J}$ and set $\mathcal{A}$ represents the transportation arcs between the facilities to customers. In [**DFLP**], we allow the facilities to open, close or remain operational in a given time period to meet the customer demand. The ultimate goal is to determine the optimum locations of capacitated facilities in each time period that will satisfy the customer demand at a minimum possible total cost. We note that when $\{V_{jt}\}_{j\in\mathcal{J},t\in\mathcal{T}} = \{U_{jt}\}_{j\in\mathcal{J},t\in\mathcal{T}} = 0$ and $\{q_j\}_{j\in\mathcal{J}} \to +\infty$, the [**DFLP**] becomes the classical uncapacitated fixed-charge location problem which is known to be an $\mathcal{NP}$-hard problem. Thus, [**DFLP**] is also an $\mathcal{NP}$-hard problem.

The major cost components in [**DFLP**] are the cost related to opening, closing and operating facilities and transportation costs across all time periods. The sets, input parameters, and decision variables used in this study are summarized in Table 1.

The [**DFLP**] can be formulated as follows:

$$[\textbf{DFLP}]\ \textit{Minimize} \sum_{j\in\mathcal{J}}\sum_{t\in\mathcal{T}}\left(\psi_{jt}Y_{jt} + \eta_{jt}U_{jt} + \mu_{jt}V_{jt} + \sum_{i\in\mathcal{I}}c_{ijt}X_{ijt}\right)$$

Download English Version:

https://daneshyari.com/en/article/1133343

Download Persian Version:

https://daneshyari.com/article/1133343

Daneshyari.com