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An efficient Reverse Distribution System for solving sustainable supply chain network design problem ☆

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ABSTRACT

This paper deals with a sustainable supply chain network design problem (SSCNDP) arising in the public sector. In the considered SSCNDP, given a manufacturer, a set of m potential distribution centers (DCs) having a given distinct capacity, and a set of n customers, each one with a particular demand, we have to select the number and the location of the DCs necessary to supply demands to all the customers and the allocation of the customers to these DCs such that the installation and transportation costs integrated with greenhouse gas (GHG) emissions are minimized. Due to the complexity of the problem, an efficient *Reverse Distribution System (RDS)* consisting of several improved classical heuristic algorithms is proposed. The developed approaches were tested and promising results were obtained on benchmark instances based on the literature, involving between 10 and 50 distribution centers and between 10 and 100 customers.

1. Introduction

Supply chains (SCs) are worldwide networks with facilities and distribution entities (suppliers, manufacturers, distribution centers, retailers). The SC performs the functions of procurement of raw materials, transformation of those into intermediate and finished products, the distribution of finished products to customers and its main objective is to satisfy the customer requirements.

In traditional supply chains, the purpose is to balance the benefits among the companies involved, to improve the operating efficiency throughout the facilities, to maximize the profitability of the processes and to create value for the customers, while in the case of sustainable supply chains (SSC) there are taken into

☆ This is a modified version of the paper "Classical Hybrid Approaches on a Transportation Problem with Gas Emissions Constraints", by C.-M. Pintea, P.C. Pop and M. Hajdu-Măcelaru [3] published in the Proceedings of SOCO 2012.

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consideration concerns regarding environment and social responsibilities. These issues along with economic gains are of top priority.

There are many discussions regarding the definition of the Sustainable Supply Chain Management (SSCM). In general, it is recognized that the scope of the SSCM is to achieve a balance between financial profits, social performance and environments concerns, see for example [5,7]. The environment concerns refer especially to the control of GHG emissions. According to the literature (see for example [6]), there exist two ways that the humans contribute to the emissions of GHG: production of energy and transportation and logistic activities. This is why, one major objective is to consider in addition to the transportation, operation and installation costs, the minimization of the greenhouse gas emissions.

The current work considers a sustainable supply chain network design problem (SSCNDP) defined as follows: given a manufacturer, a set of m potential distribution centers (DCs) having a given distinct capacity, and a set of n customers, each one with a particular demand, we have to select the number and the location of the DCs necessary to supply demands to all the customers and the allocation of the customers to these DCs such that the installation and transportation costs integrated with greenhouse gas (GHG) emissions are minimized. The SSCNDP described in this form, arising in the public sector, was introduced by Santibanez-Gonzalez et al. [6]. They described an integer programming formulation of the problem which is actually a related facility location problem (see for example Cornuejols et al. [1]) with an additional constraint that limits the total Greenhouse Gas (CO_2e) emissions of GHG and proposed as well a simple genetic algorithm for solving it. In a preliminary version of this paper, Pintea et al. [3] described some classical hybrid approaches for solving the problem.

Our paper is organized as follows. In Section 2, we define sustainable supply chain network design problem and describe a numerical example. In Section 3, we describe our developed *Reverse Distributed System*[1] for solving the problem consisting of several improved classical heuristic algorithms. The proposed approach is applied in Section 4 to the numerical sustainable supply chain network design examples from the literature and the obtained results are presented and analyzed. Finally, in the last section, we summarize the results obtained in this paper and present our conclusions.

2. Definition of the sustainable supply chain network design problem

The sustainable supply chain network design problem considered in this paper is a capacitated fixed-cost transportation problem in a two-stage supply chain network, where in addition to the transport and operation costs we are dealing with the GHG emissions costs. The problem is described as follows: there is a manufacturer with no capacity limitation in production that can ship to any of the m potential distribution centers having a given distinct capacity and each of the distribution centers can ship demands to any of the n customers, each one with a particular demand.

There are two types of costs involved in this distribution problem: fixed costs and transportation costs. The fixed costs consist of: opening costs for a potential DC i, denoted by f_i, and the fixed costs denoted by f_{ij}, for transportation from DC i to the customer j.

The considered transportation costs are: the transportation costs from the manufacturer to the DCs, denoted by c_i, $i \in \{1, \ldots, m\}$, and the shipping costs per unit from the DCs to customers denoted by c_{ij}, i.e. unit cost for shipping from the DC i to customer j. Typically, each distribution center i, $i \in \{1, \ldots, m\}$ has a_i units of stocking capacity and each customer j, $j \in \{1, \ldots, n\}$ has d_j units of demand.

We assume as in [6], that the GHG emissions are determined by the operation of the facilities and by the transportation activities necessary to fulfill the demands. These emissions are proportional with the demand and the travel distance. The GHG emissions factor of a potential DC $i \in \{1, \ldots, m\}$ in tons per CO_2e (dioxide carbon equivalent) per unit demand is denoted by α_i and the GHG emissions factor per unit

[1] A demonstrative implementation of *Reverse Distribution System* is available at http://icmresearch.weebly.com/projects.html.