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A hybrid particle swarm optimization and genetic algorithm for closed-loop supply chain network design in large-scale networks

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ABSTRACT

Today, tracking the growing interest in closed-loop supply chain shown by both practitioners and academia is easily possible. There are many factors, which transform closed-loop supply chain issues into a unique and vital subject in supply chain management, such as environmental legislation, customer awareness, and the economical motivations of the organizations. However, designing and planning a closed-loop supply chain is an NP-hard problem, which makes it difficult to achieve acceptable results in a reasonable time. In this paper, we try to cope with this problem by proposing a new and effective solution methodology. On the other hand, this research considers improving closed-loop supply chain network optimization processes through dealing with mathematical programming tools; developing a deterministic multi-product, multi-echelon, multi-period model; and finally presenting an appropriate methodology to solve various sizes of instances. Both design and planning decision variables (location and allocation) are considered in the proposed network. Besides, in order to have a reliable performance evaluation process, large-scale instances are regarded in computational analysis. Two popular meta-heuristic algorithms are considered to develop a new elevated hybrid algorithm: the genetic algorithm (GA) and particle swarm optimization (PSO). Analyzing the above-mentioned algorithms' strengths and weaknesses leads us to attempt to improve the GA using some aspects of PSO. Therefore, a new hybrid algorithm is proposed and a complete validation process is undertaken using CPLEX and MATLAB software. In small instances, the global optimum points of CPLEX for the proposed hybrid algorithm are compared to genetic algorithm, and particle swarm optimization. Then, in small, mid, and large-size instances, performances of the proposed meta-heuristics are analyzed and evaluated. Finally, a case study involving an Iranian hospital furniture manufacturer is used to evaluate the proposed solution approach. The results reveal the superiority of the proposed hybrid algorithm when compared to the GA and PSO.

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1. Introduction

The closed-loop supply chain (CLSC) has changed from being an undesirable constraint into being an economically acceptable necessity. Interestingly, it also has a close relationship with the sustainable supply chain [1]. In a classical supply chain (forward supply chain), the facilities attempt to realize the processes of fulfilling a customer's request. As customers do not use products forever, the supply chain's responsibilities also continue at the end of the products' life cycle. Reverse supply chain deals with the above-mentioned issues. Initially, some disassembly centers collect end-of-life products from customers, which are called "return products" in our context. Afterwards, some appropriate decisions are made: Some return products need some repairs after which they are qualified to be sold in the second-hand markets. They are usually repaired in disassembly centers and then distributed through redistributors. Some return products have to be forwarded to the manufacturers to be remanufactured and then sold to the second customers. Some can be used partially as raw materials, and hence they are sent to the suppliers for recycling. Finally, those parts which cannot be reused are forwarded to disposal centers (environment-friendly disposal units). A CLSC is achieved when forward/reverse processes are considered simultaneously.

An illustration of a simple CLSC is presented in Fig. 1 by Beamon [2]. Disposal centers are demonstrated by "W" through a supply chain network. Forward network flows are illustrated by a solid line and reverse flows by a dashed line.

Generally, in dealing with a CLSC in more than a short term, bi-level important decisions should be made: Design and planning. In the designing stage, which is a long-term analysis, strategic decisions are undertaken on the main characteristics of all facilities, such as network configurations, structure, capacities, coordination, etc. Then an important part of the supply chain network including the quantity of flows between all supply chain network entities should be determined at the planning level [3]. In this study, network configurations are considered in the designing stage (also called "location" here). They can clarify whether a facility should be activated (founded) in the final network or not. Besides, network flows are determined in the planning stage, which are also called allocation decisions here.

On the other hand, dealing with the design and planning problem of a CLSC as an NP-hard problem requires effective solution approaches, which can give us reliable solutions in a reasonable time especially for real-sized problems. Earlier publications, which tried to propose new solution methodologies, can give some evidence about this necessity. Besides, studying the small-size instances in the earlier research ensures that we evaluate solution methodologies in various sizes of instances. It should be mentioned that without availability of effective solution approaches, it would be difficult to apply such optimization models to real-world problems. In fact, more attempts are necessary to convert such theoretical models into practice. The missing part is engendered due to the inefficiencies encountered when using current methods to solve large-scale problems. Roughly, as CLSC design and planning is an NP-hard problem [4,5], proposing well-behaved methodologies can help practitioners to cope with the mentioned problem by achieving acceptable solutions in a reasonable time.

Finally, the aim of this paper is to cope with a large and complex CLSC design and planning problem through a deterministic approach where using meta-heuristic algorithms is an appropriate approach. The term "complex" for this problem refers to its Non-deterministic Polynomial (NP-hard) characteristics [4,5] and also to the size of the evaluated instances. Therefore, this study deals with a deterministic, large scale CLSC design and planning problem and the aim is to provide successful tools for solving large-scale problems. In addition, here, when referring to complexity issues we mean the structural

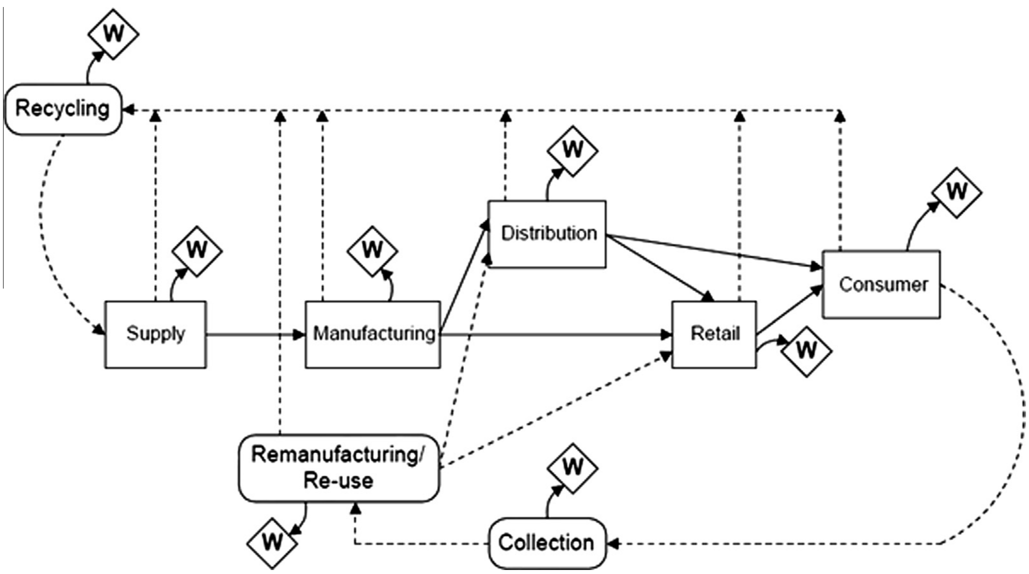

Fig. 1. A general closed-loop supply chain [2].