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Developing an ant colony approach for green closed-loop supply chain network design: a case study in gold industry

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ABSTRACT

The forward/reverse logistics network design is an important and strategic issue due to its effects on efficiency and responsiveness of a supply chain. In practice, it is needed to formulate and solve real problems through efficient algorithms in a reasonable time. Hence, this paper tries to cover real case problem with a multi-objective model and an integrated forward/reverse logistics network design. Further, the model is customized and implemented for a case study in gold industry where the reverse logistics play crucial role. A new solution approach is applied for the proposed 7-layer network of the case study and the solutions are achieved in order solve the current difficulties of the investigated supply chain. This paper seeks to address how a multi objective logistics model in the gold industry can be created and solved through an efficient meta-heuristic algorithm. A green approach based on the CO_2 emission is considered in the network design approach. The developed model includes four echelons in the forward direction and three echelons in the reverse. First, an integer linear programming model is developed to minimize costs and emissions. Then, in order to solve the model, an algorithm based on ant colony optimization is developed. The performance of the proposed algorithm has been compared with the optimum solutions of the LINGO software through various numerical examples based on the random data and real-world instances. The evaluation studies demonstrate that the proposed model is practical and applicable and the developed algorithm is reliable and efficient. The results prove the managerial implications of the model and the solution approach in terms of presenting appropriate modifications to the mangers of the selected supply chain. Further, a Taguchi-based parameter setting is undertaken to ensure using the appropriate parameters for the algorithm.

1. Introduction

Logistics is the process of planning, implementing and controlling the efficient and effective flow and storage of goods, services, and information from the beginning point to the point of consumption in order to comply with customer needs (Hugos, 2011). Logistics network design is a set of long-term decisions and it has a strategic role in effectiveness and efficiency of a supply chain. That's why it needs to be optimized through close-to-practice networks and appropriate algorithms. It usually involves multiple and differing objectives or goals, such as profit, cost, quality, customer responsiveness and so on. Green logistics describes all attempts to measure and minimize the ecological impact of the logistics activities. This includes all activities of the forward and the reverse flows of products, information, and services between the origin point and the consumption point. The final aim is to create a sustainable company which can achieve a balance between economic and environmental factors. Green procurement is defined as an environmental-friendly purchasing activities that include the reduction, reuse and recycling of materials in the process of purchasing. Besides green procurement is a solution for environmentally concerned and economically conservative business, and a concept of acquiring a selection of products and services that minimizes environmental (Salam, 2008). There are various approaches in green network design in CLSC which can be mentioned from Lin et al. (2014) in three different categories: a group of the authors regard fuel consumption optimization, the second group tries to regard gas emissions and the final groups consider the amounts of the waste and the disposals. Here, in this paper, the second approach is selected based on the necessity of the

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CO_2 emissions in the transportation system and in the production of gold industry.

In practice, the mining and minerals industry faces some of the most difficult sustainability challenges of any industrial sector (Azapagic, 2004). One of these industries is gold industry. The environmental and social impact of gold mining is particularly acute in both production and transportation (which is in low volume and high frequencies). Closing the loop and reverse logistics is a crucial issue in gold industry since gold is eminently recyclable and is primarily used for ornamentation. Excessive consumption of gold in developing countries has thus created an uncomfortable anomaly for many activists who have blamed modern high-consumption lifestyles for many contemporary social and environmental ills (Saleem, 2006).

In this paper, the design problem of an integrated multi-objective, single-product, multi-stage CLSC network is considered. The developed network includes suppliers, manufacturing facilities (factories), distribution centers, collection centers, recycling centers, and disposal centers regarding multi-capacity levels for each entity. This study aims to answer the question that how can a profit-emission based logistic model being efficiently solved through new meta-heuristic algorithm. Besides, what are the issues of implementing CLSC and the related solution algorithms in the real world problems?

According to the real world and case base approach, it is tried to find an appropriate case study in order to investigate an industrial problem in green closed-loop supply chain. Indeed, this paper obeys a near-case base approach in order to be useful for both industry and academia. There are many cases that we could choose here but based on the necessity of the gold industry in Iran, the gold industry is considered as our case study. The recent publications in the field of precious metal industries prove the necessity and importance of the selected industry such as Luque-Almagro et al. (2016) and Dobson and Burgess (2007). The supply chain of the selected case study is not optimum and more than that, regarding to new policies and legislations in the environment, it is needed to rearrange its supply chain. The result of the study reveals many shortcomings of the current supply chain of the gold industry. As a result, if the network is optimized in number of vehicles and their travel distances, the pollution will be decreased according to the "Iran-2025 Vision" which explicitly clarifies reducing the amount of industrial pollution (90% reduction).[1] The gold industry is highly expanded in all over Iran in all cities (wherever the people live) so despite its low-volume of transportation it has a vast numbers of transportation which leads to a high level of pollution.[2] Finally, it is decided to select and completely investigate a gold industry.

The aim of this study is to provide a suitable and integrated model for the gold industry that can simultaneously reduce costs and emission and also increase income in the network. The main question which this paper seeks to address is how a multi objective logistics model in the gold industry can be created and solved through efficient meta-heuristic algorithm. Here, efficient implies the quality and reliability of solutions. The research questions can be summarized as follows:

- What is the best route in this network in gold logistics network?
- How much production should be transferred between facilities in different levels?
- Which facilities should be activated?
- How a can multi-objective logistic model (with profit and pollution targets) can be solved through new meta-heuristic algorithms efficiently and reliably?
- What are the benefits of green approaches for the gold industry?

If the network is optimized the total distances of travel is decreased which result in reducing the pollution. This reduction is along the Iran's-2025 vision which seeks to reduce the amount of industrial pollution. Finally, in order to improve the proposed network minimum amount of emission, cost reduction, and profit maximization are considered and optimized. We try to model the real world with respect to the real variables. It then uses an algorithm to solve the model and the proposed algorithm with both generated and real instances.

The rest structure of this paper is as follows: Section 2 presents a literature review involving RL and CLSC modeling and solving approaches. In order to design an integrated logistics network, an integer linear programming formulation is developed in Sections 3. Section 4 discusses an efficient solution approach based on ACO for the small and large-scale instances. The appropriate computational study is presented in Section 5. The discussion of the results is presented in Section 6. The complete explanation and implementation of the model and solution approach in the case study is presented in Section 7. Finally, Section 8 presents conclusions of the paper and offers topics for future research.

2. Literature review

The literature of this paper can be divided into three main categories: forward logistics networks, reverse logistics, and Closed-Loop Supply Chain (CLSC). The Reverse Logistics (RL) consists of models that it concentrates on the backward directions. RL addresses the number of collection, recycle and disposal centers and also the related flows. In the real world, when both reverse and forward networks are integrated and considered together, then a closed loop supply chain is created (Ramezani et al., 2013). One of the most important issues in the CLSC is the configuration of the CLSC network that has a significant and long-term effects on the total performance of CLSC. Design of the forward and reverse logistics network should be integrated because designing forward and reverse logistics network leads to the optimal design with respect to the costs, service levels, responsiveness, etc (Pishvaee et al., 2010).

Many efforts for modeling and optimizing the supply chain network design problems have been studied that is mostly based on a single-objective such as minimizing cost or maximizing profit (Govindan et al., 2015). However, recently, green objectives such as emissions play an important and impossible-to-ignore role in network design problems. For example Zeballos et al., (2014) represents an objective function that minimizes the expected costs (including facilities, purchasing, storage, transportation, and emissions costs) minus the expected revenue of reselling the return products (collected from repairing and decomposition centers) through the forward network. Network emission is an important matter in a CLSC and it is a desirable choice for the most of the decision makers. Since environmental issues are one of the most effective aspects in supply chain (specially in RL), emission is considered as one of the objectives in this paper. In other words, because of the environmental legislation and the increasing environmental consciousness of the customers, this objective (emission) is added to this model. The importance of the environmental aspects is in a level that no researcher can ignore it in his/her mathematical model (objective or constraint). On the other hand, in term of proposing an appropriate solution methodology and in

[1] http://www.vision1404.ir and http://maslahat.ir/DocLib2/Approved%20Policies/Offered%20General%20Policies/policy%2006-07-1382%20Iran%20Vision%201404.aspx.

[2] http://supply-chain-management.persianblog.ir/page/scm-journal: No. (2), Vol (8).