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Solving a new bi-objective location-routing-inventory problem in a distribution network by meta-heuristics ☆

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ABSTRACT

This paper presents a novel bi-objective location-routing-inventory (LRI) model that considers a multi-period and multi-product system. The model considers the probabilistic travelling time among customers. This model also considers stochastic demands representing the customers' requirement. Location and inventory-routing decisions are made in strategic and tactical levels, respectively. The customers' uncertain demand follows a normal distribution. Each vehicle can carry all kind of products to meet the customer's demand, and each distribution center holds a certain amount of safety stock. In addition, shortage is not allowed. The considered two objectives aim to minimize the total cost and the maximum mean time for delivering commodities to customers. Because of NP-hardness of the given problem, we apply four multi-objective meta-heuristic algorithms, namely multi-objective imperialist competitive algorithm (MOICA), multi-objective parallel simulated annealing (MOPSA), non-dominated sorting genetic algorithm II (NSGA-II) and Pareto archived evolution strategy (PAES). A comparative study of the forgoing algorithms demonstrates the effectiveness of the proposed MOICA with respect to four existing performance measures for numerous test problems.

1. Introduction

Nowadays, the efficiency of industries is the bottleneck of progress in the competitive environment of marketing. That is why the companies have to increase their efficiency in all fields, specifically, in their logistics' operations. The present study considers the new integrated multi-objective model for the location-routing-inventory problem in a multi-product and multi-period supply chain system. Additionally, the model considers the probabilistic travelling time among customers. Considering these complexities make the problem more similar to real-life problems. In real world, there exist numerous industries making three location-routing-inventory (LRI) decisions and their interactions in multi-products and multi-periods system simultaneously. To the best of our knowledge, this problem has not been surveyed these assumptions altogether.

According to above-mentioned reasons, the main contributions of this paper, which distinguishes from other papers in the related literature review, are as follows:

- Considering an integrated LRI problem
- Considering a bi-objective integrated LRI problem
- Considering a multi-product supply chain system
- Considering a multi-period supply chain system
- Considering uncertainty in a multi-product and multi-period supply chain system
- Considering the probabilistic time among customers
- Considering the transportation cost consisting of the travelling distance related cost and vehicle fixed cost for determining the usage of vehicles.
- Solving the model by new multi-objective meta-heuristic algorithms (e.g., MOICA and MOPSA).
- Comparing the proposed meta-heuristics with two well-known evolutionary meta-heuristics (e.g., NSGA II and PEAS) in terms of four comparison metrics.

A logistic system consists of three important elements, namely facility location, vehicle routing and inventory control decisions. Since, these key elements are highly dependent, an integrated decision problem is considered as an integrated logistic system. This problem is represented under different assumptions in the related literature review.

Liu and Lee (2003) proposed a single product, multi-depot LRI problem and applied a two phase heuristic method to solve the

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problem. Gaur and Fisher (2004) studied a periodic inventory-routing problem in a super market chain. Liu and Lin (2005) developed the same model solved by a combined tabu search and simulated annealing algorithms. Kang and Kim (2010) considered an integrating inventory replenishment model and delivery planning in a two-level supply chain consisting of a supplier and a retailer. Shen and Qi (2007) proposed a single-product, single-period LRI problem with an approximate routing cost and solved the LRI model by a Lagrangian relaxation based solution algorithm, their model was introduced as a modified inventory-location model given in Daskin, Coullard, and Shen (2002). Chanchan, Zujun, and Huajun (2008) formulated a dynamic LRI problem in a closed loop supply chain solved by a two-phase heuristic algorithm. Ahmadi Javid and Azad (2010) developed the model presented by Shen and Qi (2007). Their model simultaneously optimizes location, inventory and routing decisions without approximation, and is solved by a heuristic method based on a hybridization of tabu search and simulated annealing.

Ambrosino and Scutella (2005) proposed the dynamic version of a model consisting of three integrated decisions. Moin, Salhi, and Aziz (2011) addressed an inventory routing, many-to-many distribution network consisting of an assembly plant and many distinct suppliers where each supplies a distinct product. Hiassat and Diabat (2011) studied the LRI problem with perishable product, through a multi-period model. Bard and Nananukul (2009) suggested a periodic inventory routing problem, with the objective of maximizing the net benefits associated with making deliveries in a specific time period, in which backlogging is not permitted. Also, the inventories can be accumulated at the customer sites. Al Dhaheri and Diabat (2010) formulated a new model of an inventory-location problem with multiple products and risk pooling. Abdelmaguid, Dessouky, and Ordóñez (2009) studied a multi-period inventory routing problem that shortage is permitted and solved by a developed constructive and improvement heuristics and obtained to approximate the solutions. Liao, Hsieh, and Lai (2011) presented a location-inventory problem based on vendor-managed inventory setup. In this model, they minimized the total system costs and maximized the customer service by two performance measurements and they solved the model by a multi-objective evolutionary approach. Hanczar (2012) proposed an application of a multi-item inventory routing problem in a fuel distribution problem. Recently Ahmadi Javid and Seddighi (2012) studied a location-routing-inventory model with a multi-source distribution network. Their model considers the LRI model in a three-level distribution network and a multiphase heuristic algorithm based on simulated annealing (SA) and ant colony system (ACS) is proposed to solve their model.

Based on the above-mentioned studies, there are a few studies, in which all the three problems (i.e., LRI) are simultaneously considered.

In this paper, we consider the LRI problem in a multi-period and multi-product supply chain network. We also assume probabilistic travelling times among customers. In this paper, an extension of the model presented by Ahmadi Javid and Azad (2010) is discussed and solved by four multi-objective meta-heuristics.

2. Problem statement

The presented LRI problem accounts for a two-echelon logistic distribution system that locates and allocates a set of distribution centers to serve a set of customers geographically dispersed in a specific region. The associated model determines an optimal inventory policy and routes of vehicles to satisfy the customers' demand through periods of planning horizon for each kind of product. Additionally, the main aims in this model are to minimize the total cost and the maximum customer service time. The total cost consists of locating open distribution centers costs, transportation costs, inventory holding and ordering costs. Different capacity levels for each distribution center are assumed, leading to a lower cost of capacity distribution centers. Assumptions considered in this study are given in Section 2.1.

2.1. Assumptions

The following are the main assumption of the presented model.

- A two-echelon distribution system is considered.
- Some distribution centers (DCs) are taken into account to meet the customer demands with multi products.
- Each customer has an uncertain independent demand and follows a normal distribution, which should be satisfied for each product in each period.
- Vehicle fleet is heterogeneous which means that vehicles do not have the same capacity.
- Each DC $_j$ follows a (Q_{jpt}, R_{jpt}) inventory policy, in this policy when the inventory level of product p in period t at distribution center j gets to or below a reorder point R_{jpt}, a fixed quantity Q_{jpt} is ordered to the supplier. In addition, each distribution center holds a safety stock from each product in each period.
- The transportation cost includes travelling distance related cost and vehicle fixed cost for determining usage of vehicle v.
- There exist a limited capacity for DCs and vehicles.
- Each DC has four capacity levels with four different costs.
- Numerous DCs are opened.
- No route is considered between DCs.
- Locating and allocating decisions are strategic and not related to periods.
- Shortage is not permitted.
- Travelling times among customers are assumed to be probabilistic nature.

2.2. Model formulation

The notations used in this model are explained below:

Sets	
K and L	Set of customers
J and J'	Set of potential distribution centers
N_j	Set of capacity levels available to distribution center $j(j \in J)$
V	Set of vehicles
M	Aggregate set of customers and potential distribution centers $(k \cup j)$
P	Set of products
T	Set of periods along time horizon
Parameters	
μ_{kpt}	Mean of customer k demand in period t from product p $(\forall k \in K, \forall p \in P, \forall t \in T)$
δ^2_{kpt}	Variance of customer k demand in period t from product p $(\forall k \in K, \forall p \in P, \forall t \in T)$
f^n_j	Establishing cost of DC j with capacity level n in time horizon$(\forall j \in J, \forall n \in Nj)$
b^n_j	Capacity with level n for DC j in time horizon $(\forall j \in J, \forall n \in Nj)$
$d_k l$	Transportation cost for travelling from node k to node $l(\forall k, l \in M)$
Vc_v	Maximum capacity of vehicle $v(\forall v \in V)$

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