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Facility Location Decisions Within Integrated Forward/Reverse Logistics under Uncertainty

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Abstract

In this paper, a stochastic mixed integer linear programming (SMILP) model is proposed to optimize the location and size of facilities and service centres in integrated forward and reverse streams under uncertainty. The objective of the model is to minimize establishment, transportation and inventory management costs and simultaneously maximize customer satisfaction with sustainable perspective. The model incorporates different elements and features of distribution networks including inventory management, transportation and establishment of new facilities as well as existing centres. The presented model is the streamlined approach for multi-objective, multi-period, multi-commodity distribution system, and it is supported by a real case study in automobile after sales network. Genetic algorithm is implemented to solve the model in reasonable time. The performance of the model and the effects of uncertainty on provided solution are studied under different cases. Competitive result of the stochastic model compared to deterministic model ensures that the proposed approach is valid to be applied for decision making under uncertainty.

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1. Introduction

Successful implementation of a closed-loop supply chain (CLSC) needs dealing with challenges in collocation and integration of forward/reverse flows as well as required resources [1, 2]. Although recycling products decreases negative effects on the environment and provides benefits in terms of recovered raw material and reused components, uncertainties which exist in the supply chains threat their performance. There are two major sources of uncertainty including variation in customers demand and return rate of used products. The second source significantly affects the configuration of the CLSC. Sub-optimal configurations may show a poor operational performance of supply chain and lead the managers to hesitate in implementing such solutions. Hence, it is essential developing practical managerial tools that support forward and reverse flow integration. These tools help to correctly implement reverse logistics, avoid poor operational performance, and encourage supply chain managers in adopting CLSC models [3].

2. Literature review

Recently, supply chain design regarding facility location has attracted increasing attention [4]. Researchers have proposed different models to handle classical facility location decisions problem including supplier selection, inventory management, distribution, routing and other logistics activities [5]. New researches support complex structure of supply chains by using dynamic, multi-objective, multi-echelon models. We divide related literature into deterministic and stochastic models. In deterministic models data about all
parameters of the model are available and known. Krikke et
al. [6] proposed a mixed integer linear programming (MILP)
model to cover economic and ecologic features of closed-loop
supply chain. The bi-objective mixed integer model proposed
by Pishvaee et al. [7] provided solution to minimize total cost
and maximize the responsiveness of closed-loop network. To
solve the model, a multi-objective memetic algorithm
(MOMA) with dynamic local search is developed which
showed more options in setting capacity options and
competitive results with exact method. Gupta and Evans [1]
presented a goal programming model for the operations in
supply chain. The purpose of the model is to maximize the
profit through different operation of the supply chain for
multiple product and multiple periods. Real cases in supply
chain witness uncertainty in at least one of the parameters. In
such cases, models that deal with uncertainty are proposed.
Salema et al. [8] presented a general model to overcome
uncertainties in product demands and returns through multi-
scenario method. The expanded formulation allows for any
number of products, establishing a network for each product
while guaranteeing total capacities for each facility at a
minimum cost. The mixed integer model of this paper was
solved using standard branch and bound technique. Francas
and Minner [9] developed two alternative manufacturing
network configurations when demand and return flows are
both uncertain. Pishvaee et al. [10] performed a stochastic
mixed integer model to deal with uncertain demand, quantity
and quality of returns, and variable costs in supply chain. Lee
and Dong [11] considered forward and reverse demand as
stochastic parameters. A two-stage stochastic programing
model based on dynamic deterministic model for multi-period
reverse logistic network was proposed.

In summary, in the most of the reviewed papers, demand
and return rate are considered as uncertainties sources in
designing and planning the closed-loop supply chains. The
deterministic and stochastic mixed integer linear programming
models are solved by application of different approaches. In
spite of validation of these models by numerical experiments,
most of used approach lack practical application. The
complexity of the methods and their solutions made it hard for
practitioners to adopt these methods for other general cases.

In this paper, a stochastic mixed integer linear programming
(SMILP) model is constructed to identify the
optimal location and size of facilities in a CLSC. The model
includes inventory management, transportation and
establishment of new facilities as well as existing centres. A
genetic algorithm is performed to return the optimal solution of
the facility location decisions within CLSC since it is a
complex and NP-hard problems [10, 12, and 13]. The model
is utilized in a real case study to redesign the current network.
Finally, two scenarios named the best case and worst-case is
considered to study the performance of the model and the
impact of uncertainty on provided solution.

3. Model description
The considered integrated logistics network in this paper is
shown in Fig.1. It is a multi-layer network including central
manufacturing/distribution facilities, regional warehouses,
customers, collection/inspection sites, and central
remanufacturing facilities. The main goal of the model is to
determine the optimal capacity and inventory level of each
facility.

In forward logistic network, regional warehouses receive
new brand products from central warehouse for seasonal
demand in each region. After that, the distribution of these
products will be carried out between customers based on their
demands. In most supply chains, particular regulations are
used to reuse/recycle used products. It happens when
customers return used part or managers are asked for pick up
those parts. The collection/inspection sites are assigned to
gather reusable parts which are returned, and disposal
collection sites are devoted to others. In collection/ inspection
sites, reusable parts are disassembled to disposals and sent to
disposal collection sites where possible parts are transported
to central remanufacturing facilities to be rebuilt. In this
process, the main decision variables are optimal location, the
number and the capacity of central and regional facilities to
serve the demand of customers.

**Nomenclature**

| Symbol | Description |
|--------|-------------|
| $L$    | Set of central warehouses |
| $M$    | Set of regional warehouses |
| $N$    | Set of customers |
| $O$    | Set of good types |
| $F$    | Set of periods |
| $d_{ij}$ | Demand of customer $i$ for commodity $j$ in period $p$ |
| $b_{jk}$ | Demand (capacity) of regional warehouse $j$ for commodity $k$ in period $p$ |
| $C$ | Cost of transportation per unit |
| $d_{ij}$ | Distance between regional warehouse $j$ and customer $i$ |
| $d_{jk}$ | Distance between regional warehouse $j$ and central warehouse $k$ |
| $e_{kj}$ | Capacity of central warehouse $k$ for commodity $j$ in period $p$ |
| $a$ | Weight of first objective function |
| $\beta$ | Minimum level of customer satisfaction for commodity $i$ |
| $q$ | Cost of installation central warehouse |
| $w$ | Cost of installation regional warehouse |
| $h_c$ | Warehousing cost per unit goods in warehouses |
| $h_t$ | Warehousing cost per unit goods in stocks |
| $\pi$ | Back ordered cost per unit goods |
| $W_r$ | Cost of establishing of recovery sites |
| $g$ | Percentage of parts which can be sent for recycling |
| $x_{pp}$ | Percentage of demand of customer $i$ for commodity $p$ that is supplied by central warehouse $j$ in period $p$ |
| $y_{pp}$ | Percentage of demand of regional warehouse $j$ for commodity $p$ that is supplied by central warehouse $k$ in period $p$ |
| $U_i$ | A binary variable which is equal to 1 if a regional warehouse is located in the potential point $i$ |
| $V_k$ | A binary variable which is equal to 1 if a central warehouse is located in the potential point $k$ |
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