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Procedia CIRP 17 (2014) 606 – 610

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Variety Management in Manufacturing. Proceedings of the 47th CIRP Conference on Manufacturing Systems

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.

Selection and peer-review under responsibility of the International Scientific Committee of "The 47th CIRP Conference on Manufacturing Systems" in the person of the Conference Chair Professor Hoda ElMaraghy"

Keyword: Facility location; Closed-loop supply chain; uncertainty; Genetic Algorithm; Distribution-service network;

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

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doi:10.1016/j.procir.2014.01.092

parameters of the model are available and known. Krikke et al. [6] proposed a mixed integer linear programing (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 programing 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 programing 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

L	Set of central warehouses
M	Set of regional warehouses
N	Set of customers
O	Set of good types
F	Set of periods
a_{pit}	Demand of customer i for commodity t in period p
b_{pjt}	Demand (capacity) of regional warehouse j for commodity t 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_{pkt}	Capacity of central warehouse k for commodity t in period p
α	Weight of first objective function
β	Minimum level of customer satisfaction for commodity t
q	Cost of installation central warehouse
w	Cost of installation regional warehouse
h_w	Warehousing cost per unit goods in warehouses
h_s	Warehousing cost per unit goods in stocks
π	Back ordered cost per unit goods
$W_j^{'}$	Cost of establishing of recovery sites
$g^{'}$	Percentage of parts which can be sent for recycling
x_{pjit}	Percentage of demand of customer i for commodity t that is supplied by central warehouse j in period p
y_{pkjt}	Percentage of demand of regional warehouse j for commodity t that is supplied by central warehouse k in period p
U_j	A binary variable which is equal to 1 if a regional warehouse is located in the potential point j
V_k	A binary variable which is equal to 1 if a central warehouse is located in the potential point k