

Uncertain Location Routing Problem (LRP) Integrated to Inventory Considering Space Limitation

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Abstract. An optimal supply chain management system has a direct effect on the performance of any enterprise and could result in substantial cost savings. Successful supply chain management involves many decisions relating to the flow of the products. The decisions fall into three levels: strategic, tactical, and operational differentiated depending on the time horizon during which the decisions are made. Since decisions at these three levels are interdependent, optimizing at individual levels will lead to sub-optimal solution for the network. In this study, location as a strategic decision is combined with two tactical decisions: routing and inventory. First, location and routing decisions are combined to form location-routing problem (LRP). LRP can be defined as solving the following three sub- problems at the same time: locating one or more plants and warehouses among a set of potential plants and warehouses, assigning customers to selected depots, and determining routes from selected depots to assigned customers to minimize the cost of the supply network. Then, to make further improvements in the network, it is proposed to integrate an inventory model under the fixed interval order policy to the LRP. Since in the real world application, warehouses are limited by space capacity, a third logistic party copes with the space limitation if needed. Moreover, it is assumed that customers demand their multi- products requirement under stochastic condition. To solve such a model a heuristic solution is proposed.

1. Introduction

As defined by Chopra and Meindl [1] “a supply chain consists of all parties involved, directly or indirectly, in fulfilling a customer request. The supply chain includes not only the manufacturer and suppliers, but also transporters, warehouses, retailers, and even customers themselves”. Improvement in supply chain can be made through its two main activities: production and logistics. While the former is associated with in plant activities such as production planning, material handling, and shop floor tasks, the later considers the procurement of raw materials from suppliers to manufacturing plants and then transportation of finished goods from manufacturing plants to retailers. This study considers the logistics part of the supply chain. Although the improvement of the supply chain processes is achievable by optimizing its divers such as facility, inventory, and transportation individually [1], due to the correlation existing among the drivers, integrating them allows even more savings. Locating facilities and determining the routings as two logistical drivers of the supply chain can be integrated to improve the supply network. Location and routing may be combined to form location- routing problem (LRP). An LRP can be seen as the simultaneous consideration of location of facilities, allocation of customers to facilities, and determining routings from facilities to customers in one model. While LRP considers the integrity, it relaxes the direct customer deliveries allowing multiple visits.

Although many LRP models have been researched well, integration other parts of logistic drivers such as inventory has not been studied well. Decision on the inventory can dramatically change the supply chain efficiency. A more efficient supply chain network can be gained by integrating inventory with LRP. It is also noticeable that most of the work in the literature on LRP consider a situation with a single product. However, in practice, multi product condition describes the actual circumstances better. Another practical issue which has not been integrated with LRP is the decision that companies make on the third party logistics to overcome their space shortage constraint. This work is a study of location-routing problem integrated with an inventory model where decisions on location, routing, and inventory are made at the same time. A three layer logistic network including plants at the first level, distribution centers (DC) at the second level, and customers at the third level is considered. The goal of this study is to select one or more plants among a set of potential plants, one or more DCs among a set of potential DCs, assigning customers to selected DCs, and determining inventory levels at DCs to minimize total cost of the system. In order to capture reality, it is assumed that customers demand their multi- products requirements under uncertainty while third party logistics will cover any storage capacity

shortages. Moreover, homogenous vehicle fleets transfer goods from distribution centers to customers, which means that all vehicles have the same capacity.

2. Problem Definition

The problem under consideration is a three layer location- routing problem (LRP) consisting of plants (first layer), depots (second layer), and customers (third layer) integrated with the inventory model under fixed interval policy. In such a network, products are transferred from plants to depots and from there to customers. Located at the pre-determined locations, customers demand their requirements stochastically. The goal is to select locations for plants and DCs among sets of potential locations, allocate customers to DCs, find routes from DCs to customers, and determine the order intervals and maximum inventory at depots so as to minimize total network cost.

Development of a mathematical model

This problem is modeled as a mixed integer linear programming problem. There are five sets of variables in this model of which three sets are binary. The binary variables are defined as follows: The first set of variables indicates the routing decision which equals one if there is a route between two predetermined nodes (for instance node i and j) and zero otherwise. The next set of variables is the location which decides whether a supply point (plant and depot) should be open ($=1$) or not ($=0$). Allocation variables are the third set of variables in the proposed problem. When a customer is assigned to a depot, the corresponding allocation variable will be equal to one; otherwise zero. Two sets of non-negative variables include quantity variable implying the number of products shipped from a plant to a depot and the third party logistics variable indicating the third party decision. If a depot needs to use a third party, the value for that particular depot is as much as the space limitation. A single objective function considers the total annual cost of the network including the fixed cost of opening one or more plants and depots, direct transportation cost which is equal to the shipment cost of products from plant (s) to depot (s), and inventory cost. When a third party logistics is needed, the corresponding holding cost will be added to the inventory cost. The constraints of the network include the routing, allocation, and capacity constraints.

Generation of solution approach

Since the proposed model is categorized as Np-hard class, a two phase heuristic method is applied to solve it. The problem is divided into two sub-problems; location- allocation, and routing. In the first phase a heuristic algorithm identifies the location of the plants and depots and assigns customers to the depots. Using feedback from the first phase, the vehicle routing problem (VRP) is solved by another heuristic algorithm in the second phase. The results are plugged into the first phase and the algorithm is repeated until a termination criterion is satisfied.

2.3 Computational Analysis

Different sizes of the problem are solved by the developed algorithm and results are reported for the best solution. Since it is not guaranteed to achieve an optimal solution, the results are reported as the *best* solution rather than *optimal* solution. Moreover, the solution obtained from the proposed LRP integrated with the inventory (LRIP) and that of the decomposed LRP and the inventory are compared to indicate that the integrity will improve the objective function value.

3. Conclusion

Since a large potential improvement exists in any supply chain network, this proposal presents a model to improve the logistical part of the supply chain. This study presents a model in which location, routing, and inventory decisions are combined together to improve the supply chain. To capture the reality some feature such as multi- products assumption, probabilistic demand and third party logistics are considered in the model. Presenting the mixed- integer programming of the proposed model, a two phase heuristic approach is presented to solve the model.

Reference

[1] Chopra, S., and Meindl, P., "Supply chain management: strategy, planning, and operation", 3rd ed., Upper Saddle River, New Jersey, 2007