CHAPTER 8

SUMMARY AND CONCLUSIONS

This study is related to three issues of reverse supply chain management, namely, design options for integrated forward and reverse networks, performance evaluation of these networks and incentive issues related to flow of product in the network. A case study organization which is manufacturing and marketing automotive batteries is selected and the following issues are studied in detail.

(a) Evaluation of different configurations of facility networks for collection of used products for recycling and to select an optimal configuration.

(b) Performance evaluation of both reverse and forward supply chain networks of battery manufacturing in terms of inventory and flow time

(c) Impact of incentive system to increase the flow of used batteries in the reverse supply chain network.

8.1 SUMMARY OF WORK DONE

A case study organization, which is manufacturing and marketing automotive batteries was identified, which features a bi-directional open-loop supply chain network (BDOLSCN). This system study of organization also provides opportunity to investigate into performance modeling of forward and
reverse networks and incentive issues. The data collected from this organization were used extensively in this thesis.

A BDOLSCN is an integrated network, which handles full forward distribution of new products and partial handling of return flow of used products. The present configuration of the forward distribution network and reverse used battery collection network of case organization were studied for its structure and network cost. The reverse network cost of collecting, transporting, and storing used batteries using the existing forward network also estimated.

The existing forward network which is used to distribute new batteries was first studied for optimization to minimize the operating cost and transportation cost of the network. A mixed integer linear programming (MILP) model was developed to configure this network. This model proposes some major changes in the existing network. (Config-1).

A hypothetical network configuration is developed to study the possibility of having an independent collection and storage facilities for used products. (Config-2). The franchisees of the existing network are expected to collect used batteries but warehouses and smelters are chosen external to the present network. It is assumed that the warehouse in each region should be nearer to franchisee so that last mile collection can be improved. A mathematical model using MILP was developed to evaluate this configuration to select appropriate number of warehouses and smelters. Constraints like capacities of facilities and demand constraints are properly considered in the model. The allocation of warehouses to recycling facilities also considered in the model. The minimum cost of operating separate and independent reverse network was estimated for the above model.
An integrated hypothetical network of both forward flow of new batteries and reverse flow of used batteries was proposed. The present BDOLSCN network may not be optimum because it was designed without consideration of recycling facilities. Two different configurations of BDOLSCN are proposed for this study. The first configuration, namely Config-3 considers franchisees, warehouses and smelters as part of the network. The second configuration, namely Config-4 considers franchisees and recycling plants without warehouses. Mathematical models using MILP were developed to evaluate these configurations to select appropriate number and locations of franchisees, warehouses and smelters. From the results of MILP, the Config-4 is optimal. All the above referred four network configurations are compared based on cost and suitable network configuration was suggested for implementation.

The facility network models generally considers transportation costs, facility fixed costs, production costs and inventory costs. There are network models to incorporate inventory, routing and scheduling and production costs like Location-routing models and Location-inventory problems. But these models are basically deterministic models and may not permit to performance measures like inventory and flow time which are influenced by stochastic factors like variability in demand. For this purpose, simulation, as a performance evaluation model is proposed.

The existing supply chain network of case study organization (CSO) is modeled as a queuing network with each stage of the network represented by associated service nodes. At each node the process time variability is considered along with arrivals and departures of the entities, namely, batteries. At each node in the network it is assumed that the batteries arrive in batches. The arrival of shipments at each node and the time spent by batches of batteries at each node may not be of Markovian type. Hence in this
case, Jackson’s theorem for product form solution cannot be applied to measure the performance of the network. Because of this limitation, an approximation analysis is adopted by simulating the queuing networks.

The queuing networks of existing forward and reverse supply chain are incorporated in the simulation model proposed. The arrival of batteries at each stage is modeled with appropriate random distribution and inter-arrival time also modeled with suitable theoretical distributions. The simulation model was developed using EXTEND 6.0 software. The output analysis of the simulation was conducted and initialization bias was removed by ignoring initial batch data set. The model verification and validation was carried out using observed data.

The simulated values of performance measures of mean flow time and mean stock for each stage of the network were estimated. For the reverse network also, the mean flow time and mean stock were estimated. The above mentioned supply chain network simulation model was used to conduct the four categories of simulation experiments to study the performance of the network. The reverse network was simulated to study the impact of inventory policies at two stages of the network, namely franchisee and warehouse. Both fixed period and fixed quantity inventory models were used to study the network. These experiments provide guidelines in terms of shipping policies for reverse flow of used products in the supply chain.

The optimum BDOLSCN developed with MILP was also modeled as queuing network and incorporated in the simulation model. The performance of this network was also studied.

In the simulation models, it is assumed that all the batteries collected by retailers are returned to franchisees. But, there is a problem in
getting 100% return from retailers, because they may get better buyback price for used batteries from unauthorized smelters. A system dynamic model was developed to capture the issues of incentives and returns of the used batteries, the price offered by unauthorized smelters and to find out their impact on performance of reverse supply chain network.

As a first part of system dynamics model, a causal loop diagram was developed to represent the role of different variables and its interaction effect in reverse supply chain. The key variables of interest in the system dynamic modeling are inventory at each stage of the network, the retailer return rate, the shipping rate and arrival rate at each stage, the price offered by manufacturer and unauthorized smelter, the time to adjust the price, the profit and a list of endogenous variables. These variables include, new batteries sales, margin for the unauthorized smelters, costs related to recycling, storage and transportation. As a part of system dynamic model, the causal loop diagram is converted into stock and flow diagram where variables are represented as stocks, flows and auxiliary. Using observed data, the model was simulated using VENSIM software and results are presented. Experiments were conducted by varying different parameters and results were studied. The model also recommends some important policy decisions that the manufacturer should implement with respect to Price adjustment time, Time to return and Buyback price. A hypothetical mathematical model was proposed to capture relationship between return volume and buyback incentive price and this model can be used as a part of system dynamic model.

8.2 CONTRIBUTIONS OF THE RESEARCH

This research work provide some guidelines to the organizations, who are following supply chain networks for product distribution and reverse network for used product collection. The research contributions are:
I. Identification and development of bi-directional open-loop network (BDOLSCN) for new product distribution and used product recovery from the customers along with alternative configurations for forward and reverse flows.

II. Different network configurations for forward distribution of new products and reverses collection of used products were analyzed in the research work. Each configuration was studied for minimum cost while identifying the associated facilities namely warehouses, franchisees and smelters in the network. This study describes design and development of a four-stage supply chain network, consisting of a manufacturing plant, group of warehouses, a set of franchisees for each location and selected recycling plants.

III. Development of queuing network model for the supply chain network facilities, considering each node as a service point for performance evaluation of the network.

IV. Incorporating combination of pull and push supply chain concepts in the simulation model of the supply chain network.

V. The research work provides policy guidelines in terms of inventory policies for reverse flow of products. It identifies appropriate inventory policy for each stage of the reverse supply chain network for used products. Reverse supply chain network with two different inventory policies of P-system and Q-system were simulated. The performance evaluation of reverse supply chain network in terms of flow time and inventory is conducted for various policies.
VI. The research work also provides policy guidelines in terms of appropriate incentive policies to improve the volume of used product collection from customers and retailers. A system dynamics model was developed to study the dynamics involved in handling the return volume of used products, the incentive price for returns, the unauthorized recyclers’ existence in the market and organizational profit. This model facilitated to simulate the impact of (i) buyback incentives for channel partners, (ii) administrative pressure exercised on channel partners and (iii) cost recovered on used products.

8.3 LIMITATIONS

The following points are considered as limitations while conducting the research work.

(i) The network model assumed that the retailers will return 70% of the used batteries collected at their level but the returns may vary with respect to incentives.

(ii) In the case of independent network for collection, the location of warehouse was assumed to be in any one place of existing franchisee. Sometimes it may not be possible to locate because of some practical difficulties.

(iii) Fixed and operating costs of smelters are not included in the MILP model. Also, the revenue from sale of used batteries not considered in the model.

(iv) The tradeoff between inventory costs and transportation costs are not dealt in the MILP model.
Three performance measures only are used to evaluate the supply chain network namely cost, mean stock and flow time.

In simulation, the distribution with respect to arrival and time of retention for some franchisees are assumed to follow patterns of available data from Franchisee-1, Franchisee-4 and Franchisee-7.

The battery return volume in system dynamic model was assumed to follow exponential relationship with buyback price difference.

The system dynamic model was not validated due to non-availability of data related to incentive pricing and return volume from manufacturer.

8.4 SCOPE FOR FURTHER RESEARCH

a) The present BDOLSCN model can be extended to incorporate recycler fixed cost, and revenues from disposal of batteries.

b) In the BDOLSCN model, it is feasible to incorporate routing problem for both forward distribution and reverse collection and transportation.

c) Application of network model for other products like Computers, Tyres, Consumer durables, can be explored.

d) In the evaluation of forward and reverse networks, the use of different performance modeling tools like Petri nets, parametric decomposition approach and Queuing network analyzer, can be explored.
e) The networks can also be evaluated for its flexibility, responsiveness, quality, and resources utilization.

f) System dynamics model can be extended to study shipping and inventory policies at each stage of reverse supply chain and coordination between stages of the supply chain.

g) System dynamics model can be extended to include dynamics of forward supply chain with the reverse supply chain.

h) Extension of system dynamics model to study network performance under various conditions can be explored.

i) Development of incentive mathematical model for past data can be explored.

j) The application of hub and spoke model in reverse supply chain can be explored.

k) The use of RFID technology in managing product returns can be explored.