ABSTRACT

In today's supply chain, product flow does not end with reaching the customer. Many products and parts after accomplishing the original task lead to a second and third or even fourth life of their function. Hence, product and parts may generate revenues several times in industries, rather than once. Capture of the value of the product and parts requires broadening of the supply chain perspective to include a new process, known as Reverse Logistics (RL). RL becomes a very important aspect for industries in capture of the value of used products and parts. To manage the mix of return products and parts, use of return information from a customer, maintenance of the green image imposed by legislation finds difficult for remanufacturing industry. Traditionally, the focus of industries is on improving the forward supply chain for their products. Now-a-days, economic incentives, legal pressure and shorter life span of products have led more and more industries getting engaged in product recovery activities associated with regaining materials in a backward loop. The important field of product recovery is remanufacture which refers to bringing used products back to a condition wherein the recovered products and parts are just as good as new. In many industries, Original Equipment Manufacturers (OEMs) are very active in remanufacturing activity. By bringing remanufactured products back to markets, the OEMs establish direct links between forward and reverse logistics activities, thus building up and operating a Closed Loop Supply Chain (CLSC).

One of the most challenging issues in CLSC is the inventory management of returned products and parts which disassembled at various

sites. The flow of return parts takes different forms of dimensions such as some parts being sent to repair site, some parts being sent for recycling and some other items disposed off. Some products like printer cartridge, electronic items and pharmaceutical products have very short life span. Within this short life of the product, maintaining and determining the inventory of products and parts become difficult for supply chain managers and executives. For academicians, modelling the inventory with a standard policy in CLSC within a short duration becomes a challenging task considering various dimensions of parts at different sites like repair, disassembly, recycle, and disposal.

This research investigates the inventory of manufacture of products having a short life. Considering the environmental legislation, industries want to take back the used products from the customers by keeping collection sites at various places. Industries have to integrate their forward and reverse supply based on the quantity and quality of their returns. As integrated as CLSC systems, the used and unused products from the customer should flow as reverse supply and not in the direction of the forward supply. Industries have to manage their resources for the flow of products effectively by keeping appropriate inventory levels at repair, remanufacture, disassembly, and recycle sites.

The proposed framework of the CLSC model consists of a manufacturer, a distributor, a retailer, a collection site, a repair site, a disassembly site, a disposal site, a recycling site and an external supplier. Some of the customers return the products after use at different periods. During different periods, the returned products are collected at collection sites and segregated into two types of returns, namely commercial returns of the return products which are sent to the repair site for refurbishing and other products disassembled into parts in disassembly sites. Unused parts can be despatched to disposal site. Usable parts in the form of end-of-life can be sent to recycling site for processing and the parts in the good form can be taken to end-of-use in the part inventory during multiple periods. In this model, product recovery is categorized into three types: (i) commercial returns of the product, (ii) end-of-life returns and (iii) end-of-use returns along with important aspects of inventory positioning. Further, if demand of the product is more than that for returned products, manufacturer has to produce new products or purchase them from external suppliers during multiple periods.

In the first part of this work, a flow balance inventory equation is carried out for the investigation of inventory in the model without using any inventory policy. In the proposed frame work, frequently referred standard closed loop supply chain model is considered for a multiple period. The same model is used for investigating the inventory in multiple products and multiple parts with three different scenarios of demand and returns.

The maximum capacity of repair site, disassembly site, recycling site, supplier site and manufacturing site and inventory cost, setup cost, shipping cost are considered for multiple products and parts. The objective of this research is to investigate the effect of the Fixed Order Quantity (FOQ) inventory model for multiple periods in the CSLC network. The proposed model is developed by adding costs such as unit inventory holding cost, ordering cost, back order cost to the model. This FOQ model is used for maximizing the profit of the centralized manufacturer who controls the entire part of the CLSC. A single product consisting of three different parts (Part A – 2units, Part B-1unit and Part C-1unit) is considered. The computational results of the model are validated using sensitivity analysis. A simulation study is used for understanding inventory levels at various sites with ARENA software(Version 15.1) A case study related to CLSC network of fixed order quantity inventory policy was investigated. All the above said mathematical models are developed as deterministic one with objective function and constraints equations in the form of Mixed Integer Linear Programming (MILP). These equations are programmed and executed in IBM ILOG CPLEX OPL (Version 12.5) studio with appropriate input data and results obtained are investigated to get appropriate insights.