Strategic Network Design and Capacity Management of a Manufacturing - Remanufacturing System

ABSTRACT

Increasing concerns over environmental protection have opened various research outlets for industry and academic research. In today's global economy, firms are seeking any and every opportunity to differentiate from competitors by reducing supply chain costs and adding value to end customers. One increasingly popular option, under growing consumer awareness and increasing legislation, is to reintegrate returned products into the supply chain to achieve economic benefits as well as improve sustainability. The idea of taking back the used products and components to be used again in the supply chain is known as Reverse Logistics (RL). RL was presented from the context of recovery options (reuse, remanufacturing, recycling, etc.) that restore returned products ("cores") or their major modules to operational condition for using in place of a new product or distributing through other channels (e.g., spare parts).

RL is emerging as a significant area of activity for business and industry, motivated by both commercial profitability and wider environmental sustainability factors. However, planning and implementing an appropriate RL network within existing supply chains for product recovery that increases customer satisfaction, decreases overall costs, and provides a competitive advantage over other companies is complex. This thesis initially focuses on the on designing RL network through the integration of facility location, operational planning, and vehicle type selection, while simultaneously accounting for carbon emissions from vehicles, inspection and remanufacturing centers. Next, we developed a mixed-integer linear programming model for an RL network design in a multi-period setting. Since the network design problems are NP-hard, we propose a three-phase solution approach and a benders decomposition-based heuristic based on the structure of the problem. Finally, to establish the performance and robustness of the proposed solution approaches, the results are compared with benchmark results obtained using CPLEX in terms of both solution quality and computational time. From the computational results, we validated that the benders decomposition-based heuristic approach performs superior to the other methods. We also evaluated the proposed model with an illustrative case and presented valuable managerial insights.

Further, the thesis focuses on the capacity investment and inventory planning for a hybrid manufacturing - remanufacturing in the circular economy. Towards this, we present a two-stage stochastic linear model for a make-to-order hybrid manufacturing-remanufacturing production system that optimizes the use of resources, maximize the value of the product and minimize the total cost. We consider the uncertainty in demand; core returns rate and yield to impose flexibility as both operations are considered with a collective production capacity on the same assembly line. we consider the demand cannibalization between two products (new and remanufactured) in two ways: i) common demand stream for both new and remanufactured products, i.e. only the primary market ii) separate demand for new and remanufactured products would be met at primary and secondary markets respectively. Furthermore, we performed scenario analysis by generating three levels of uncertainty for each stochastic parameter. We also considered two levels of capacity usage while solving the proposed model, namely: less capacity intensive case and more capacity intensive case. Closed-form analytical expressions corresponding to the optimal policies of the hybrid production system are derived, and numerical examples are cited. Practical insights are obtained on the level of capacity investment, the level of raw material inventory, decision on manufacturing or remanufacturing and other optimal decisions.

Keywords: Reverse Logistics, Remanufacturing, Network Design, Carbon footprint, Benders decomposition, Demand Cannibalization, Capacity planning, Inventory decisions, Mixed Integer Linear Programming

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