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Research Paper

Reverse Logistics and Closed-Loop Supply Chain- A Literature Review and Future Opportunities

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ABSTRACT
Manufacturers adopt product recovery and remanufacturing as two essential business strategies to reduce landfill waste and get economic advantages. Parts are recovered from the used products for recycling, remanufacturing, and repairing. Manufacturers were forced to switch to reverse or Closed-Loop Supply Chain (CLSC) as the traditional supply chain doesn't support product recovery. This paper summarizes the current state of the literature on reverse logistics and closed-loop supply chain-related potentials in the applications concerning supply chain management. The review study conducts a systematic literature review based on more than 200 academic articles, analyzed and categorized to construct a useful foundation of past research. Finally, we have identified the gaps in the literature to clarify and to suggest future research opportunities.
KEYWORDS: *Supply Chain Management, reverse logistics, analytics, closed-loop supply chain, Review*

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I. INTRODUCTION

Supply chain management manages the flow of goods and services and includes all processes that transform raw materials into final products. Closed-loop supply chain (CLSC), as one of the critical configurations of the circular economy (CE), has received considerable attention in sustainability matters. CLSC has two parts, such as Forward Logistics (FL) and Reverse Logistics (RL). RL has become a fundamental part of Green Supply Chain Management. It exists in different industries, including electronics, primary materials, and others. Consumers are well aware of the dangers around them, like a growing population, rapidly depleting natural resources, and impacting our environment. Also, the government has imposed several laws to protect the environment. Manufacturers have adopted Green as an essential business strategy, which increases their image in this competitive environment. Manufacturers are trying to use recycled and remanufactured parts from post-consumer products or outdated products to reduce landfill waste.

Along with the Green image, recycling and remanufacturing parts are some economic advantages instead of disposing of them. Researchers and practitioners are keen on solving Closed-Loop Supply Chain (CLSC), Green Supply Chain (GSC), Disassembly Line Balancing (DLB), Remanufacturing, CO2 saving rate, and Vehicle Routing Problem (VRP) models [1]. Recapturing proper disposal value, the flow of raw materials, in-process inventory, finished goods, and related information, from the point of consumption to the origin, is known as Reverse Logistics (RL) [2]. Due to legislative, environmental, and economic reasons, RL's importance has increased significantly in the last two decades. Value recovering as much as possible is the use of RL [3] and reduce the extraction of virgin materials and solid waste dumps. Rajamani et al. [4] and Lundin [5] focused on the cash reverse supply chain. CLSC and product lifecycle has considered for cost reduction and environmental impact on carbon emission, energy usage, and waste management can be lowered. The economic success or failure has determined by the productivity and efficiency of a recovery program and its RL process. Increase customer's awareness and concern for the environment. The products that are not environmentally friendly have given less importance, and refurbished products are sometimes used to fill warranty pools of sold products, with the remaining refurbished units traded in secondary markets [6]. German packaging ordinance obliges packaging companies to collect packaging material from the different chain members and reuse or recycle 80% of the collected packaging material, which reduced the raw material purchase cost and avoided landfills. Remanufacturing is a favorite research topic among researchers and practitioners in developing countries due to resource scarcity [7]. Research on remanufactured products market development and pricing for the remanufactured products is more [8]. Remanufactured products will result in less green-house emissions over virgin manufacturing practices with less energy and cost [9]. As there is a need to extend the life of End of Life (EOL) products and balance various environmental pressures, companies have to develop a system that avoids landfills [10].

The first sector to implement remanufacturing is the Automobile sector for EOL vehicles with strategies like repair, reconditioning, or reuse with warranties equivalent to the new product with better quality, modern appearance, upgraded parts, and original specifications. Remanufacturing has become popular in another sector, especially in electronic industries where the EOL and the premature product is more. But in developing countries, remanufacturing is still in the initial stages and still struggling with remanufacturing implementation [11]. The remanufacturing concept exists for more than a decade, but even the Indian economy plays a secondary role. It is still mostly unfamiliar and dreams for developing or small and medium scale enterprises and only a few established organizations are practicing remanufacturing strategies. Remanufacturing is becoming more popular due to its economic benefits [12]. Manufacturers realize the importance of protecting the environment and social responsibilities. Manufacturers are spending a lot of money on R&D for EOL and End of Use (EOU) products and its reprocessing technique for gaining social credits. In product recovery, Disassembly is the first phase. The line Balancing (LB) concept has been used in the assembly system, and it has extended to the disassembly system [13, 14]. DLB is the assignment of disassembly tasks in sequence to different workstations. All precedence relations are taken care of to optimize the number of workstations, cycle time, and profit [15, 16, 17]. A disassembly system is required to recover valuable parts and materials for Reuse or recycles at the EOL stage in the product life cycle [18]. Recycling factories are constructed and operated to recover various kinds of products in disassembly systems [19]. Factories will consider economic and environmental advantages for deciding either disassemble or disposes of each part. The disassembly process and some disassembly steps need to have been altered or skipped entirely due to product defects, making Disassembly more exciting and challenging [20]. Researchers are keen on solving these challenges. On the other hand, Researchers also have interested in building a low-carbon supply chain. CO2 emission in the supply chain beyond a single organization has been reduced and visualized [19]. CO2 emission is considered in the reverse supply chain for the EOL phase [21].

In the CLSC, manufacturing and remanufacturing activities should be integrated by recovering parts from return products and purchasing new parts from the suppliers. Recovery becomes more complicated when quantity, quality, and timing of the return are quite uncertain. Products/parts recovered rates are affected by different recovery options like Reuse, refurbishment, recycling, and disposal by this uncertainty. In various facility centers, the processing and set-up cost has changed due to the fraction of parts recovered by different recovery options. The minimization of the total cost has become more challenging as determining the number of products to be remanufactured and the numbers of parts to be purchased are uncertain in a CLSC network. The network's complication increases when other costs like buying cost from the supplier(s), transportation cost, processing cost, and set-up cost at each facility have included. The reverse supply chain has more uncertain parameters than the forward supply chain. But these uncertain parameters affect the forward supply and thus make the whole supply chain environment uncertain. CLSC, GSC, and DLB are modeled mostly using Integer Linear Programming (ILP), Mixed Integer Linear Programming (MILP), and Mixed Integer Non-Linear Programming (MINLP). Models are optimized using the Mathematical Programming Method, Simulation Method, Heuristic Method, Hybrid Method, and Analytical Method. Multi-objective models are solved efficiently using Mathematical Programming Methods and Heuristic Methods. Heuristic Methods are most popular in explaining a complex model, which has exponential time algorithms. Heuristic Methods give the best solution with lesser processing time. Genetic Algorithms (GA), Simulated Annealing Algorithm (SA) [22, 23], Greedy Randomized Adoptive Search Procedure (GRASP) [24, 25] and Particle Swarm Optimization (PSO) [26] are the most popular algorithms used to solve the problems.

II. REVERSE LOGISTICS

Reverse supply chain (RSC) refers to a series of activities necessary to retrieve a product from a customer for the product recovery or disposal. Pochampally and Gupta [27] considered the collection, recovery, and demand as the essential RSC network design elements. Sasikumar and Kannan [28] have examined collecting, sorting, and product recovery as RSC's vital activities. Santhosh Srinivasan and Shahul Hamid Khan [29] have also considered collection, testing, remanufacturing, and redistribution as RSC's critical activities. From the above discussion on the essential elements/activities of reverse logistics and reverse supply chain, it has been observed that the key aspects/activities are the same for them both and have been interchangeably used in the literature. Collection, sorting, testing, and the recovery of returned products are the key elements used in the reverse logistics and reverse supply chain. In reverse logistics, the collection is the first and important element. The used products have moved to some point for conducting further treatment to recover parts. According to Fleischmann et al. [30], companies need to identify methods to collect recoverable products from users, inspect collected products to recover valuable resources, a place to reprocess collected products and identify the distribution methods for the recovered products to customers. The literature on collection in RL can be divided into three categories, i.e., location-allocation of collection centers, methods of collection, and collection with incentive.

III. PRODUCT RECOVERY

The most crucial activity of reverse logistics is product recovery. It manages the flow of products or parts. Guide et al [31] identified the strategies to increase the product's life by repairing and remanufacturing in product recovery management. Product recovery reduces the use of virgin natural resources, reduces environmental pollution, and reduces the landfill space. Many authors have recommended product recovery as an essential path. Bulk recycling networks, assembly product remanufacturing networks, and reusable item networks are the three classifications made by Fleischmann et al. [30] based on product recovery characteristics. Criteria for manufacturability and 75 different product types that are routinely remanufactured are identified by Lundin [5]. Automobiles, electronics, and tires are the industries that typically apply to remanufacture. In a cellular phone remanufacturing company case, Guide et al. [31] considered the acquisition of used phones with different quality levels, remanufactured them to a single quality level, and sold them to maximize the profit.

Many recovery options are possible for a returned product after reaching the organization. Reuse, repair, refurbish, remanufacturing, retrieval, recycle, and disposal are the seven recovery options identified by Jayaraman [32]. If the product meets sufficient quality levels, then the first option is to sell the product. If the product has some repair, then the product should be repaired, which involves fixing and replacement of failed parts is the second option. The third option is to refurbish units and sell them [33]. Refurbishing is upgrading by replacing old modules and components with technologically superior ones. The fourth option is remanufacturing, where the product will be disassembled, remanufactured, reassembled, and sent back to the consumer. One or more valuable parts of the product will be retrieved and used in the fifth option. The sixth option is to recycle, where the product will be reutilized with other raw materials after some initial processing. The seventh option is to dispose of. Different authors have categorized and classified the product recovery process. The collected products which can be directly reused after cleaning and minor maintenance fall under the direct recovery category. Bottles, pallets, or containers, telecommunications equipment is some of the examples of direct recovery. Without purchase, if the product has been used again, it is called Reuse, and if the products have sold also is called re-sale. These are two options used for direct recovery. For Technical or economic reasons, the products that cannot be reused will dispose of. Disposal may include landfill or incineration. The products that have been rejected at the inspection level or sorting level due to not satisfy the market demand/ potential or due to excessive repair requirements have been disposed of.

IV. CLOSED-LOOP SUPPLY CHAIN

The integration of the forward supply chain and reverse supply chain constructs a closed-loop supply chain (CLSC). In other words, there are both forward and reverse channels in CLSC networks. Closed-loop supply chain is a relatively new terminology that entails combining traditional forward supply chain activities and reverse supply chain activities into a single system with the potential to raise the environmental performance of industrial operations to new standards and to create new profit opportunities and competitive advantages for supply chain participants. The closed-loop supply chain has many benefits, but a significant issue in CLSC is the integration of information between the forward and reverse supply chain [34]. To achieve optimum planning and reduce costs, the return information should be integrated with the forward supply chain. The uncertainty of quantity further complicates product return quality and timing. In CLSC, the manufacturer needs to consider the manufacturing and remanufacturing activities to meet customer demand [35]. The manufacturer needs to decide the number of products to be remanufactured and the number of parts to be purchased from an external supplier to minimize the total cost. The whole CLSC network can be designed so that it can increase the company's profitability and the company's environmental reputation. The closed-loop supply chain research focuses mainly on reverse logistics and their integration with forwarding logistics and less on managing the forward supply chain. The framework for a closed-loop supply chain is to provide an overall understanding of the supply chain. A framework is "a basic conceptual structure" to identify the different elements of a closed-loop supply chain, to structure them, and to describe their relationship to each other. Figure 1 represents a generalized framework for a closed-loop supply chain containing both the forward and reverse supply chain. The upper part of the figure with solid lines represents the forward supply chain, while the bottom part with dashed lines represents the reverse supply chain. The forward supply chain constitutes the external suppliers, manufacturer, distributor, retailer, and customers. Reverse logistics starts with the collection of returned products from customers. Out of the returned products, the products that can be reused after minor repair have been sent to the distributor, and the rest are forwarded to the disassembly center to disassemble into parts. To check the reusability of parts, sorting and testing have been done parallel to Disassembly. Here the parts are divided into different categories depending on their residual quality and other end-of-life options, like refurbishable parts, recyclable parts, and disposable parts.

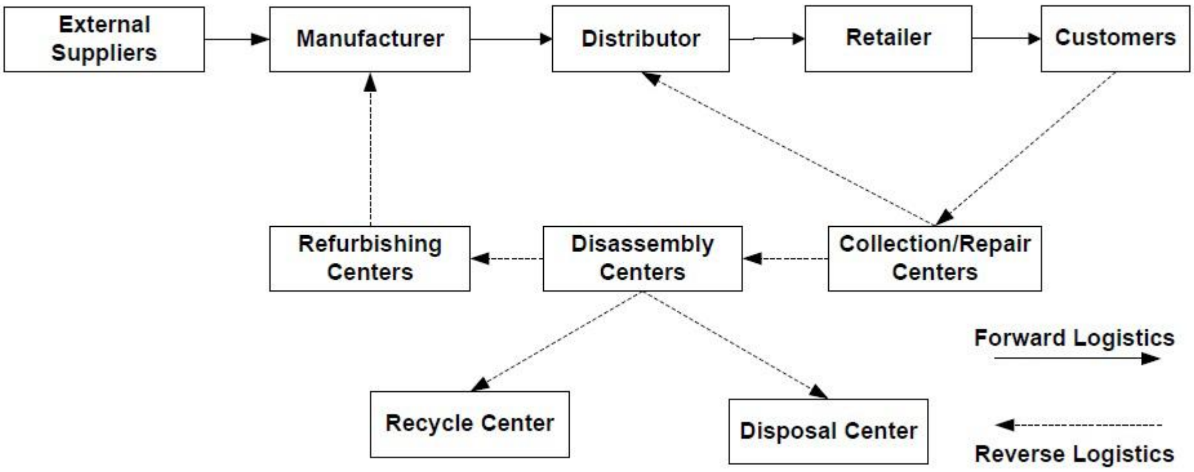

Figure 1. A generalized framework for closed-loop supply chain [36]

V. CONCLUSIONS

This paper tried to present a literature review on Reverse Logistics and Closed-loop Supply chain management. The review of closed-loop supply chain network models is based on the type of framework, number of objectives, product recovery options, different costs and methods of handling uncertainty.

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