Chapter 13

Enhancing Efficiency and Sustainability in Reverse Logistics Through Inventory Modelling for Cost Analysis and Environmental Impact Reduction

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ABSTRACT

As global environmental awareness grows, sustainable development is gaining momentum. A key strategy in achieving sustainability is the adoption of reverse logistics (RL), which manages the backward flow of materials from customers to manufacturers. This often occurs due to product damage, unmet expectations, or warranty returns. This study presents a comprehensive investigation using both mathematical analysis and computational tools. The mathematical model aims to minimize the planning horizon and maximize total profit, incorporating a non-constant return fraction and a carbon reduction function influenced by green tech-

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nology investment. Computational analysis, performed using MATLAB, supports the theoretical framework. The main goal is to optimize profits in a reverse logistics system while addressing cost efficiency and environmental impact. The model focuses on reducing solid waste through repurposing materials for use in production and remanufacturing, and also determines the optimal conditions for manufacturers to achieve maximum profitability.

1. INTRODUCTION AND LITERATURE REVIEW

With the rising concern over environmental impacts, sustainable development has gained significant importance, and reverse logistics (RL) has emerged as a key strategy to achieve it. RL refers to the backward flow of products from customers to manufacturers, whether due to damage, dissatisfaction, or warranty claims. Beyond enhancing customer satisfaction, RL contributes to sustainability by minimizing raw material consumption through reuse, repair, and recycling. Increasingly stringent government regulations and environmental policies have also pushed industries to adopt RL as part of responsible waste management, offering not only ecological but also legal and strategic benefits.

Despite its advantages, RL faces several practical challenges, including uncertainties in the timing, volume, and quality of returned items, the need for inspection and sorting, and limited capacity for repair and recycling. Firms must also navigate the economic trade-offs of providing incentives for returns, mitigate the risk of cannibalizing new product sales, and comply with extended producer responsibility regulations, all while developing cost-efficient collection and processing networks.

Meanwhile, emerging industry trends are reshaping RL practices. The adoption of circular economy principles, digital technologies such as blockchain and IoT for traceability, and AI-driven inspection tools are enhancing operational efficiency. The rapid growth of e-commerce has further increased product returns, while deposit–refund systems and investments in green technologies are promoting greater sustainability.

In practice, RL has become central across sectors such as electronics (e.g., take-back programs), automotive (remanufacturing and battery recovery), home appliances (refurbishment), e-commerce (large-scale returns management), and packaging and beverages (bottle return schemes). These examples highlight how RL not only improves environmental performance but also strengthens profitability, positioning it as an essential component of modern supply chains.

Also, industries across sectors have increasingly invested in green technologies to strengthen reverse logistics while reducing environmental impacts. For instance, in the electronics sector, advanced disassembly systems are being adopted to recover

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