Integrated Optimisation Informed by Predictive Models in a Sustainable, Carbon-Conscious Supply Chain with Reverse Logistics

Summary

This dissertation examines the integrated optimisation of procurement, production, remanufacturing, maintenance, and transportation. The study is set within reverse logistics-based, carbon-conscious, sustainable supply chains.
Chapter 1 introduces the fundamental concepts and latest developments in modern supply chains. It addresses procurement strategies, inventory control, transportation, optimisation strategies, manufacturing-remanufacturing flows, reverse logistics, and planning techniques. The discussion emphasises sustainability and maintenance as essential components of integrated supply chain models. Furthermore, the contribution of data-driven optimisation and machine learning to improve forecasting and decision-making for both forward and reverse flows is investigated. The chapter concludes with a review of integrated optimisation techniques and a summary of the primary research question that guides the remainder of the dissertation.
Chapter 2 discusses the optimisation of a multi-period planning for production, remanufacturing, transportation, and acquisition in supply chains that take into account both operational and financial factors. A MILP model is developed to determine the optimal plans, accounting for procurement strategies, storage capacities, transportation costs, and vehicle limitations. A study of different procurement strategies shows that the Contract Based procurement such as Fixed Lot Size and Hybrid increases economic efficiency and flexibility compared to Simplified acquisition Strategy. Numerical experiments demonstrate the model's ability to optimise transportation, regulate return flows, and dynamically adjust production while preserving operational viability, profitability, and service-level compliance.
Chapter 3 analyzes three carbon regulatory strategies, while maximising the overall profit. The findings demonstrate that strict emission control is provided by carbon taxes, increased flexibility and cost efficiency are made possible by the Cap-and-Trade mechanism, and proactive environmental management is encouraged by the Limit-and-Subsidy approach, which rewards low-emission performance. All things considered, the chapter provides an analytical framework that integrates environmental responsibility with operational and financial performance to help decision-makers in carbon-conscious supply chains.
Chapter 4 explores the integrated optimization of maintenance and transportation in supply chains with reverse logistics. MILP model is developed to balance maintenance intervals against total system costs incorporates both preventive and corrective measures. The results show that reliability and costs are significantly impacted by the frequency of maintenance, and that transportation is crucial for integrating supply chain operations with maintenance. Sensitivity analysis demonstrates how cost parameter variations reshape optimal policies, underscoring the the necessity of striking a balance between dependability and cost effectiveness.
Chapter 5 develops a multi-period optimisation model for a comprehensive supply chain using a MILP framework that takes into account realistic storage and vehicle capacities, such as two vehicles and contract carriers. In order to ensure sustainability and practicality, the model incorporates a city-based collection centre, clear transportation decisions, and the carbon tax

strategy with the Paris Agreement. It balances efficiency and environmental responsibility while capturing operational complexities by taking into account both forward and reverse flows. Scenario analyses show flexibility in response to shifts in production schedules, returns, and demand. The use of sophisticated predictive models, especially the hybrid SARIMA/VAR approach, which improves forecast accuracy and robust decision-making, is a significant contribution. As a result, the chapter offers a strict framework that synchronises long-term sustainability objectives with profitability.

Mots clés : *Integrated Optimisation,Sustainable Supply Chain,Reverse Logistics,Predictive Models,Carbon Footprint,*