DISSERTATION ABSTRACT

In the wake of the COVID-19 pandemic and ongoing geopolitical conflicts, small and medium-sized enterprises (SMEs) face heightened financial and operational pressures. Vertical collaboration with financially stronger manufacturers has emerged as a strategy to integrate SMEs into large-scale production systems and enhance supply chain resilience. This study develops computational optimization models for a multi-supplier, single-manufacturer supply chain operating under stochastic demand, employing a (Q, R) inventory policy to determine optimal replenishment strategies. The models consider both homogeneous and heterogeneous suppliers delivering raw materials in batch shipments at varying intervals. Two optimization strategies are examined: an integrated model, which jointly minimizes total supply chain costs, and a Stackelberg leader-follower model, where the manufacturer optimizes its costs independently while suppliers adjust production rates competitively. Pseudocode-driven algorithms are developed to implement both approaches, with key decision variables including production rates, batch sizes, reorder levels, lot sizes, and the number of delivery trips per cycle.

Sensitivity analysis is conducted primarily with the analytical model to evaluate the impact of parameters such as mean demand, demand variability, supplier production-to-manufacturer consumption ratios, raw material requirements per finished product, and holding costs. Building on these results, discrete-event simulation optimization using Arena and OptQuest relaxes the analytical assumptions by allowing asynchronous dispatch, equal batch sizes across suppliers, and the introduction of a dynamic reorder timing buffer as a decision variable. This flexibility enables the supply chain to respond effectively to variations in supplier production rates, delivery capabilities, and operational constraints, achieving greater cost savings compared with the synchronized, lead-time-driven analytical approach.

This research advances computational optimization in supply chain management by providing quantitative decision-support models that improve cost efficiency and operational resilience in uncertain multi-echelon systems. The findings demonstrate that flexible dispatch policies, equal batch sizes, and dynamic timing can enhance collaboration between manufacturers and SME suppliers while reducing overall supply chain costs through data-driven decision-making.