CHAPTER 43

OPERATIONAL RESEARCH

Doctoral Theses

01. AHMAD HASAN
Sustainable Inventory Models for Imperfect Production Process and Closed-Loop Supply Chains.
Supervisors: Dr. Amrina Kausar and Dr. Chandra K Jaggi
Th 28412

Abstract

As the global focus on sustainability continues to grow, inventory management has undergone significant transformation, leading to the development of models that strive to balance environmental and economic objectives. In response to these evolving needs, this thesis presents sustainable inventory models specifically developed for systems characterized by imperfect production processes and closed-loop supply chains. These models comprehensively address real-world complexities, including production defects, inspection errors (Type I and Type II), carbon emissions, and demand fluctuations influenced by price and advertising strategies. To reduce waste and improve system performance, the models incorporate strategies such as remanufacturing, salvaging, and inspection. A key contribution is the introduction of a circularity index, which captures the influence of product design, material selection, and supplier choice on demand, return rates, and product reusability. The study also incorporates multi-shipment policies to maintain product freshness and reduce holding costs, along with learning effects that reflect cost reductions through accumulated experience. In addition, cooperative and non-cooperative game-theoretic models are formulated to analyze pricing and decision-making across multi-retailer supply chains with price-sensitive demand. The Nash Bargaining, Integrated, and Stackelberg strategies are evaluated to highlight the benefits of collaboration in improving both profitability and environmental outcomes. Extensive numerical analysis and sensitivity analysis validate the effectiveness and applicability of the proposed models. The research provides valuable insights for firms shifting from linear operations to circular, resource-efficient supply chains. It demonstrates that incorporating remanufacturing, multi-shipment policies, and circularity metrics enhances environmental outcomes and profitability. Collaborative strategies further improve supply chain performance, supporting sustainable practices alongside strong economic results in competitive markets.

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1. Introduction 2. Literature review 3. Modeling imperfect production with salvage strategy for defectives under advertisement and price-sensitive demand 4. Optimizing closed-loop supply chains with imperfect production and inspection errors under multi-shipment strategy 5. Advancing sustainable closed-loop supply chains with imperfections using circularity

02. ANKUR KUMAR

Innovation Adoption Modelling Inculcating Dynamic Market Size Phenomena.

Supervisors: Prof. Ompal Singh

Th 28814

Abstract

This thesis develops a comprehensive modelling framework for understanding innovation adoption by integrating multi-stage behavioural processes, dynamic market expansion, distribution-based diffusion structures, and stochastic uncertainty. The study begins by examining the innovation adoption pathway through detailed stage-wise formulations, where individuals transition across phases such as awareness, persuasion, motivation, and final acceptance. By introducing explicit transition rates, the thesis provides a quantitative interpretation of how users progress through these stages, offering a more refined representation than existing qualitative frameworks. A simplified two-stage structure is also proposed, incorporating learning functions to capture dynamic variations in awareness formation and adoption. Recognizing that real markets seldom remain static, the research extends diffusion modelling toward environments with evolving market size. Two key perspectives on market expansion are explored: the freemium-driven user base growth mechanism and the potential adopter domain function, which collectively explain how consumer pools evolve over time. These formulations are tested with real-world data to demonstrate their applicability. The thesis further evaluates diffusion models constructed using adoption rates derived from alternative distribution functions. By extending simple models into multi-parameter frameworks, the study captures diverse market behaviours with greater precision. Comparative analyses reveal that enriched parameterization significantly improves goodness-of-fit over conventional models. Given the presence of randomness in large and long-duration markets, the research incorporates stochastic elements using stochastic differential equations. These models reflect uncertainty more realistically and exhibit superior predictive performance. The framework is further expanded by integrating promotional efforts within a stochastic environment, recognizing the combined influence of marketing activities and random behavioural variations. Overall, the thesis offers a unified, flexible, and empirically validated modelling approach that advances understanding of innovation diffusion in dynamic and uncertain market settings, contributing both methodological depth and practical insights for decision-makers.

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03. SATYA RANI

Some Aspects of Reliability Analyses of Phased Mission Systems Using Copulas.

Supervisor: Prof. Preeti Wanti Srivastava

Th 28413

Abstract

A phased mission system (PMS) is defined as a system consisting of phased sub-missions with relevant configuration changing from phase to phase. The reliability analyses of such systems are not only important but imperative as the operation of missions encountered in aerospace, nuclear power, chemical, electronic, navigation, military fields, and many other applications involves several different tasks or phases that must be accomplished in a sequence. In this thesis, copula-based approach has been used for reliability analyses of PMSs. The dependency amongst the components in a phase and that across the phases is modeled using such copulas as Gumbel-Hougaard, Frank and Clayton. The cumulative exposure model that takes into account previous exposure history of a component is used to model a PMS. Chapter 1 is introductory. Copula-based approach to the reliability analysis of two three phases PMSs with and without inactive components, and five-phased spacecraft PMS along with reliability importance analyses have been studied in Chapter 2. Chapter 3 focuses on predictive maintenance scheme for a PMS. It is found that the use of predictive tools with periodic maintenance reduces overall equipment maintenance costs with higher mean residual life. In Chapter 4 optimal spare package has been determined for a PMS subject to cost and weight constraints and method proposed explained using numerical examples with special reference to Fire-Fighting PMS for a chemical factory. Chapter 5 focuses on formulation of reliability analysis of a PMS using time-varying Gumbel-Hougaard Copula which facilitates capturing environmental instability over a period of time. Chapter 6 deals with reliability analysis of a PMS under Degradation using Wiener Process and Copulas. An Aircraft flight PMS is used for illustrative purpose in chapters 3, 5, and 6. The extensive computational work for reliability analyses of complex PMSs has been acomplished using 'Mathematica 11.0' and "R".

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04. SHARMA (Priya)

Advances in Large-Scale Multi-Criteria Decision-Making Using Generalized Fuzzy Numbers.

Supervisors: Prof. Mukesh Kumar Mehlawat and Dr. Shilpi Verma

Th 28736

Abstract

This thesis develops five advanced frameworks to address large-scale multi-criteria decision-making (LSDM) problems under uncertainty using generalized fuzzy numbers. Real-world decision situations often require selecting the most suitable alternative from several options evaluated against multiple, and frequently conflicting, criteria. While Multi-Criteria Decision-Making (MCDM) methods provide a mathematical foundation for such analyses, traditional techniques face major challenges when the number of decision-makers (DMs), criteria, or alternatives increases substantially, especially under uncertain environments. Because uncertainty is intrinsic to human judgment, it is modeled here through various extensions of fuzzy set theory. To overcome the limitations of classical approaches, the thesis presents five independent frameworks designed for group decision-making and various LSDM scenarios. These frameworks address critical issues such as high dimensionality, consensus in group decisions, objective criteria weighting, and robust ranking of alternatives. A combination of mathematical optimization, fuzzy logic, statistical methods, machine learning (ML), and deep learning (DL) is integrated within the decision process. Dimensionality reduction is achieved through clustering mechanisms (including an improved K-means++ algorithm) and ML/DL-based feature-selection techniques. Criteria weights are determined using optimization-based models, fuzzy goal programming, Integrated Determination of Objective Criteria Weights (IDOCRIW), and the Method based on the Removal Effects of Criteria (MEREC), adapted for different fuzzy environments. Rankings of alternatives employ extended versions of TOPSIS, cross-efficiency Data Envelopment Analysis (DEA), Additive Ratio Assessment (ARAS), and the VIKOR method. The performance of the proposed models is validated through numerical illustrations, comparative analyses, simulations, and sensitivity analyses. The results demonstrate that the proposed LSDM frameworks, developed under various generalized fuzzy settings, offer flexibility, scalability, and robustness, making them suitable for a wide range of complex decision-making problems.

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05. SINGH (Jitendra)

Integrated Relief Supply Chain Inventory Models for Multi-Echelon Distribution.

Supervisor: Prof. Chandra K. Jaggi

<u>Th 28414</u>

Abstract

Effective humanitarian logistics is critical in mitigating suffering during disasters, yet relief operations are fraught with complexities that traditional optimization models often overlook. This thesis confronts this gap by developing a suite of progressively integrated mathematical models to enhance decision-making in multi-echelon humanitarian relief supply chains. The research systematically incorporates layers of operational reality often addressed in isolation. The thesis sequentially introduces four interrelated models, each incorporating increasing levels of realism and operational complexity. The first model establishes a foundational framework by quantifying the significant, often-hidden costs of commodity deterioration and disposal, demonstrating that high damage rates can threaten the feasibility of an entire operation. Building on this, the second model introduces multi-product complexity and a novel, nonlinear risk-adjusted transportation cost function. The third model directly tackles the volatile post-disaster environment by integrating a dynamic demand function based on beneficiary population flows and a granular, route-specific risk assessment. This creates an adaptive framework far superior to static planning. Finally, the fourth integrated model introduces capacity constraints and dual shortage mechanisms, balancing local procurement and unmet demand have beneficiary impact value to address resource limitations common in humanitarian operations. The work concludes by outlining avenues for future research, including uncertainty modeling, multi-objective optimization, and technology-enabled decision systems for resilience planning. Collectively, this research provides a holistic, quantitative framework that offers decision-makers more realistic and robust tools for designing and managing cost-effective, resilient, and responsive relief operations. The results demonstrate that deterioration, risk exposure, and dynamic demand significantly influence total operational costs and network feasibility. Further, the findings yield actionable insights for strategic planning, resource allocation, and preparedness investments, ultimately aiming to maximize the life-saving impact of humanitarian response.

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