Advanced Optimization Model Under Uncertainty for Sustainable Closed-Loop Supply Chain of Electric Vehicle Battery

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Abstract

Transportation is a major source of global greenhouse gas emissions. To mitigate this problem and its climate impacts, electric vehicles (EVs) have been proposed as a key solution in the transportation sector. However, battery electric vehicles (BEVs) face significant challenges, mainly related to their supply chain. The limited availability and uneven distribution of mineral resources, especially lithium, create vulnerabilities in the supply chain. At the same time, used BEVs have a high potential for recycling. Therefore, a closed-loop supply chain aims to optimize resource use by integrating raw material sourcing with waste recycling. However, the existing literature has some gaps: the lack of uncertainty handling in BEVs' supply chain models and the lack of sustainable models that consider both forward and reverse flows. This study aims to fill these gaps by developing a sustainable multi-objective fuzzy model considering all supply chain elements under uncertainty. The model uses fuzzy parameters and variables, such as BEV demand, EV demand, costs, BEV return rate, energy consumption, facilities capacity, and BEV and mineral batteries order amount. The model is solved using the GAMS software and the results show the trade-offs between sustainability aspects, the optimal material flows, and the sensitivity analysis of the model. This study can provide useful insights for the decision makers and the stakeholders of the BEVs supply chain.

Keywords
Battery Electric Vehicle, closed-loop supply chain, multi-objective fuzzy mathematical model, sustainability

Biographies
Mina Kazemi Miyangaskary earned her M.S. in Industrial Management from Guilan University and subsequently achieved her Ph.D. from Tehran University, Iran. Presently, she serves as a research assistant at Polytechnique Montreal University. With a decade's worth of academic and industrial exposure in both Canada and Iran, she has made significant contributions in teaching, research, and development. Mina's research is at the forefront of advancing our understanding of uncertainty in supply chain dynamics, with a special focus on fuzzy mathematical modeling.

Samira Keivanpour is an assistant professor in the Department of Mathematical and Industrial Engineering at Polytechnique Montréal, Canada. She conducts research on sustainable solutions for supply chain and logistics

management, with a focus on end-of-life product treatment, circular manufacturing, and the integration of Industry 4.0 technologies**.**

Amina Lamghari After receiving a BSc and a Master's in Applied Mathematics, Amina Lamghari obtained a PhD in Operations Research from the University of Montreal, Canada, after which she worked as a post-doctoral fellow and later as a research associate at the COSMO Stochastic Mine Planning Laboratory at McGill University. Amina is currently an associate professor in the Management School at the University of Quebec at Trois-Rivières. Her research interests are centered on various techniques and algorithms —(meta)heuristics, hyper-heuristics, and matheuristics -- for optimization and their integration and application to solve complex scheduling and planning problems in an efficient manner accounting for uncertainty

Asad Yarahmadi is a PhD candidate in Civil Engineering - Transportation Engineering at Polytechnique Montreal University. He completed his master in GIS and Remote sensing. With his unique blend of expertise in Geographic Information System (GIS) tools, Machine Learning techniques, and Remote Sensing, he excel at integrating technology to address the environmental impact of transportation. Throughout his academic and professional journey, Asad has demonstrated his commitment to sustainable transportation solutions. He also has a proven track record of effectively managing both academic research and industrial projects aimed at tackling crucial environmental issues, such as vehicle emissions. His ultimate goal? Facilitating a greener, more sustainable future.