Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/WC02.20250089
Published: October 14, 2025

Bilevel Robust Optimization for Design and Pricing of Electric Vehicle Battery Reuse Network

Qi Wang
College of Mathematics & Information Science
Hebei University
Baoding, China
Department of Mechanical, Automotive and Materials Engineering
Faculty of Engineering
University of Windsor
Windsor, Canada
qip@uwindsor.ca

Yankui Liu
Professor, College of Mathematics & Information Science
Hebei University
Baoding, China
lyk@hbu.edu.cn

Guoqing Zhang
Professor, Department of Mechanical, Automotive and Materials Engineering
Faculty of Engineering
University of Windsor
Windsor, Canada
gzhang@uwindsor.ca

Abstract

The rapid proliferation of electric vehicles has led to a significant increase in the quantity of used electric vehicle batteries (EVBs). This necessitates the design of a waste reverse supply chain to reuse and recycle EVBs and protect the environment. This study examines an integrated reuse network design and pricing problem for EVBs. To design a reliable EVB reuse network to hedge against return quantity uncertainty, we present two bilevel globalized distributionally robust (GDR) design and pricing models. We derive computationally tractable reformulations of GDR expectation and chance constraints. For the resulting joint chance-constrained model, we propose a tailored branch-and-cut (B&C) algorithm and introduce a strengthened formulation to speed up the solution process. A real-world case study is conducted to validate the superiority of the proposed methods and examine the impacts of key model parameters on profitability. Results demonstrate that the globalized distributionally robust optimization models exhibit greater robustness than stochastic optimization models. The computational performance of the tailored B&C algorithm incorporating a strengthened formulation is assessed compared to the standard solver. Finally, based on the numerical results, we derive managerial insights from the analytical findings.

Keywords
Network design; pricing; used electric vehicle battery; distributionally robust optimization; algorithm

Acknowledgements
This work was supported by the Natural Science Foundation of Hebei Province (No. A2023201020), the Operations Research and Management Innovation Team of Hebei University, China (No. IT2023C02), the National Natural Science Foundation of China (No. 61773150), and the Natural Sciences and Engineering Research Council of Canada Discovery grant (RGPI-2019-07115).

Biographies
Qi Wang received the bachelor's degree in mathematics from the Department of Applied Mathematics, Qufu Normal University, Qufu, China, in 2019. She is currently pursuing the Ph.D. degree with the College of Mathematics & Information Science, Hebei University, China. She is currently a visiting Ph.D. student at the University of Windsor, majoring in supply chain management and logistics. Her research interests include bilevel robust optimization, supply chain network design problems, and exact algorithms. Her previous research has been published in journals, such as Engineering Optimization, Applied Energy, and Transportmetrica A: Transport Science.

Yankui Liu received the B.S. and M.S. degrees in mathematics from the Department of Mathematics, Hebei University, Baoding, China, in 1989 and 1992, respectively, and the Ph.D. degree in computational mathematics from the Department of Mathematical Science, Tsinghua University, Beijing, China, in 2003. He is currently a Professor with the College of Mathematics and Information Science, Hebei University. He has authored or co-authored more than 100 research articles and six monographs. His research interests include credibility measure theory, robust stochastic/credibilistic optimization, supply chain management, transportation, and exact algorithms. Based on the citations in the Scopus database, he was featured among the most cited Chinese Researchers in the fields of computer science (from 2014 to 2019) and management science and engineering (since 2020) and he has also been selected as one of the Stanford/Elsevier World's Top 2% Scientists in the field of Operations Research (2022 and 2023).

Guoqing Zhang, PEng, is a Professor of Industrial Engineering in the Supply Chain and Logistics Optimization Research Lab at the Department of Mechanical, Automotive & Materials Engineering, University of Windsor. His research interests include supply chain management and optimization, operations research, manufacturing modeling, e-commerce, warehouse management, data-driven optimization, machine learning, and intelligent decision support systems. He has published over 100 articles in these areas. Dr. Zhang's research is supported by NSERC, MITACS, and CFI. He has provided consulting services to several world-leading companies in the automotive, energy, airline, and food industries. In 2015, his team received the CORS Practice Prize. Additionally, he developed a solver for large-scale linear programming based on the interior point method.