ABSTRACT

The urgent global adoption of Electric Vehicles (EVs) is a response to environmental concerns, reducing reliance on fossil fuels, and combating global warming. To effectively implement the Sustainable Development Goals (SDGs) and mitigate the environmental impact of increased mining and high demand due to widespread EV adoption, the management of used Electric Vehicle batteries (EVBs) is crucial. As a critical component of EVs, batteries present various challenges in their development and adoption. This thesis conducts a comprehensive review of recent research on the reverse logistics network and closed-loop supply chain of used EVBs, aligning with the SDGs and emphasizing the significance of environmental, resource, and waste management.

The primary objective is to develop a comprehensive framework for addressing the management of used EVBs, encompassing efficient collection, potential reuse, and material recovery. Through this, we seek to raise awareness about the crucial role of sustainable waste management and circular economy principles in tackling these issues. By establishing a foundational framework, we lay the groundwork for future research and identify prospects for further innovation. Emphasizing proper battery management within the context of sustainable development and resource conservation, we aim to inspire ongoing research and foster innovative solutions. Ultimately, the objective is to advance the understanding and implementation of effective strategies for EVB management, supporting the SDGs, and effectively addressing the environmental challenges associated with widespread EV adoption. This endeavor will contribute to a circular economy approach to waste management and resource utilization, facilitating a sustainable and greener future.

The thesis starts with a literature review to develop an understanding of factors that influence consumer attitudes and behaviors toward EVs and batteries, underscoring their critical role in the shift toward sustainable transportation. It also assesses the role of socioeconomic determinants, technical specifications, policy impacts, and battery end-of-life perceptions. The research identifies key socio-economic factors driving consumer choices and perceptions through a comprehensive survey and logistic regression analysis. The findings will guide policymakers and businesses in developing effective strategies to promote EV use, supporting SDGs related to sustainable cities, communities, and economic growth. The insights gained from this study can inspire private sector growth and innovation, leading to new business opportunities that benefit companies and consumers.

One of the biggest challenges for the future is managing the used-up batteries from EVs. These batteries must be collected for potential after-use and element recovery to minimize the effects of intensive mining, high anticipated demand, and expense. A structured reverse logistics network is needed to retrieve these spent batteries from customers. The next objective outlines a design strategy for such a collection network and includes a case study for Delhi (India), where potential collection centers should be established. The problem is formulated using the traditional facility location problem variations: set covering and p-median. The methodology used in this study determines the number and location of collection centers required in an urban area. The goal is to locate collection centers where 2 Wheelers used batteries can be collected so customers can get to them within a reasonable threshold while considering real-life constraints. To achieve this, a mathematical programming model is created and solved using the CPLEX 12.10 solver and the Artificial Bee Colony approach where relevant. The results provide effective infrastructure designs for new policies that governments and other stakeholders may choose to implement and support sustainable practices for collecting and properly managing used EVBs.

The thesis then presents an innovative model aligning with SDGs 11, 12, and 9. Focused on enhancing operational profits, the model integrates a robust reverse logistics network and policy framework to ensure safe disposal and environmental preservation. Employing the CPLEX solver software, we evaluated various scenarios to maximize profitability and efficiency in battery return systems. Our findings underscored the limitations of conventional proximity-based methods, emphasizing the necessity of advanced optimization. Additionally, the sensitivity analysis highlighted the collection rate parameter's pivotal role in influencing customer behavior and overall system profitability. The study also emphasizes the significance of accessible collection centers, revealing disparities in accessibility across customer zones. These findings call for nuanced analyses to ensure equitable access.

Next the thesis presents a study that employs a rigorous multi-criteria approach to systematically evaluate and prioritize barriers hindering the widespread adoption of second-use EVBs. The study’s overarching objectives are to overcome these barriers, aligning with broader sustainability goals, and to offer insights shaping policies addressing environmental, social, and economic impacts, in coherence with SDGs 8, 11, 12, and 13. The research unfolds through a three-phase approach involving literature reviews, field visits, and expert interviews for barrier identification, theoretical framework development through literature

and Delphi studies, and prioritization using the Fuzzy Best-Worst Method (FBWM). Results indicate that addressing Cost and Technological Challenges is pivotal for successful second-use EVB adoption, with proposed solutions involving regulations, recycling, and awareness. The study underscores the circular economy perspective, connecting identified barriers to specific SDGs.

The thesis also evaluates strategies to increase the recycling infrastructure for used EVBs, filling a significant knowledge gap regarding sustainable management methods. The Fuzzy Decision-Making Trial and Evaluation Laboratory (Fuzzy DEMATEL) and FBWM techniques are employed to assess the factors that impact the expansion of the recycling network. The primary goal is to elucidate the influence of the environment on the management of used batteries, assess its economic viability, evaluate its social implications, ensure compliance with regulations, and optimize logistical efficiency. The Fuzzy DEMATEL research uncovers causal connections between identified factors, resulting in a Total Influence Matrix and Final Outcomes. The FBWM technique assigns weights to factors and prioritizes them. This assists decision-makers in identifying the most crucial criteria. This study establishes the groundwork for well-informed policy suggestions, facilitates the EV industry's shift towards a more environmentally sustainable future, furnishes stakeholders with data-driven strategies, and ensures that technological progress aligns with social and environmental obligations.

Overall, this thesis presents a multi-faceted approach to the sustainable management of used EVBs, addressing critical environmental, economic, and social challenges. Through comprehensive reviews, empirical studies, and advanced optimization techniques, the research offers valuable insights and practical solutions for policymakers, industry stakeholders, and the broader academic community.

Keywords: Electric Vehicles (EVs); Sustainable Development Goals (SDGs); Battery Management; Circular Economy; Reverse Logistics; Environmental Sustainability; Resource Optimization; Second-use EV Batteries; Sustainable Transportation