

Optimizing Freight Transportation through E-Mobility Integration: A Case Study from Sri Lanka

Lahiru Rathuge, Varuna Adikariwattage, H.R. Pasindu

Abstract

The transportation sector globally faces growing pressure to adopt sustainable practices, as freight transport significantly contributes to greenhouse gas emissions and diesel consumption. In Sri Lanka, freight systems exacerbate environmental degradation, with transport-related activities accounting for a substantial portion of air pollution. Electric vehicles (EVs) present a transformative opportunity to reduce emissions and operational costs, yet their integration into freight systems, particularly in developing countries, remains underexplored. This research investigates the optimization of freight transportation through e-mobility integration, addressing challenges such as rural routes, limited charging infrastructure, variable demand, and time-sensitive delivery requirements. While the study focuses on a case involving perishable goods logistics, its findings aim to be broadly applicable to freight transportation, developing a scalable mixed fleet model that combines EVs with conventional vehicles. The research is driven by inefficiencies in Sri Lanka's freight systems, characterized by dispersed collection points, variable loads, and geographical challenges, which lead to elevated costs and reduced productivity. Transitioning to EVs aligns with national e-mobility goals and global sustainability targets, offering a pathway to lower environmental impact. The primary objective is to determine an optimal strategy for introducing e-mobility into freight transportation, focusing on enhancing the efficiency of collection and distribution networks. The methodology unfolds in five stages. Initially, the current freight system is evaluated by collecting data on route characteristics, fleet performance, and operational metrics to establish a baseline for comparison. Next, accessible EV technologies are investigated, assessing their operating costs, performance parameters such as range and payload capacity, and infrastructure needs like charging solutions. A cost model is developed to compare EVs with conventional vehicles, providing a financial basis for integration. The third stage involves a feasibility assessment to identify routes suitable for EV deployment, considering range limitations, charging infrastructure availability, and payload requirements. In the fourth stage, mixed fleet scenarios are modeled using the Capacitated Vehicle Routing Problem with Time Windows (CVRPTW) and Mixed Integer Linear Programming (MILP), testing various fleet compositions while factoring in route lengths, terrain challenges, and charging constraints. Finally, the best-performing scenario is selected based on cost efficiency, emission reductions, and operational feasibility, validated through global case studies of successful EV integration in urban logistics. Preliminary findings suggest that EVs, such as electric light trucks and three-wheelers, are well-suited for shorter rural routes, complementing conventional vehicles for longer hauls. Technological advancements, including improved battery ranges and solar-powered charging, help overcome rural infrastructure gaps. International examples of EV adoption in urban freight logistics demonstrate significant emissions reductions and cost savings on optimized routes,

though challenges like range anxiety persist, which this study addresses through localized modeling.

Keywords: *E-mobility, Sustainable transportation, Freight transport, VRP*

Author details;

1. Research Assistant, Department of Civil Engineering, University of Moratuwa.
lahirurathuge@gmail.com
2. Senior Lecturer, Department of Civil Engineering, University of Moratuwa.
varunaa@uom.lk
3. Professor, Department of Civil Engineering, University of Moratuwa.
pasindu@uom.lk