

Effect of educated decision-making towards uncertainty in battery electric buses network design

Sara Momen, Delft university of technology

Abstract

In recent years, Battery-powered Electric Buses (BEBs) have been adopted in urban public transport widely due to their environmentally friendly, zero-emission features. However, compared with conventional buses, BEBs face limitations in terms of driving range due to battery capacity constraints. Despite advancements in battery technology that have increased the theoretical driving range of BEBs to match that of a diesel bus with a full tank, actual energy consumption and driving range for BEBs are significantly different from the theoretical values. Factors like weather conditions, battery degradation, passenger loads, and more all affect BEB energy consumption. Consequently, designing a reliable BEB network, which involves optimizing the locations and types of charging stations and onboard battery sizes, heavily relies on accurately estimating energy consumption variation between stations.

Various methods in the literature aim to address fluctuations in the energy consumption of the BEBs. These methods include stochastic and robust programming. Stochastic programming necessitates a substantial amount of data to estimate the distribution of uncertain energy consumption. Conversely, robust programming relies solely on the mean and the extreme (worst) values for uncertainty, potentially resulting in more conservative and costly solutions. Moreover, when electrifying existing conventional bus networks, collecting real energy consumption data (for example by performing field experiments) is expensive and provides a limited number of data points, making stochastic programming impractical, especially when considering energy consumption interdependencies between stations. Since many scenarios are required to be generated to capture all the various combinations of energy consumption. Hence, Distributionally robust optimization (DRO) offers an alternative approach capable of yielding optimal solutions even with limited observed data while considering the energy consumption interdependencies among the stations.

In this research, our goal is to explore the impact of accounting for uncertainty in BEB energy consumption in an informed manner by employing the DRO chance constraint method. We will compare the outcomes of three distinct models: the nominal model (where energy consumption is treated as a deterministic parameter), the robust budget of uncertainty model, and the DRO-chance constraint model. We will evaluate these models in terms of their decision variables and the overall cost associated with electrifying an existing bus line.