Making the operations of battery electric bus systems more efficient: Short turning strategy

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The first case represents a situation with the central business district located around one corridor terminus. The second case has the same number of stops and comparable demand level, but represents a typical cross-town peak-demand route pattern. Credit: Dr. W. Zhang and Dr. M. Xu

Urban transit operation presents seriously uneven passenger load along

bus lines during peak periods. This is especially serious in electric battery bus fleets; electric buses must recharge batteries after executing several route circulations, and the charging time is long.

We have designed a short turning strategy for the electric battery bus system to effectively minimize operation costs and passenger waiting times. In consideration of both vehicle configuration and charge scheduling, our results show that the strategy achieves total cost savings higher than 11 percent.

The frequencies and charging schedules of the two electric battery bus fleets along the whole bus line and the short turning line are jointly optimized by formulating a microeconomic model for electric battery bus systems. Moreover, we identified the optimum battery capacity that ensures the electric battery buses operate properly and recharge as few times as possible during peak periods.

Short turning line fleet and whole line fleet use different charging strategies

During the peak period, there are two distinct electric battery bus fleets: One is intended for serving the whole line, while the other is designed for serving the short turning line. The need to recharge the buses while improving the operating efficiency brings significant challenges for operators. By mathematically seeking the optimum charging schedules and short turning line, the electric battery bus system can minimize the total passenger waiting time while reducing operational costs. The short turning strategy for diesel buses focused on determining the starting and end stops for operating a short turning line; we tracked not only the selection of the start and end stop, but also the recharge scheduling for two fleets to avoid running out of charge.

The bus operating the short turning line serves the passengers between stops s0 and s1, if the bus needs to recharge battery at the charging station, it will run without passengers as soon as possible from stop s0 to the charging station. After fully charging the battery, the bus will deadhead back to stop s0 and start the next service circulation. Credit: Dr. W. Zhang and Dr. M. Xu

We analyzed the impact of the recharge schedule on electric battery bus operation, explicitly established the costs of operating the whole line and short turning line with given frequencies. The short turning line design problem was then modeled as an unconstrained optimization problem to obtain the analytical expressions for optimal frequencies.

Because the large charging trip distance and the long charging time incurred by battery charging will significantly reduce the efficiency of operating a short turning line, the batteries of fleets serving the short turning line should be large enough to support the buses operating continuously during the peak period. To the contrary, a smaller battery is best for the fleet serving the entire line, as they contribute less to the reduction of passenger waiting time.

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