UTC Project Information	
Project Title	MPC-513 – Optimal Deployment of Wireless Charging Facilities for an Electric Bus System
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Brief Description of Research Project	Greenhouse gas (GHG) emissions from the transportation sector account for about 27% of the total GHG emissions in the United States. Due to increased travel demand and limited improvement in fuel efficiency, the GHG emissions from transportation have increased by 16% since 1990 (USEPA, 2015). About 80% of transit buses are currently powered by diesel engines, which are a primary source of the particulate matter (PM) and nitrogen oxides (NOx) emitted by motor vehicles. Furthermore, most transit buses are operated in densely populated urban areas, and they are generally in-use for large portions of the day. Electric buses, which produce zero tailpipe emissions, offer huge potential in improving environmental sustainability and livability of urban areas. However, the range problem associated with on-board batteries has substantially limited the popularity of electric buses. Wireless charging technology, also called inductive charging, an application of wireless power transfer (WPT), offers the promise of eliminating the range problem of electric vehicles (EVs). Dynamic wireless charging provides bus operators with the ability to charge buses while in motion, using wireless inductive power transfer pads embedded underneath the roadway. The technology potentially makes pure electric buses as capable as their diesel counterparts. The dynamic wireless charging technology has been implemented in a bus line in Gumi City, South Korea (Jang et al., 2015). The United Kingdom

	recently conducted a feasibility study of implementing this technology on its strategic road network (Highways England, 2015). Another benefit of wireless charging technology is that it could reduce the on-board battery size substantially. Battery packs on electric buses can account for about a quarter of the weight of the vehicle and cost as much as 39% of the cost of a pure electric bus (Bi et al., 2015). Bi et al. (2015) demonstrated the potential of downsizing the battery to about one-third the weight of a plug-in charged battery, assuming stationery wireless charging is employed. The battery downsizing not only makes electric buses more affordable, but also offers additional energy saving benefits, due to reduced curb vehicle weight. To enable dynamic wireless charging for an electric bus system, wireless charging facilities must be built strategically in the road network. The charging facility deployment problem is twofold. First, it is necessary to locate the optimal location for building wireless charging facilities. Existing studies on this topic (e.g., Jeong et al., 2014; Jang et al., 2015a; Jang et al., 2015b; Ko et al., 2015; Ko and Jang, 2013) only consider electric bus systems with a single bus line. However, a real-world bus system almost always contains more than one bus line. Moreover, multiple transit lines may have significant portions of overlap, especially for areas with high transit demand, e.g., downtown, or shopping malls. For overlapping transit lines, they could share wireless charging pads. The synergistic effect among different transit lines could substantially bring down the average cost of constructing a charging facility for individual bus lines and make wireless charging more economically attractive for real-world implementation. Second, one must consider the trade-off between on-board battery size and the number (length) of wireless charging facilities. These two problems should be treated simultaneously, in a network setting.
Describe Implementation of Research Outcomes (or why not implemented) Place Any Photos Here	The DWPT electric bus system, which is clean and sustainable, could be widely adopted in the near future. The proposed modeling framework in this study provides practitioners with an effective tool to determine the optimal allocation of DWPT facilities as well as the battery size of each bus line for a DWPT electric bus system.
Impacts/Benefits of Implementation (actual, not anticipated)	The DWPT electric bus system, which is clean and sustainable, could be widely adopted in the near future. The proposed modeling framework in this study provides practitioners with an effective tool to determine the optimal allocation of DWPT facilities as well as the battery size of each bus line for a DWPT electric bus system.
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