2016 UDOT RESEARCH PROBLEM STATEMENT

****** Problem statement deadline is March 14, 2016. Submit statements to Tom Hales at tahales@utah.gov. ******

Title: Optimal Deployment of Wireless Charging Facilities for an Electric Bus System **No. (office use):** 16.06.06

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Select One Subject Area

- ☐ Materials/Pavements
- ☐ Maintenance
- ☐ Traffic Mgmt/Safety
- ☐ Preconstruction
- ☐ Planning
- ☒ Public Transportation

1. Describe the problem to be addressed.

Electric buses, which produce zero tailpipe emissions, have great 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, 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. The United Kingdom recently conducted a feasibility study of implementing this technology on its strategic road network. 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. Studies 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 we propose to address in this study is twofold. First, it is necessary to locate the optimal location for building wireless charging facilities. Existing studies on this topic 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, and 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.

2. Explain why this research is important.

Utah has some of the worst air quality in the nation, particularly during the winter months due to its unique geography and weather patterns. The state struggles to meet federal air quality standards for particulate matter (PM), especially PM2.5. Improving air quality along the Wasatch Front will require multiple solutions from all types of emission sources. The transportation sector has been a major source of hazardous air pollutants (HAPs) in the state. It is estimated by the Utah Department of Environmental Quality (UDEQ) that motor vehicles account for more than half of the emission inventory of the four urbanized Wasatch Front counties: Salt Lake, Davis, Utah, and Weber.

About 80% of transit buses are currently powered by diesel engines, which are a primary source of the 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. Therefore, it is critically important for UTA to adopt innovative technologies to reduce greenhouse gas (GHG) emissions from the transportation sector.

3. List the research objective(s):

1. Develop an optimization problem that determines the location for building wireless charging facilities in a road network and explicitly considers the trade-off between on-board battery size and the number (length) of wireless charging facilities simultaneously.

2. Conduct a case study for UTA to demonstrate the viability of applying dynamic wireless charging technology to an electric bus system with multiple overlapping bus lines.

4. List the major tasks:

1. Perform a thorough literature review on wireless charging technology and its applications in public transportation.
2. Formulate the optimal deployment of wireless charging facilities for an electric bus system as a mathematical programming problem.
3. Explore and compare solution algorithms identified in the literature review.
4. Conduct a case study in Utah. Sensitivity analysis will be conducted to access the impact of transit demand variation and travel time uncertainty on the deployment of wireless charging facilities.

5. List the expected results:

1. Develop an optimization procedure to deploy wireless charging facilities for an electric bus system.
2. A case study for UTA that demonstrates the viability of applying dynamic wireless charging technology to an electric bus system with multiple overlapping bus lines.

6. Describe how this research will be implemented.

The research findings will not only have theoretical significance, but also have a wide range of applications in implementing more sustainable public transportation systems. The end product will be useful to UTA, UDOT, and other transportation agencies in planning new electric bus systems. The results of this study will be presented at conferences, published in professional journals.

7. Requested from UDOT: $50,000 **Other/Matching Funds:** $50,000 **Total Cost:** $100,000
(or UTA for Public Transportation)

8. Outline the proposed schedule, including start and major event dates.

The proposed research will be carried out in a period of 12 months with an estimated start date of September 2016. The project will follow the schedule below:

- Literature review: 2 months
- Formulating the optimal deployment problem: 3 months
- Solving the optimal deployment problem: 3 months
- Case study: 3 months
- Report writing: 1 month