2016 UDOT RESEARCH PROBLEM STATEMENT

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

Title: Economic Viability and Architecture Optimization of Wireless Power Transfer for Public Trans. **No. (office use):** 16.06.10

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Select One Subject Area

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

1. Describe the problem to be addressed.

The proposed project is focused on the critical evaluation of wireless power transfer (WPT) integrated into Utah public transportation systems. Integration of WPT systems in roadways and buses represents a promising alternative to traditional internal combustion transportation systems and other advanced transportation concepts such as hybrid electric buses, plugin hybrid electric buses, and electric buses. A schematic illustration of the technology is presented in Figure 1.

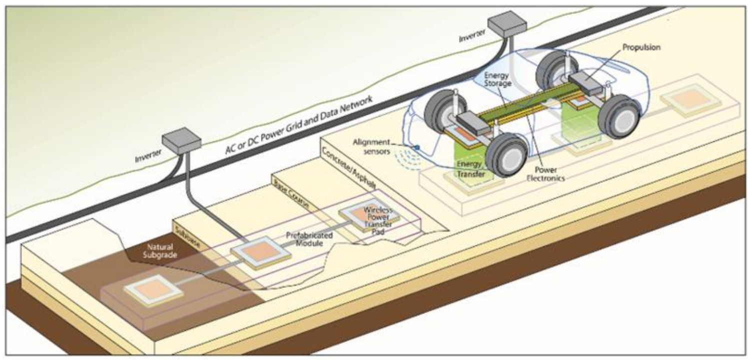

Figure 1. System concept for integration of WPT into an electrified transportation system.

WPT would enable the transformation of bus architecture and address many of the current limitations associated with the electrification of public transportation such as range limitations and vehicle weight. Preliminary work has highlighted the potential economic feasibility and environmental impact of WPT applied to the transportation system through the development of dynamic vehicle models and integration with real world dynamic drive cycles. Significant cost savings are seen through regenerative braking and decreased vehicle weight through reduced on-board energy storage. Environmental impact is decreased compared to traditional internal combustion buses with the added benefit of relocating emissions to outside the valley at power production facilities thus positively impacting air quality. WPT has a variety of advantages that are synergistic with current transportation research and commercialization emphasis including reduced energy consumption, decreased vehicle weight, decreases in ownership, and improvements in environmental impact.

2. Explain why this research is important.

Despite significant public interest and commercial availability of multiple alternatives to internal combustion engines, there has been minimal penetration into transportation fleets. The barriers include ***return on investment, and sustainability***. Hybrid and plug-in electric buses have higher purchase costs and limited environmental benefits due to the combined cost and weight of ICE and electric drivetrain components and limited electric range. All-electric battery EVs have zero tailpipe emissions, but suffer from a high up-front cost, long charging times, limited range and a life-cycle energy use that is only 20% lower than ICE.

Wireless power systems have been considered since Nikola Tesla's patent was filed in 1900, with significant renewed interest recently. Examples of commercial pilot EV demonstrations include A 40 passenger, all-electric bus operating on a University of Utah bus route utilizing 50 kW stationary WPT technology by USU spin-off company WAVE and 24 km in-motion WPT bus route by KAIST and OLEV. Major industrial transformations require an alignment of many factors—technological, economic, societal, and often political. Evidence indicates that such an alignment for a transformation toward a sustainable electrified transportation system is occurring now. While solutions posed to date have not gained strong commitment (due to limited ROI and environmental benefits and an industry hesitant to invest due to risk of limited potential gain), a WPT system provides an opportunity to leap frog current directions in industry.

Current research and commercial efforts are focused on development of the WPT technology, however the requirements of the technology and the architecture of a system have not been investigated. Further, the impact of the deployment of the technology dictates the feasibility of integration. The proposed work is focused on the development of dynamic models that can be leveraged to understand the techno-economic feasibility, the technology requirements, and optimization of the roadway and bus architecture specific to Utah public transportation systems. The work directly addresses the need to 1) integrate systems architecture optimization with dynamic drive cycle data specific to public transportation, 2) a vehicle level understanding of the effects of WPT on battery sizing, vehicle performance, and vehicle components, and 3) understand the potential impact of the technology in terms of environmental and economic costs. In moving forward Utah needs to be a leader with the proposed technology driving two major paradigm shifts: 1) transition of roadways from passive systems to providers of power, connectivity, and enhanced safety, and 2) transition of electric buses from large and expensive battery centric systems to lightweight power management centric systems. The proposed technology is modular and scalable where the same roadway provides power for multiple transportation systems.

3. List the research objective(s):

1. Wireless power transfer (WPT) vehicle modeling and component optimization
2. Modeling modularity to facilitate the evaluation of integrating vehicle simulations with infrastructure requirements and performance
3. Integration of geographic and temporal resolution to understand traffic patterning and infrastructure requirements
4. Combined techno-economics (TEA) and life cycle assessment (LCA)
5. Understanding the commercial viability and rollout of the technology
6. Utilize results in support of ongoing development of demonstration bus at USU

4. List the major tasks:

The proposed work is divided into 3 integrated tasks that will be performed in a parallel path

1. Task 1: Development and integration of dynamic vehicle and WPT models
   a) Sub-task 1.1: Transportation system modeling: Includes the modeling of various components such that electric based transportation and traditional ICE vehicles can be accurately modeled
   b) Sub-task 1.2: Wireless power transfer modeling for integration into vehicle and roadway systems
   c) Sub-task 1.3: Integration of vehicle and WPT models
   d) Sub-task 1.4: Assessment of WPT compared to traditional transportation systems.
2. Task 2: Economic feasibility and environmental impact assessment
   a) Sub-task 2.1: Development and integration of economic assessment with vehicle/WPT modeling
   b) Sub-task 2.2: Integration of life cycle modeling with transportation system modeling
   c) Sub-task 2.3: Evaluation through sensitivity analysis and stochastic analysis
3. Task 3: Optimization/Commercial viability/Case studies
   a) Sub-task 3.1: Understand bus architecture and roadway requirements: real-world drive cycle data
   b) Sub-task 3.2: Case study of Utah bus routes

5. List the expected results:

1. Development of a tool set that can critically evaluate and understand the impact of integration of WPT with Utah public transportation systems
2. Optimization of bus architecture and infrastructure requirements to satisfy transportation needs
3. A direct comparison of WPT technology to conventional internal combustion systems on the metrics of cost of ownership and environmental impact

6. Describe how this research will be implemented.

Overall Approach: The PI will head all project oversight and will be working closely with the Co-PI (Zane) and two graduate students supported. Expertise within the program is divided between the researchers. The WPT Scientific Team will be led by Dr. Quinn supported by Dr. Zane. The team will meet on a weekly basis to discuss progress towards program tasks and will be responsible for developing revised plans when any milestone lags behind its targeted completion date. In Program Management meetings the team will discuss program implementation, data collection and analysis, identify barriers and benefits, and develop strategies for overcoming barriers and enhancing benefits.

Market Transformation/Commercialization Plan: The WPT technology being evaluated represents a market transformer as it dramatically changes the way energy is delivered and consumed in the transportation sector. Competing technologies to WPT would include improved onboard energy storage and conductive energy transfer. On board energy storage is the focus of extensive DOE and commercial R&D efforts. Conductive energy transfer has significant safety concerns and limitations on use by conventional buses. The WPT technology does not have these limitations and has a variety of advantages including unlimited electrical range, decreased on-board energy storage resulting in decreased weight, isolated power systems resulting in improved safety, and reduced operational costs compared to traditional systems. Preliminary work shows a promising economic payback on infrastructure from savings in ownership cost compared to traditional transportation systems. The preliminary work was limited and focused on a high level societal level model. The proposed work is intended to better understand the true commercial feasibility of WPT applied to Utah transportation systems and identify viable demonstration pathways.

Target Market: The modeling work will be leveraged to identify initial deployment of the technology in Utah. Infrastructure represents a critical barrier to the deployment of WPT. Initial demonstration on specific lines will lead to the adoption of the technology on other routes. The ultimate goal of the work is to identify and understand the potential of the technology including a roll out plan.

Ultimately the proposed work is intended to evaluate the potential of the technology and generate a tool that can be used by researchers, funding agencies, and policy makers to better support the development of the technology for commercial use. The work includes the evaluation of various opportunities ranging from small to national scale systems.

Technical Qualifications and Resources: The research team proposed for the project includes the PI, Jason Quinn, CO-PI, Regan Zane, CO-PI, and 2 graduate research students. The team has unique capabilities in the three tasks proposed. The majority of the tasks outlined in the proposal will be performed by graduate students on the project who will be directly supervised by the PI and CO-PI.

7. Requested from UDOT: $50,000 **Other/Matching Funds:** $70,000 **Total Cost:** $120,000
(or UTA for Public Transportation)

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

The proposed project is a 1 year project with a start date of July 1, 2016. The schedule includes the tasks, subtasks, and major milestones. The research is structured in sub-tasks to be parallel pathed with periodic integration of the various research components.

Significant investment in the first project period is required to establish modeling foundation (M1-M6). The second performance period includes multiple objectives designed to enhance the final tool set to include economic and environmental assessment capabilities that will include optimization of the system (M4-M11). The third period is focused on the use of the tool set to understand the potential of integrating WPT into Utah public transportation systems and roadways at different scales and highlight areas for strategic investment by industry and state agencies for commercialization (38-M12).

Milestones:

The work proposed is focused on the development an integrated vehicle and WPT modeling system that can be leveraged to critically evaluate and optimize system architecture for public transportation systems in Utah. The milestones that have been developed are in support of the generation of this tool set and the evaluation of various transportation routes on the metrics of economic viability and environmental impact. The project is broken down into three primary thrusts that are all integrated into the tool set: 1) System modeling development and validation, 2) TEA and LCA work, 3) Optimization and evaluation. In support of these thrust areas the following milestones are defined:

Milestone 1: Development of vehicle sub-system component modeling (energy storage, motor, engine, vehicle dynamics, transmission, etc.)

Milestone 2: Development of wireless power transfer models for roadway and bus systems incorporating flexibility in design parameters and power transfer size.

Milestone 3: Direct comparison of energy consumption and performance of traditional transportation buses with WPT equipped wireless power bus systems.

Milestone 4: Development of techno-economic data base and integration with dynamic vehicle models to evaluate the cost of ownership of WPT systems as a function of bus and roadway architecture.

Milestone 5: Environmental impact assessment of WPT equipped bus systems based on dynamic vehicle models and roadway infrastructure system.

Milestone 6: Optimization of bus and roadway infrastructure as a function of transportation system requirements on the metrics of economic and environmental impact for general drive cycles.

Completion of these milestones will facilitate the delivery of the proposed toolset and provide insight into the economic feasibility, environmental impact and optimization of system architecture as a function of the transportation system.

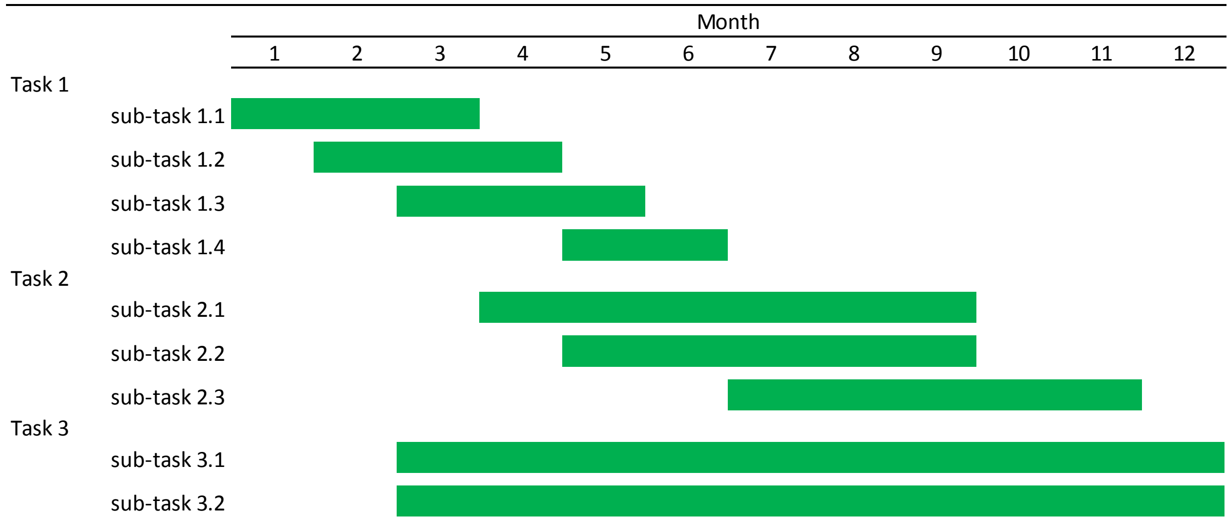

Figure 2. Gantt chart for completion of the project.