Request for Research Funding for FY 2023-2024			
Project Number (Research Center Use Only): D5-24-03			
Requesting Office	FDOT D5, Office of Modal Development	**Priority**	3 of 3
Proposed Title	Innovative planning and design of transportation infrastructure for Electrification of Vehicles		
Justification	Driven by policy shifts (i.e., tax reduction) targeting the growing demand for electric vehicles in place of combustion/natural aspiration, electrification of vehicles is becoming one of the biggest trends in the automotive industry[1] due to its great contribution to the sustainable goals of the United Nations Framework Convention on Climate Change[2]. In addition, electric vehicles (EVs) are well-designed, quiet, spacious, reliable, cheap (i.e., low purchase and maintenance costs), and simple to drive such that EVs are favored by more and more people to even replace fuel vehicles. However, design and planning of electrified transportation infrastructure often lags behind electrification of vehicles, especially from a multi-modal perspective. Specifically, there is a lack of related efforts to fully incorporate electrification of vehicles into the existing and future transportation planning process such that electric vehicles cannot be charged and operated in a very efficient manner. Furthermore, electrified transportation infrastructure should accommodate both electrification of public transport (i.e., electric buses, microtransit, and micromobility)[3] and private electric vehicles[4]. At present, transportation infrastructure such as multi-modal hubs/public charging hubs and EV transit hubs, that can accommodate electrification of public transport in the state of Florida, and even in the nation, is typically at the preliminary stage of conceptual products and lacks real-world functionality analysis. While for infrastructure of private electric vehicles, the optimal selection and dispatch of electric vehicle batteries between battery charging stations and battery swapping stations[5] still remains unaddressed. Therefore, there is a need to assess the impacts of electrification of vehicles on transportation infrastructure, as well as the efficiency of varying alternatives to public charging/multi-modal hub design, operations, and technology. Motivated by these gaps, this research project aims to answer what is required for transportation infrastructure to support electrification of public transport and private electric vehicles. Specifically, this project will explore the feasibility of designing and planning public charging/multi-modal hubs for electrification of public transport and optimize the selection and dispatch of battery charging/swapping stations to make the battery charging and interchange among different modes of transportation more efficient and energy-saving. Therefore, the objectives of this research include: (1) To complete a literature review to summarize the need for electrified transportation infrastructure, for example, where we are and what is missing in practice. (2) To conduct performance assessment of battery charging and swapping stations for private electric vehicles and optimize their selection and dispatch to make the battery charging more effective. (3) To propose a framework of designing and planning multi-modal/public charging hubs for electrification of public transport, including the layout, charging infrastructure/schedules, as well as energy management plan. (4) To evaluate the feasibility and performance of multi-modal/public charging hubs, in terms of the interchange time, charging efficiency, as well as other costs and benefits.		
Impact	The outcome of this research includes a feasibility report and final recommendation about the impact of electrification of vehicles on transportation infrastructure, for example, the feasibility of designing and planning multi-modal/public charging hubs for electrification of public transport and replacing battery charging stations with battery swapping stations for private electric vehicles. Furthermore, the results from this research will produce profound impacts on electrification decision-making in the following ways: (1) Inform EV and electricity-powered autonomous vehicle (AV) planning activities at all levels of government. (2) Add value to numerous multi-modal hub and EV charging studies currently under development. (3) Prepare Florida's decision makers for the realities of the quickly approaching EV/AV conversion.		

[1] https://blogs.sw.siemens.com/automotive-transportation/2022/01/14/how-vehicle-electrification-is-transforming-the-automotive-industry/
[2] https://unfccc.int/process-and-meetings/what-is-the-united-nations-framework-convention-on-climate-change
[3] Sinhuber, P., Rohlfs, W., & Sauer, D. U. (2012, October). Study on power and energy demand for sizing the energy storage systems for electrified local public transport buses. In 2012 IEEE vehicle power and propulsion conference (pp. 315-320). IEEE.
[4] Zhang, X., Zou, Y., Fan, J., & Guo, H. (2019). Usage pattern analysis of Beijing private electric vehicles based on real-world data. Energy, 167, 1074-1085.
[5] Zhang, X., & Wang, G. (2016, July). Optimal dispatch of electric vehicle batteries between battery swapping stations and charging stations. In 2016 IEEE Power and Energy Society General Meeting (PESGM) (pp. 1-5). IEEE.

	(4) Add value to nationwide studies demonstrating our inability to accommodate expected electrification infrastructure needs, with a closer look at Florida's infrastructure specifically. (5) Present alternative means of electrification charging and battery charging/swapping operations. (6) Infrastructure improvements identified within the study may lead to additional work/study from numerous agencies. (7) If this work is not completed, the state will continue to move, at an ever-increasing rate, towards further/additional electrification of personal, transit, and freight vehicles without a clear picture of how these technology advancements will impact statewide power/transportation infrastructure. (8) We may find that considerable investment in previously unidentified infrastructure is needed before we even get close to achieving state EV goals. (9) We may find that the future of power creation and distribution drastically changes the landscape of infrastructure needs.
Affected Offices	Executive leadership, and in turn all Offices, e.g., Office of Modal Development (EV/AV pilot considerations, multi-modal/public charging hubs), Transit Agencies (EV/AV buses & necessary charging and distribution infrastructure) Ex: Recent LYNX electric bus conversion required an electrical engineer be provided by the power company as there was no expertise at the agency. Costs for the entire system were higher than expected due to on-the-spot infrastructure alterations and problem solving. Not to mention, the power consumption/billing rates were also calculated by the power company. At the present stage, there is no way to check the work or evaluate one option over another.
Existing Work	There are one NCHRP (National Cooperative Highway Research Program) report, four ACRP (Airport Cooperative Research Program) reports, and two TCRP (Transit Cooperative Research Program) reports related to this research. (1) NCHRP Synthesis 20-05/Topic 53-08 (2022): *Strategies and Programs For Electric Vehicle Charging* documents current strategies and practices in use by state DOTs to facilitate and coordinate the provision and operation of EV charging facilities. Also, it includes current plans to address the future maturity of EV charging, such as preparation for medium and heavy-duty electrification. (2) ACRP 03-71 (2023): *Growth of Airport Electrification: Vehicles, Mobile Equipment, and Aircraft* aims to develop a planning guide, including an executive summary, for airports to inventory and assess the anticipated growth in electrification needs for vehicles, aircraft, and mobile equipment. (3) ACRP 03-51 (2019): *Electric Aircraft on the Horizon -- An Airport Planning Perspective* prepares a guidebook for airport industry practitioners to account for electric aircraft operations in their planning efforts. (4) ACRP Synthesis 11-03/Topic S10-11 (2014) & Topic S02-23 (2023): *Electric Vehicle Charging Stations at Airports Parking Facilities* summarizes the state of the EV industry, highlights the motivations for airport sponsors to provide EV charging stations, identifies current EV charging technologies, and describes practices for installing EV charging stations at airports in terms of finances, planning, implementation, and operation of the charging stations. (5) TCRP Synthesis J-07/Topic SA-60 (2022): *Examination of Transit Agency Coordination with Electric Utilities* documents the current practices by transit agencies to coordinate or partner with electric utilities to negotiate rate structure and increase energy loads in relation to transit fleet electrification and other zero-emissions fleet transitions. Specifically, the synthesis focuses on bus fleet electrification whether for specific bus routes or the larger transit network. (6) TCRP Synthesis J-07/Topic SA-41 (2016): *Battery Electric Buses - State of the Practice* provides an overview of the current state of practice regarding the deployment of Battery Electric Buses (BEBs), in terms of planning, service, operations, and maintenance, etc. However, our proposed research is different: (1) Most of these reports only document current practices of electrification of vehicles in use by state DOTs, there is a lack of innovative strategies to improve and promote the adoption of EVs. (2) Our proposed research focuses on incorporating electrification of vehicles into the existing and future transportation planning process, and provide clear guidance, particularly for the design and planning of multi-modal/public charging hubs that can accommodate different modes of transportation, which is nonexistence in the literature. (3) Most of the existing research projects ignore considerations of the optimal selection, design, and dispatching of different charging infrastructure, e.g., battery charging/swapping stations, while these are the focus of our research.
Keywords Used In Existing Work Search **(Cannot leave blank)**	Electrification of vehicle, Transportation infrastructure, Multi-modal charging hub, Battery charging/swapping station, Charging efficiency

Related Contracts (Give contract numbers)	None		
Funding Request	$395,000 (2 PI teams)	**Anticipated Duration**	18 months
Project Manager	Paul Schoelzel	**Contracting Method**	Direct contract with UF (Dr. Peng)
Equipment	N/A	Comments: N/A	
Urgency	1	Comments: Sales of EVs in the United States continue to climb over the last decade, from under 100,000 sold in 2013 to 471,426 sold in 2021. However, the construction of electrified transportation infrastructure, i.e., charging stations, often lags the rapid increase of EVs in use so that they cannot well satisfy the charging demand of EVs and even restrict the use of EVs. To mitigate the imbalance, the Infrastructure Investment and Jobs Act (IIJA) in Florida provides $7.5 billion for EV infrastructure funding. Meanwhile, FDOT has received many requests from Districts, MPOs and local governments for EV projects and is making decisions about how and where to put the money to fund EV infrastructure. At present, there is a lack of innovative strategies and optimal plans about EV infrastructure that can help FDOT make objective and optimal decisions to promote electrification of vehicles in Florida. The rapid increase of sales of EVs in recent years further highlights the urgency of the issue. Therefore, there is an urgent need to conduct this research to study the feasibility of some innovative strategies such as designing and planning multi-modal/public charging hubs for electrification of public transport, which can provide information to facilitate decision-makers to make more informed decisions.	
Implementability	1	Comments: This research project aims to study the impact of electrification of vehicles on transportation infrastructure needs, especially from a multi-modal perspective. Therefore, the results from this project, particularly for the feasibility, potentials, and recommendation of designing and planning a multi-modal charging hub, would be directly implementable by FDOT Central Office and Districts in making their investment decisions for EV infrastructure planning about where to put the money into EV projects in priority to maximize the investment results and promote electrification of vehicles in Florida. These innovative strategies about EV infrastructure planning are the core elements in FDOT's EV initiatives and other strategies related to FDOT's Vital Few of safety, mobility, and innovation.	

Project Benefits (Succinct, complete explanation)

1. This research will help FDOT, Districts, MPOs and local government agencies to better assess the feasibility of designing and planning multi-modal charging hubs for electrification of public transport and compare the performance between battery charging stations and battery swapping stations for private electric vehicles, in terms of charging costs and efficiency.
2. If a multi-modal charging hub is feasible & successful and battery swapping station is a better option than battery charging station, it would be much more timesaving and energy-efficient for the battery charging of electric vehicles and help Florida DOT better plan and prepare for electrification of vehicle to promote the adoption of electric vehicles.
3. The research results will provide information for FDOT and local governments to make more informed decisions about future EV infrastructure planning.
4. This project will solidate FDOT as the leader in optimizing EV infrastructure planning in the nation, and further increase the national and international visibility of FDOT's innovation in promoting electrification of vehicles.

Project Benefits **(Select all that apply and explain)**	**Quantifiable Benefits (units, dollars, etc…if applicable)**	**Methodology or Data Sources Used to Determine Quantifiable Benefits. If not applicable, please give justification of project benefits**
o Materials Enhancement		

○ Materials Savings		
○ Time Savings		
○ Lives Saved/Injuries Prevented		
○ Other (Explain)	Provide feasibility report and final recommendation of designing and planning multi-modal charging hubs for electrification of public transport and comparing battery charging stations with battery swapping stations for private electric vehicles to FDOT, Districts, MPOs, and local governments.	The research results would help decision-makers in FDOT, Districts, MPOs, and local government agencies to make more informed decisions in future EV infrastructure planning to improve the efficiency of battery charging and further promote electrification of vehicles in Florida. The benefit is demonstrated if the decision-makers cite and use this research results, and make proper decisions.

*Comments should explain and support urgency, financial benefit, and implementability scores