

Request for Research Funding for FY 2022-2023

SPR Subpart B Project: PTO-23-01

Requesting Office	Transit	Priority	1 of 4 (projects may not have the same ranking – no ties)
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Proposed Title A Comparative Analysis of Alternative Fuel Fleet of Buses (AFB) to Enhance Mobility in Central Florida

Justification

As one of the largest universities in the nation, the University of Central Florida (UCF) took the initiative to become climate neutral by the year 2050 and reduce carbon dioxide emissions by 42% by 2030. The university has converted 75% of its diesel bus fleet into propane while the remaining 25% will be bi-fuel, diesel/biodiesel. Due to budget constraints, UCF could not purchase or lease electric buses although the infrastructure of electric vehicle charging stations is available at five (5) garage locations. Besides, there will be two fueling stations few miles outside the campus for the propane bus fleet. There are several challenges that face Central Florida’s transit system in general and UCF in particular. Central Florida is still considered a suburban region with long distances between destinations, which requires an exorbitant operation and maintenance budget on a yearly basis (mainly due to fuel consumption and fleet breakdown). Public agencies are not able to cope with the increase in fees and the decline in transit ridership due to the low frequency of buses during periods of high demand as well as budget constraints. Moreover, UCF students had several complaints regarding frequent fleet breakdown at least twice per semester with incidents involving smoke from the engine and catching fire. Other incidents included the need for refueling after students boarded the bus. Environmentally friendly public transportation is of utmost importance to reduce GHG emissions from the transportation sector and provide socio-economic benefits to the public. An imperative strategy is to transition to alternative fuel-powered public transportation. However, several challenges still exist that may potentially jeopardize market penetration of alternative fuel buses (AFBs), including electric buses, such as range, charging time, driving cycle and other uncertainties associated with the emerging AFB technologies. Electric buses (EB) are low maintenance compared to diesel buses and are zero emissions. However, Electric vehicle charging stations designed to provide the fastest recharging scenario are expensive and might require grid service upgrades especially with increased load and demand from increased fleet. All of these expenses have a detrimental impact on the feasibility of establishing a viable electric vehicle supply equipment (EVSE) infrastructure that needs to be analyzed and the true economic cost for charging a large fleet of buses needs to be investigated.

To address these crucial issues, the proposed research aims at procuring an electric bus from the City of Orlando along with the newly leased fleet of propane and diesel/biodiesel from UCF to evaluate the three types of alternative fuels (biodiesel, propane and electric buses) and their supporting infrastructure, as a proof-of-concept demonstration between UCF’s Campuses (main Campus, UCF Downtown, Rosen College of Hospitality Management, and the Health Sciences Campus at Lake Nona) and City routes. The research will develop a set of decision-support tools to manage an optimal transition to alternative fuel bus technologies, with a particular focus on electric buses, while taking into consideration national sustainability goals. For this purpose, the project team will investigate and conduct a data-driven analysis of the impacts of the battery electric bus options, under a set of “what-if” scenarios such as various real-world driving cycles, solar charging stations for electric buses, the optimal location of solar or grid-connected charging stations, and various market penetration scenarios for electric bus operations. Furthermore, their sensitivities to potential changes in different environmental, social, and economic parameters will be measured. An integrated sustainable fleet management tool will be developed to help better inform policymakers and allocate resources efficiently to the transitioning to AFB fleets. The following summarizes the main project objectives:

- 1- Conduct a comparative analysis for the three alternative fuel bus technologies to quantify their life cycle sustainability impacts, including environmental impacts (e.g., carbon footprint, air pollution, energy consumption), social impacts (e.g., human health), and economic impacts (e.g., life cycle costs).
- 2- Investigate the impacts under different policy-relevant scenarios such as solar charging infrastructure, different ridership profiles, and different routes to better aid effective policymaking.
- 3- Determine the optimum fleet composition including the number of refueling stations under different market penetration rates, using multi-objective optimization techniques to help ease the transition period and avoid unnecessary investment in the infrastructure.
- 4- Collect performance data from the buses in real time with trip mapping to perform various sustainability analytics to aid transit agencies in optimizing fleet utilization and policymakers in designing effective policies.

The Central Florida Clean Cities Coalition (CFCCC) is collaborating with UCF and is providing full support in terms of resources, such as U.S. national laboratories, local fleets and stakeholders. CFCCC is one of nearly 100 local and regional partnership organizations that support the deployment of alternative fuel vehicles to promote transportation sustainability. LYNX and the City of Orlando is also supporting UCF with one of its electric LYMMO busses.

Impact The aforementioned objectives will reveal the potential environmental, economic, and social impacts of transitioning to AFBs while contributing to the scientific body of knowledge in transportation sustainability. Specifically, developing a

	<p>transit bus driving cycle will bring several advances to the state-of-the-art in public transportation research from at least four aspects. First, a drawback of current transit bus LCSA (life cycle sustainability assessment) projects is that sustainability impacts of transit bus operation are incorporated based on bus characteristics rather than route characteristics, given the lack of accurate drive cycle information representative of local conditions based on real-world transit bus operations. Hence, the developed drive cycle will provide essential and accurate data regarding bus operations in the Southeast and particularly in Orlando, Florida, and enable the research team to more accurately estimate the sustainability impacts of bus operations as well as life cycle sustainability impacts of transit bus fuel consumption. Second, the developed transit bus driving cycle can be used as a “testbed” for testing specific parameters peculiar to electric buses such as battery capacity, state-of-charge, hybridization ratio, etc., which enable transportation agencies to optimize their infrastructure investments. Third, enhanced life cycle sustainability assessment (LCSA) results will be better suited to support strategic policymaking in terms of infrastructure investment and AFB procurement. To elaborate, the ability to understand the costs and benefits of adopting a certain transportation technology based on real-world driving patterns greatly improves the effectiveness of relevant policies, as transit agencies can compare operational characteristics of conventional and AFBs without having to rely on foreign drive cycle characteristics. Although there are various drive cycles existing in the U.S. (e.g. Central Business District cycle, Orange County Transit Authority cycle, King County Metro cycle, etc.) and Europe (e.g. Standardized On-Road Test (SORT) cycles), there is a lack in this regard to adopt a single cycle accurately representative of our studied region. Thus, limiting the ability to maximize the benefits of relevant policies. Hence, once such a driving cycle developed for the region, it will allow us to modify the emissions standards that the State conforms to according to local driving conditions. Finally, this research will provide specific, implementable strategic-level criteria/standards regarding AFB performance, propose new efficient transit routes based on AFB type to increase transit reliability, ridership and achieve sustainability in Central Florida.</p>		
Affected Offices	State Transit Office/District 5 (Gabriel Matthews, David Sherman), UCF Transportation Services (Anand Rampersad), LYNX (Doug Jamison), City of Orlando (LYMMO), MetroPlan Orlando (Nick Lepp).		
Existing Work	<p>While alternative fuel vehicle technology (AFVT) is extensively studied, there are few studies in the literature, assessing the life cycle sustainability impacts of alternative fuel buses (AFBs) especially electric buses. Ally and Pryor (2007) evaluated diesel, hydrogen fuel cell, and natural gas buses from a life cycle perspective and concluded that AFBs could reduce GHG emissions by up to 50%. McKenzie and Durango-Cohen (2012) investigated the environmental and economic impacts of AFB and concluded that AFBs require significant infrastructure investment, making them the less favorable option as opposed to conventional diesel vehicles. In another study, Cooney et al. (2013) quantified the GHG emissions of electric buses and concluded that electric buses are better in only 8 states in the United States due to the source of electricity generation. Yue et al. (2019) concluded that it is difficult for clean-energy buses to outperform conventional buses in a life cycle (normally eight years), unless subsidies are provided. Liu et al. (2019) also demonstrated that it is always beneficial to install on-route fast charging stations for battery electric buses (BEBs). Ercan and Tatari (2015) investigated the environmental impacts of AFBs in the USA using a hybrid life cycle assessment model. They quantified the environmental impacts of both electric and compressed natural gas (CNG) buses and concluded that electric buses are superior alternatives in the United States in terms of the environmental impacts of both options. Lajunen and Lipman (2016) conducted a cross-country comparison study using a vehicle simulation model, called Autonomie, to quantify and compare life cycle costs and CO₂ emissions of AFBs within the context of California, U.S., and Finland. The researchers found alternative transit bus powertrains could significantly improve energy efficiency and reduce GHG emissions. Emiliano et al. (2018) applied a multi-objective optimization technique for a case study in Joinville, Brazil to attempt to find a Pareto optimum bus fleet based on air pollutant emissions and life cycle cost; the study confirmed the significance of using multi-objective optimization approaches to tackle lifecycle-based optimum transit bus fleet composition problems. While these studies investigated the environmental and economic aspects of such buses, they all employed the traditional life cycle assessment approach, in which higher degrees of supply chain impacts are not covered. Given the geographical and sociocultural differences among cities, sustainability impacts of transit buses differ significantly (Zhao et al., 2018). Therefore, understanding the effects of transit bus driving cycle is crucial to inform policymakers of fuel efficiency implications of both existing and emerging transit bus technologies to eliminate unexpected outcomes of AFB procurement and support strategic planning in that regard (Leon (2011).</p>		
Keywords Used In Existing Work Search (Cannot leave blank)	Electric Bus, Life Cycle Assessment, Driving Cycle, Fleet Monitoring System, Alternative Fuel Vehicle Technology.		
Related Contracts (Give contract no.)	N/A		
Funding Request	Estimated cost: \$250,000	Anticipated Duration: months	Estimated length of time to complete work: 20 months

Project Manager	David Sherman	Contracting Method	Anticipated procurement method: direct contract with UCF Dr. Hatem Abou-Senna (PI) & Dr. Omer Tatari (Co-PI)
Equipment	Estimated equipment cost (or N/A): \$8k-10k	Data collection devices including GPS telematics, OBD2, air quality sensors and cameras will support the data collection program.	
Urgency	Score 1-5 1= highest, most immediate need	Sustainable public transportation could potentially have far-reaching implications in terms of transportation system's overall efficiency (e.g., GHG emission reduction, diversion from fossil fuels, improved public health, sustainable land use, etc.). However, distinct socio-cultural and socio-economic characteristics of cities make it challenging for transit authorities to make procurement and planning decisions that can accelerate the deployment of alternative fuel buses to improve the state of public transportation sustainability. In addition, individual transit agencies may well be subjected to different economic and/or regulatory constraints that influence the decision-making process concerning transit bus fleet management. A Holistic and well-established data driven analysis as proposed in this research can be utilized to assist agencies in making swift informed decisions.	
Implementability	Score 1-5 1=greatest likelihood of and proximity to implementing results	Given the level of transportation system's complexity, it is not an easy task for the stakeholders involved to efficiently overcome the challenges faced and achieve sustainable transportation goals. Hence, this research will provide specific, implementable strategic-level criteria/standards to enhance mobility in Central Florida, propose new efficient transit routes based on AFB type to increase transit reliability and ridership. Incorporate criteria/standards into the STARS (Sustainability Tracking, Assessment and Rating System) for transit agencies, cities and universities to select the optimal mix of AFB fleet along with the needed infrastructure to achieve sustainability goals such as UCF, MetroPlan Orlando and LYNX.	

Project Benefits (Succinct, complete explanation)

Transitioning to alternative fuel bus fleet, as an emerging technology, not only requires effective planning of mobility but also a reliable transformation of the prevailing infrastructure according to the needs. The overall success (or failure) of AFB adoption also depends on regulatory efforts. Carefully designed policies and regulations employ a life cycle perspective, which significantly affect the adoption of AFB in general and electric vehicle technologies in particular. This includes careful consideration of policy-relevant factors such as procurement of EBs (e.g., initial EB price) and investment in EB charging stations that are affected by socio-economic constraints (e.g., budget for appropriate infrastructure). Therefore, it is crucial to get insights into the life cycle cost of EB technology to expedite the adoption of this technology and determine how different policy scenarios would potentially affect the life cycle sustainability performance of EB implementation. To that end, effective and analytical decision-making tools are needed to maximize the benefits associated with EB adoption as well as other AFB types.

The project outcomes will reveal the potential advantages and disadvantages of diversifying transit bus technology options in terms of human health impacts, air pollution, carbon emissions, energy efficiency, and life cycle costs. The results of this project will aid policy makers in making informed decisions on efficient allocation of resources to the optimal fleet of alternative bus technology, as real-world driving data from the project will be used to evaluate the efficiency of each bus type. The findings of this research will help gain insights into the consequences of different investment policy options in terms of incentives, charging infrastructure, in addition to the environmental, economic, and social benefits. Hence, the project will support relevant public transportation agencies in developing alternative transportation policies to achieve sustainable and efficient public transportation at the city and national levels and pave the way for the deployment of AFBs.

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
<input type="checkbox"/> Materials Enhancement		Efficient allocation of resources
<input type="checkbox"/> Materials Savings		
<input type="checkbox"/> Time Savings		The performance data (emissions, speeds, travel time, fuel consumption, energy consumption) collected from the onboard diagnostic telematics will enable better vehicle and fleet analytics which will assist staff in making swift informed decisions and save several hours of analysis.

