Request for Research Funding for FY 2023-2024			
SPR Subpart B Project: (Research Center use only) D5-25-02			
Requesting Office	Maintenance	**Priority**	2 of 5 (projects may not have the same ranking – no ties)
Proposed Title	Improving Facilities Operations and Maintenance through the Digital Twin-Based Road Design Technology		
Justification	Digital twin (DT) serves as a dynamic virtual counterpart of a physical system, offering an interactive reflection of physical entities. When applied to traffic management, DT technology can create a virtual representation of the entire transportation network, including static and dynamic objects such as traffic signs, object markers and signalized intersections infrastructure. The concept of Transportation Digital Twin (TDT) is to facilitate seamless data exchange between the physical traffic control system and its digital twin. So, TDT consists of three components: the tangible traffic elements in the physical world, the digital model of the traffic facility, and the interconnected data and perspectives bridging the gap between the tangible and virtual aspects. In practical terms, TDT technology harnesses real-time traffic flow data from physical entities such as sensors, traffic cameras, vehicles, etc., to forecast future traffic patterns and disseminate this intelligence to the traffic control system. The idea is to simultaneously run the real-time high-resolution data acquisition, simulation, and integration. Moreover, incorporating TDT into the framework of traffic control system (TCS) presents a forward-looking strategy wherein all prospective traffic demands at an intersection are used. These anticipated traffic demands are then employed to execute a series of parallel real-time simulations. Subsequently, a comprehensive evaluation is undertaken, considering various outcomes from these simulations. The evaluation primarily centers on parameters such as reduction in delays and optimization of the distribution of traffic flows in the network in time and space. In anticipation of a forthcoming surge in travel demand within Orlando, adopting TDT-driven approach within TCS and design framework will open novel avenues of real-time traffic flow optimization for transportation authorities. This approach can potentially address and mitigate the escalating traffic control challenges expected to emerge due to the mounting traffic volumes. Recently, the Florida Department of Transportation (FDOT) is investigating to improve operations and safety along a 1.7-mile section of State Road 426 (SR 426) between Park and Lakemont Avenues, collaborating closely with residents from neighboring areas, local government, business and community partners. This specific stretch of SR 426 that includes Osceola, Brewer, and Aloma Avenues, situated in Orlando, is one of the busiest and has gained a reputation as a high-crash area, witnessing approximately 666 crashes between 2017 and 2022, resulting in two fatalities, 203 injuries, 424 instances of property damage, and 24 crashes recorded from March to August 2023. These statistics are based on data compiled by the Winter Park Road Crisis Campaign and information shared through its associated social media platform. Contributing factors to the crashes include the road's configuration, which extends from Aloma Avenue to Orlando Avenue with an undivided 4-lane setup, as well as issues related to speeding and traffic rule violations, both of which have been raised as concerns by residents in the area. Therefore, the primary goal of this research project is to enhance pedestrian safety and reduce accidents. After multiple meetings between FDOT and concerned parties, FDOT has proposed a list of safety measures including dynamic chevron signs, raised intersections, high visibility crosswalks, lighting and barrier walls. However, numerous residents believe that ensuring safety will need more measures to be taken. Furthermore, FDOT has a forthcoming plan to implement a bike lane, but this endeavor encounters a significant challenge stemming from constraints related to roadway expansion scope which may require a road diet option and converting the lane configurations in the subject area. Hence, this research project delves into the cooperative initiatives involving FDOT and local stakeholders, with the objective of building a TDT model. The aim is to assess the concept of a road diet by transforming the existing four-lane undivided 4-lane configuration into a two-lane divided or three--lane layout, which incorporates a dedicated turning movement lanes as well as other safety measures proposed by FDOT. This research recognizes the need to fully understand the potential of road diet and explore the user needs in a controlled, learning environment. Therefore, the TDT model will replicate the physical features along Aloma Avenue from North Lakemont Avenue to Orlando Avenue such as signalized and non-signalized intersections, different lane configurations, adaptive traffic control, signs, markings, vehicles, pedestrians, and surrounding environments. This will facilitate the assessment of the interaction between vulnerable road users and infrastructure, as well as the prediction of traffic patterns and driver behaviors. Through this research, we can evaluate the changes in traffic operations due to change in lane configuration, and added facilities like bike lanes, and raised intersections. The analysis will also identify areas that need improvements, such as congestion management, speed management, signal timing, and addressing challenges like unprotected left turns. In addition, we can determine the practicality and efficiency of TDT model in complex urban environments, including connected signalized corridors and traffic densities which can be replicated in other study areas.

	The main project objectives are summarized as follow:
	1) Gather data from different sources and create a detailed representation of the geometric and traffic characteristics of the road segment.
	2) Develop a DT-based model to allow for a seamless integration of real-world data for assessment of current conditions and future changes. This DT model will enable visualizing and optimizing the geometric configuration of the proposed solutions, employing a road diet concept to reduce congestion, minimize delays, and enhance traffic efficiency and safety.
	3) Develop a fusion model of integrating sensor data (e.g., ATSPM detectors) and predictive models of traffic behavior for real-time traffic monitoring and control under the DT-based model.
	4) Identify infrastructure and technology gaps and solutions to traffic control system in Aloma Avenue.
	5) Inform and engage policy makers, transportation stakeholders, and the public on the value of DTs and their potential applications in transportation.
Impact	FDOT's effort to make SR 426 safer and congestion-free can play a significant role in enhancing overall transportation safety, improving traffic flow efficiency, and fostering a more secure and sustainable commuting experience for residents and commuters alike. Upgrading roadway features such road signs, markings, crosswalks, barrier walls and lighting represent the first step of the FDOT and Local stakeholder's combined effort to the right direction. FDOT also acknowledges the need to investigate more long-term upgrade options capable of accommodating future growth and demand. Therefore, the purpose of building a DT model is to ensure successful outcomes of the ongoing initiatives and identify superior alternatives for upcoming transportation plans. Determining an optimal roadway design is crucial in this case since the current initiatives of FDOT will likely require significant financial investment and include potentially disruptive technology. Before undertaking improvements to existing roadway features, especially changes like altering roadway geometry and safety features, several critical issues need careful consideration. The issues include traffic and environmental impact assessment, infrastructure compatibility, accessibility, inclusivity, economic impact, alignment with community needs and regulatory compliances. Utilizing a DT model coupled with simulation tools offers a comprehensive approach to address these complex issues. For instance, the DT model can simulate various traffic scenarios, allowing for a detailed assessment of traffic impacts as well as other alignment and environmental impacts. The model can integrate existing infrastructure data, facilitating an analysis of compatibility and identifying necessary adjustments, and predict the impact of proposed changes on infrastructure components. It can simulate the accessibility of proposed changes for all users, including pedestrians, cyclists, and those with disabilities. Moreover, the findings of this research are likely to have a significant impact on practical applications of road diet concept by providing useful insights and data to enable the seamless integration and implementation of typical four-lane undivided configuration to three-lane configuration including dedicated left turn lanes. These findings will address various aspects of practice, including infrastructure planning, operational strategies, and user experience. 1. Infrastructure Planning: The research will provide insights into the optimal design and configuration of infrastructure to improve safety along Aloma Avenue. This includes identifying interconnected intersections with different lane types such as dedicated left and right turn lanes, shared lanes and bike lanes, pedestrian crossing, signalization, and efficient traffic management systems. The results will guide decision-making on infrastructure investments. 2. Operational Strategies: The research will inform operational strategies for road diet configurations, such as real-time data collection and integration with other data sources/models, prediction of future traffic conditions, and assessment of alternative traffic control and management strategies. 3. User Experience: The research will contribute to improving the overall user experience by assessing the impact of new 3 lane configuration on the overall level of service (LOS). This includes addressing average waiting time and speed and incorporating derived user feedback into the model design and performance. The results will help create an improved travel experience and identify potential opportunities for future developments through real-time traffic monitoring and control.
Affected Offices	FDOT District 5, Seminole County, City of Winter Park
Existing Work	Digital twins (DTs) have rapidly gained attention of researchers, primarily within the context of lifecycle management and predictive analysis across diverse industries. However, in the transportation sector, their application has mainly centered on infrastructure maintenance and the development of intelligent transportation systems, encompassing areas like autonomous vehicles and advanced driver assistance systems. Research focusing on utilizing DT technology for real-time traffic flow optimization within urban environments has been very few, with only a limited number of studies. Studies by Wu et al., (2022) and Rudskoy et al., (2021) explored the potential of DT technology to expedite the evolution of intelligence in transportation systems, showcasing its efficacy in optimizing traffic flow, ultimately leading to reduced traffic congestion and accident rates. Recent research, including Kušić et al., (2023) and Saroj et al., (2021) has demonstrated the DT model's capability to accurately reflect real-time traffic dynamics and provide real-time performance measures related to traffic and the environment. Another study by Abdulhai et al., (2003) demonstrated the feasibility of reinforcement learning methods,

	akin to DT-based real-time traffic data prediction, for analyzing traffic flow and velocity data monitored by sensors and transmitted via 5G. In a study conducted in Alabama, Dasgupta et al., (2021) introduced a DT approach for adaptive traffic signal control (ATSC) and found significant enhancements in a traveler's driving experience through the reduction and redistribution of waiting time at intersections. While the existing literature points to the transformative potential of DT, there is a noticeable gap in the availability of ample evidence regarding its application specifically in optimizing roadway design that can facilitate traffic movement and ensure safety. Our research seeks to address this gap, establishing a comprehensive conceptualization of DT and their potential for future deployment and enhancement in this critical domain.
Keywords Used In Existing Work Search (Cannot leave blank)	Transportation digital twins, road diet, traffic control system, real-time signal optimization, simulation, vehicle delays.
Related Contracts (Give contract no.)	N/A

Funding Request	250,000	**Anticipated Duration: months**	24 months
Project Manager	Mo Hassan	**Contracting Method**	Direct contract with UCF, Hatem Abou-Senna and Samiul Hasan.
Equipment			
Urgency	Score 1-5 **1**= highest, most immediate need		
Implementability	Score 1-5 **1**=greatest likelihood of and proximity to implementing results		

Project Benefits (Succinct, complete explanation)

SR 426 is a crucial transportation network that serves in Orange County, and it connects some major facilities such as University of Central Florida (UCF) with the Interstate Highway-4 (I4). As the UCF student community and residents' migrations in Orlando continues to grow, the existing traffic control system along SR 426 is encountering challenges in maintaining safety and meeting travel demands. The situation is anticipated to worsen in the near future, necessitating the exploration of more optimal solutions. With TDTs capability to represent actual traffic characteristics and predict future patterns, it can greatly contribute towards FDOT plans for reducing traffic congestion and ensuring transportation equity. TDT can prioritize public transit vehicles, improving service reliability as well as enhance mobility for all road users, including pedestrians and cyclists.

However, successful adoption of a new technology requires identifying and addressing several key factors. These include understanding the technology's potential benefits, aligning it with specific organizational goals and needs, and securing adequate resources for implementation. Maintaining a consistent understanding of the technology, by conducting research while also monitoring what is happening elsewhere, will help ensure that the FDOT continues to play a part in how this technology is developed and ultimately deployed to benefit the local public.

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		
o Materials Savings		
o Time Savings		
o Lives Saved/Injuries Prevented		

○ Other (Explain)		

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

References

Abdulhai, B., Pringle, R., & Karakoulas, G. J. (2003). Reinforcement learning for true adaptive traffic signal control. *Journal of Transportation Engineering*, *129*(3). https://doi.org/10.1061/(ASCE)0733-947X(2003)129:3(278)

Kumar, S. A., Madhumathi, R., Raj, P., Leí, T., & Wang, S. (2018). A novel digital twin-centric approach for driver intention prediction and traffic congestion avoidance. Journal of Reliable Intelligent Environments, 4(4), 199–209. https://doi.org/10.1007/s40860-018-0069-y

Dasgupta, S., Rahman, M., Lidbe, A. D., Lu, W., & Jones, S. (2021). A transportation digital-twin approach for adaptive traffic control systems. *ArXiv Preprint ArXiv:2109.10863*.

Kušić, K., Schumann, R., & Ivanjko, E. (2023). A digital twin in transportation: Real-time synergy of traffic data streams and simulation for virtualizing motorway dynamics. *Advanced Engineering Informatics*, *55*. https://doi.org/10.1016/j.aei.2022.101858

Rudskoy, A., Ilin, I., & Prokhorov, A. (2021). Digital Twins in the Intelligent Transport Systems. *Transportation Research Procedia*, *54*. https://doi.org/10.1016/j.trpro.2021.02.152

Saroj, A. J., Roy, S., Guin, A., & Hunter, M. (2021). Development of a Connected Corridor Real-Time Data-Driven Traffic Digital Twin Simulation Model. *Journal of Transportation Engineering, Part A: Systems*, *147*(12). https://doi.org/10.1061/jtepbs.0000599

Wu, J., Wang, X., Dang, Y., & Lv, Z. (2022). Digital twins and artificial intelligence in transportation infrastructure: Classification, application, and future research directions. *Computers and Electrical Engineering*, *101*. https://doi.org/10.1016/j.compeleceng.2022.107983