Exhibit D

Research Project Requirement Template

Improving Mobility Options through Transit Signal Priority (TSP)

Recipient/Grant (Contract) Number: The University of Texas at Austin/Grant # 69A3552344815 and 69A3552348320

Center Name: Center for Understanding Future Travel Behavior and Demand (TBD)

Research Priority: Improving Mobility of People and Goods

Principal Investigator(s): Michael Hunter

Project Partners: N/A

Research Project Funding: $200,000 (Federal + non-Federal funding)

Project Start and End Date: 6/1/2024 - 5/31/2025

Project Description: TSP seeks to optimize the interaction between busses and the infrastructure, creating a minimum resistance path for transit buses through signalized intersections. TSP may improve travel time reliability (TTR), schedule adherence, and ultimately the quality of service and ridership for transit systems. Bhat and Sardesai explicitly includes of TTR in mode choice, demonstrating the significance of this measure, with higher sensitivity seen for those with less flexible work schedules. The importance of TTR in mode choice is further shown through survey results by Li et al., as well as in the consideration of individual's public transport route selection by Swierstra et al. Thus, improving transit service quality has high potential benefits, with transit disproportionately serving essential workers and traditionally underserved communities. Additionally, improved quality of service may encourage traveler mobility choice behavior to switch from personal vehicles to transit, with associated benefits of reduced congestion, vehicle miles traveled, and emissions. An efficiently designed TSP system can lead to a more sustainable and equitable transportation system.

Past TSP research has mainly focused on developing optimization strategies to improve bus performance, typically while limiting impacts to the general traffic. Although, the acceptable level of impact to general traffic (typically single occupancy vehicles) is a policy decision that should be explicitly considered by agencies, while recognizing the potential constraints such policies place on transit performance. Adaptive TSP with online optimization has been studied and are increasingly being piloted. Existing adaptive TSP algorithms are primarily analytical models and mathematical programming, integrating real-time data for traffic state definition and actuation triggering. Most of the proposed strategies need further evaluation and testing to achieve field ready status. Additionally, for widespread adoption, more efficient real-time optimization algorithms need to be developed.

Focusing on real-time operational control, this project will develop and test novel AI/ML based TSP actuation and optimization algorithms in a simulated environment. The algorithms shall seek to integrate automatic passenger counting (APC), automatic vehicle location (AVL), connected vehicle (CV) data, and real time signal phasing and timing (SPaT) data. The project builds on a recently completed Georgia Department of Transportation (GDOT) funded study that explored TSP fundamental principles in a simulated environment and laid the groundwork for more advanced TSP algorithms.

The proposed project is structured under the following four main tasks. Task 1 involves performing a comprehensive review of the most recent literature to establish the state-of-the-practice and state-of-the-art for TSP in both research and industry. Task 2 expands an under-development reinforced learning (RL) TSP. The current RL development is based on a single intersection, assuming availability of CV bus data.

This task seeks to determine if alternate AI/ML approaches provide superior performance. This task will explicitly consider the potential tradeoffs between transit and general traffic KPIs. Additionally, this task will consider computational efficiency and scalability to larger networks, significant challenges in current methods. The final selected TSP algorithms shall be benchmarked against currently available best performing TSP models. Task 3 builds on Task 2 to extend the developed algorithms to a corridor level implementation. Corridor level modeling involves coordination of the strategies developed for each individual intersection. Task 4 explores opportunities for adopting aggressive transit schedules by using TSP to ensure reliable bus travel times and schedule adherence.

US DOT Priorities: This project addresses the RD&T Strategic Plan goal of Equity and Accessibility Assessment, which seeks "access for users of all abilities through infrastructure and access to new transportation innovations and technology". Transit, and transit serving technologies such as TSP, address this objective, directing innovation at traditionally underserved and rural communities, and essential workers; thus, contributing to inclusive multimodal transportation and "Equitable Mobility". Additionally, this effort addresses transformation, providing advanced services, through the leveraging of "Connectivity & Digital Ecosystem", "Artificial Intelligence (AI) and Machine Learning", and "Smart Sensors". This effort will stress three technology transfer components: 1) From the beginning of this effort algorithm development is guided by the expectation of Software-in-the-Loop Simulation (SILS) and field implementation; 2) This effort seeks to accelerate the advancement and deployment of advanced, innovative TSP. Code will be open source to allow for commercialization and development by others.

Outputs: This research project develops and tests novel adaptive TSP algorithms based on AI/ML and CV in a simulated environment. The primary anticipated output is the developed TSP algorithms. In addition to the final project report, anticipated project outputs shall include journal articles for each of the stated objectives, conference presentations, and open access source code for the developed algorithms. The report and journal articles will detail the modeling framework including the model architectures, data inputs, and algorithm pseudo codes. Open access source codes shared through GitHub shall cover the entire model development process including data preparation and inputs, algorithm processes, and output evaluation. This will not only enable reproducibility but also allow easy adoption of the algorithms in other studies and for potential field implementation. Simulation model files shall also be appended to the final report.

Outcomes/Impacts: The next steps on the road to agency adoption of the developed TSP are SILS testing and pilot deployment on a corridor. It is anticipated that there will be increased research activity in AI/ML based TSP going forward. The framework, open access source codes, and training data developed under this study will support these efforts. Ultimately, assuming significant performance findings, increasing adoption of TSP systems by agencies should be experienced long term. Additionally, the results of the study may inform and be expanded to other transportation applications, such as School Bus Priority, energy efficient freight movement, real-time infrastructure responsive routing, etc.

With further testing and pilot implementation, it is anticipated that the proposed AI/ML based algorithms may experience widespread adoption in field TSP implementations. More reliable transit service may result in increase ridership, with corollary improvements in corridor operations. Improved service, thus improved mobility options, will be provided to traditionally underserved communities, improving quality of life. Additionally, agencies my deploy tighter transit scheduling, allowing for increased services with the same number of vehicles, reducing the operating cost per transit trip per route.

Final Research Report: A URL link to the final report will be provided upon completion of the project.

Bhat C. and, S. Sardesai, The impact of stop-making and travel time reliability on commute mode choice, Trans. Res. Part B: Method., Vol. 40, Iss. 9, 2006, pp 709-730,

Li, H., Gao, K., Tu, H., Ding, Y., & Sun, L. (2016). Perception of Mode-Specific Travel Time Reliability and Crowding in Multimodal Trips. Transportation Research Record, 2566(1), 22-30. https://doi.org/10.3141/2566-03

Swierstra, A. B., Nes, R. van, & Molin, E. J. (2017). Modelling travel time reliability in public transport route choice behaviour. European Journal of Transport and Infrastructure Research, 17(2).