Exhibit D

Research Project Requirement Template

Quasi-Sparsity in Transportation Origin-Destination Demand

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): Xuegang (Jeff) Ban

Project Partners: N/A

Research Project Funding: $120,000 (Federal + non-Federal funding)

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

Project Description: Quasi-sparsity (QS) indicates that for a large-scale transportation network, most origin-destination (OD) demands are concentrated on a small fraction of the OD pairs, while majority of the OD pairs exhibit small (maybe non-zero) travel demands. One example is the King County network (the area that includes the City of Seattle in the State of Washington): more than 90% of the nearly 500,000 OD pairs in the network have less than 2 trips per day, and such trips count for less than 15% of the total demands in the network. While QS was proposed in Wang et al. [1] and used therein for the estimation of vehicular OD demands, its existence on real-world transportation networks and other modes has not been well studied, and its potential to help improve existing OD demand estimation methods (e.g., for vehicular demand matrices) or OD synthesis methods (e.g., for freight demand matrices) has not been explored. Many interesting questions still remain open: e.g., does QS hold for all the major modes (car, transit, freight) of a network? If so, how similar are the QS properties between different modes? Also, how does the QS property for the same mode on the same network evolve over time? Answers to these questions are not only scientifically intriguing but also helpful to the understanding of inherent human mobility patterns and to practical OD estimation/synthesis. This research aims to investigate the QS of OD trave demands on large-scale transportation networks, aiming to answer the above key questions. We plan to collect agency and open-source data, and will also leverage the aggregated big mobility data from third-party from previous research projects. Using the data, we will define formal measures of QS, and apply them to study the QS property of different networks and for different modes, including vehicular traffic, transit, ride-hailing services, and freight traffic. We will also compare the similarities of the QS measures for the OD matrices of different travel modes on the same network, and investigate the connections between the similarities and the inherent human mobility patterns of the network.

Key research questions:

1) Does QS hold in general for the OD demand matrices of different modes on a large-size transportation network?
2) How does QS evolve over time for the OD matrix of the same mode on the same network?
3) Does QS hold similar properties for the OD matrices of different travel modes on the same network?
4) What is the connection between the similarities and the inherent human mobility pattern of the network?

The following data will be collected and used:

1) Travel demand matrices from several MPOs, ideally for the total travel demands and for different travel modes

2) Open-source data for ride-hailing OD demands [2,3]
3) Big transportation data from third-party [4]

Summary of main research methods:

1) Statistical analysis methods: correlation analysis, similarity analysis of matrices;
2) Time series analysis to investigate patterns changes
3) Compressed sensing techniques to infer OD matrices from limited data, based on the QS property

Outreach Plan: Brian Lee and Stefan Coe from PSRC will help the team collect multimodal OD demand data, provide input on research directions and methods, comments on research results and findings, and if appropriate, apply some of the findings to their regional planning practices.

US DOT Priorities: This research helps address the Data-Driven Insight research priority of USDOT, and in particular:

- Data Science: Harness advanced data collection and data processing capabilities to create timely, accurate, credible, and accessible information to support transportation operations and decision-making.
- Strategic Foresight: Assess, anticipate, and plan for changes to the transportation system.

This research is exploratory and helps address the T2 priority on "Ensure research investments are fully integrated through the demonstration and deployment of the resulting products and technologies" (page 67). In particular, the following objectives will be addressed:

- Research Planning: Require that T2 performance measures be incorporated into research project lifecycle planning at an early stage.
- Early-Stage Identification: In partnership with the modes, identify potential research and lab efforts ripe for demonstration

Outputs: This research will produce conference presentations and papers, and journal publications. Data, analysis methods of the data (such as QS measures), and software tools will be documented and shared with the research community.

Outcomes/Impacts: The research results and findings can help practitioners and policy makers better understand the OD demand data and human mobility patterns in a region, enabling more informed decision makings about transportation planning and services, e.g., regional growth plans, transit service planning and scheduling, and OD synthesis and estimation.

Understanding the QS property of OD demands, especially the similarity and difference of patterns among different modes of a network, can help improved demand management strategies, better mobility services (e.g., by transit agencies and ride-hailing companies), and bring positive travel experiences to the communities.

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

[1] Wang, J., Liu, H., Lu, S., Ban, X., 2022. Transportation network origin-destination estimation with quasi-sparsity. *Transportation Science*, 57(2), 289-312.
[2] Wang, J., Song, J., Zhao, C., Ban, X., 2024. Distributionally Robust Origin Destination Demand Estimation. To be presented at the 25th International Symposium on Transportation and Traffic Theory (ISTTT) and full paper is under review by Transportation Research Part C (2nd revision).
[3] Chicago Data Portal, 2024. Internet Link: https://data.cityofchicago.org/Transportation/Transportation-Network-Providers-Trips-2018-2022-/m6dm-c72p/about_data
[4] NYC Open Data, 2024. Internet Link: https://opendata.cityofnewyork.us/
[5] Chen, C., Ban, X., et al., 2017. Understanding GPS and Mobile Phone Data for Origin-Destination Analysis. Federal Highway Administration Report (FHWA-HEP-10-027).