Shipper's utility functions according to commodity groups and freight modal split – Project 4

Deliverables and Reporting Requirements for UTC Grants Awarded in 2023 (June 2023)

Exhibit D

Recipient/Grant (Contract) Number: The University of Tennessee; Texas A&M University, Grant No. 69-A3552348338

Center Name: Center for Freight Transportation for Efficient and Resilient Supply Chain (FERSC)

Research Priority: Improving Mobility of People and Goods

Principal Investigator(s): Bruce Wang (TAMU), Lee Han (UTK), Yunlong Zhang (TAMU)

Project Partners:

Research Project Funding: $217,400 Federal and $108,700 non-Federal funding

Project Start and End Date: 08/01/2024 – 07/31/2025

Project Description: The U.S. freight transportation network consists of railroads, highways, waterways, pipelines, and airways. It carries the flow of commodities along the supply chains from the origin of production to the destination of consumption. The already congested transportation system faces fast-growing freight demands. The annual freight volume is expected to grow from 19 billion tons in 2022 to at least 29 billion tons in 2050, according to the US Bureau of Statistics. In particular, imports and exports account for over 13% of the total freight volume and will grow at a much faster rate than domestic freight. The mode and route choices of shippers will play an important role in network performance and in the planning consideration of planners and public policy makers because they determine the freight volumes on the network according to their modes, and therefore determine congestion and delay on the routes. From a microscopic and operational perspective, to address bottlenecks and choke points on the network requires understanding of the shipper's choice of mode and routes. Shippers make their rational choices based on the premise of maximizing their utility functions. In this project, we proposed to study the utility functions and other means for route and mode choices by the shippers. However, shipper's choices also have to do with the commodity types. For example, higher value commodities such as machinery or electronic products may be less sensitive to the price charged than bulk commodities. The ultimate goal of the project is to propose a framework for predicting the network commodity flows so that policy makers and planners may use. The midterm goal of the effort is twofold. The first is to explore the format of the shipper's utility function in their decision of mode and route choices. The Second is to study the differences between the utility functions of different commodity groups by using a few groups that have data available. This project focuses on exploring the shippers' utility function: the format and calibration by using example commodity groups specifically.

There are several alternative approaches for the research. One means is based on artificial intelligence and neural networks, the second is based on the Logit model using utility functions and the third is to use the Probit model.

Although this project may consider using artificial intelligence for the modal and route choices, it will first consider proposing the general utility function for shippers and will then calibrate the utility functions according to the commodity types. The general methodology to adopt, when the utility function is considered, will be the maximum likelihood estimation method. The Logit model, for its ease of use in practice, will be calibrated, and will then be utilized for estimating the commodity mode and route choices. The resulting aggregate flow of commodities is the output from this research that may be used for long-term planning.

The duration of this project will be one year, and the deliverables will comprise of: (1) A literature review of the freight shipper behavior studies and the general utility theory as applied to the freight commodity flows. (2) Utility functions for a select number of commodity groups; (3) Utility function calibration using observed/collected commodity data; (4) Examine the difference between commodity groups in their sensitiveness to cost and time; (5) Final Report.

The major research tasks are further detailed as follows.

Task 1: Literature review
There is a rich literature on utility theories and on using Logit Models to predict traveler behaviors in terms of format of the function, functional calibration, data need/survey, etc. There is another category of literature is shipper related, including the major factors that shippers typically consider in choosing their modes and routes. The third category is about model calibration using maximum likelihood method.

Task 2: Establishing utility functions for a select number of commodity groups
This task focuses on the specific format of the utility function, which will be calibrated by using example commodity groups available from the CFS dataset. An ideal process is to explore alternative formats and determine on the best one. Major factors on a preliminary examination would naturally include time, distance, cost, shipping time reliability, volume, etc.

Task 3: Utility function calibration using observed/collected commodity data
A major work under this Task includes data preparation. The currently available CFS data has its origin and destination based on zones instead of specific points for the origin and destination of a shipment. This approximation in the CFS data effectively blurred the exact distances of shipments which are critical to calibrating the utility functions. The team will investigate means of using the CFS data and develop a procedure to overcome the data gaps. A meaningful question is whether a set of alternative paths may be generated for each origin/destination pair of zones of a particular commodity group between the two regions. What are the error implications? Is there a simulation method to assess the potential errors from this method?

Task 4: Examine the difference of sensitivity to cost/time between commodity groups
A great advantage of having shipper's utility function is making it possible to assess the shipper's sensitivity to major factors in the utility function such as time, cost, and shipping time reliability, etc. among different commodity groups. This study will make effort to choose a few representative commodity groups for the study.

Task 5: Final report
The report will document the major findings, processes, models, and other information for result dissemination in compliance with the federal sponsor's guideline and the FERSC center's requirement.

US DOT Priorities: Improving Mobility of People and Goods; Economic Strength and Global Competitiveness

Outputs: The deliverables will comprise of: (1) A literature review of the freight shipper behavior studies and the general utility theory as applied to the freight commodity flows. (2) Utility functions for a select number of commodity groups; (3) Utility function calibration using observed/collected commodity data; (4) Examine the difference between commodity groups in their sensitiveness to cost and time; (5) Final Report. This research achieves its mission through academic conferences, seminars, and journal publications as well as discussion with policy makers and planners. The project team will reach out to the Oak Ridge National Lab teams for discussion of the models developed for input and advice.

Outcomes/Impacts: The commodity flow from the shippers' choices may underlie the Freight Analysis Framework (FAF) predicted flows that are widely used in the U.S. by policy makers, researchers, and planners alike. Also note that shippers' behaviors also determine the freight network resiliency to disturbances due to political, economic, and natural events. This project will continue to examine the differences of shippers between different commodity groups in terms of how their utility functions affect their mode and route choices. The goal is to develop a unifying framework for predicting the network freight flows for the purpose of planning and operations.