Final Technical Report

Research Project Identifying No. 922927-Task 7, changed to 896371-Task 1

Urban Commodity Flow Data Collection and Analysis Using Global Positioning Systems

by

Rasaratnam Logendran, Associate Professor and Principal Investigator

Christopher Peterson, Graduate Research Assistant

Department of Industrial and Manufacturing Engineering
118 Covell Hall
Oregon State University
Corvallis, Oregon 97331-2407

Report prepared for:

Transportation Northwest (TransNow)
123 Moore Hall
Box 352700
University of Washington
Seattle, WA 98112

and

Port of Portland
121 NW Everett Street
P.O. Box 3529
Portland, OR 97209-4049

in cooperation with
U.S. Department of Transportation
Federal Highway Administration

May 2006

Rasaratnam Logendran is an Associate Professor in the Department of Industrial and Manufacturing Engineering at Oregon State University in Corvallis, Oregon. He received a Bachelor of Science Degree with honors in Mechanical Engineering from the University of Sri Lanka, a Master of Engineering Degree in Industrial Engineering and Management from the Asian Institute of Technology in Thailand, and his PhD in Industrial Engineering and Management from the Oklahoma State University. Dr. Logendran has co-edited a book titled Group Technology & Cellular Manufacturing: Methodologies and Applications, and has authored or coauthored over 75 publications in numerous journals and refereed proceedings. His areas of research include manufacturing cell design, routing and scheduling, facilities layout design, manufacturing simulation, and integration of design and manufacturing. Dr. Logendran's research has been supported by The National Science Foundation (NSF), TransNow, and by various state and industrial sponsors. In 1996, he was awarded the "Most Favorite Teacher of the Year" award by the IIE Student Chapter at Oregon State University. Besides teaching, he has held research fellowship positions with various organizations, including the Air Force Office of Scientific Research (AFOSR) - McClellan Air Force Base in Sacramento, CA; The Boeing Company in Everett, WA; and the NASA Johnson Space Center in Houston, TX, and has made significant contributions aimed at solving industry-relevant problems. Recently, Dr. Logendran was a Fulbright Scholar at the School of Mechanical and Manufacturing Engineering, University of Science, Malaysia from June to September 2000. Currently he is a senior member of IIE and SME, a member of INFORMS, ASEE, and the Faculty Advisor for the Alpha Pi Mu Industrial Engineering Honor Society at Oregon State University.

Christopher Peterson was a graduate student for a brief period of time in the Department of Industrial and Manufacturing Engineering at Oregon State University in Corvallis, Oregon. He received his B.S. degree in Computer Science from Western Oregon University, Monmouth, Oregon.

Introduction

The Urban Commodity Flow Data Collection and Analysis project is a joint effort between Oregon State University (OSU) and the City of Portland, Oregon Travel Forecasting Group (Port of Portland and Portland Metro). The broad objective of this project is to gain a better understanding of the role of the trucking industry and the requirements that it places on the highway managed by the Oregon Department of Transportation (ODOT). Specifically, the project focuses on leveraging technology to supplement data collection methods typically used to aid in the development of commodity flow models by the Travel Forecasting Group.

The project is an extension of the efforts pursued in the previous year to attract additional carriers who would be willing to participate in this study by allowing the OSU project team to install GPS units on their trucks to collect data. The data is collected at a series of collection points at desired time intervals, each comprised of measurements of latitude, longitude, date, and time. In the previous year, the GPS units were left in the trucks for a period of four weeks for data collection, and the pattern of collected data on trucks was very repetitive any time after the second week. Thus, it has been decided to install the GPS units on trucks for a continual period of two weeks. Leveraging upon the information acquired from the two carriers that participated in the previous year, the OSU team spent time to use the information as well as the analysis performed to develop a website. The website http://ie.oregonstate.edu/research/transnow/) is in place, and it includes sections such as project description, project objectives, project partners, data collection/allocation, pilot study results, analysis, and conclusions. The analysis section is divided into four parts: regional analysis, pick and delivery analysis, transportation analysis, and street use analysis.

In the second year, the OSU team met with collaborators from Portland Metro to discuss various ways of performing the analyses of additional data to be collected in order that such analyses would better support the development of commodity flow models by the Travel Forecasting Group. The OSU team also contacted the collaborators at Port of Portland and obtained updated information on all of the carriers that deliver and pick up commodities in the Portland metro area. In the following paragraphs, a summary of all of the activities pursued in the second year, including the challenges faced, experiences in installing and uninstalling GPS units on trucks, and data transfer and compatibility issues are described. Following this, the results obtained for the six different research questions set out to be addressed in the second year are documented. Finally, conclusions from the pursuit of this project are made.

Challenges Faced by the OSU Team in Contacting Trucking Companies

With previous experience from contacting several trucking companies and successfully collecting data from two, the OSU team presumed that in the second year it would be easier to approach the rest of the trucking companies in the Portland metro area and get them to collaborate in data collection. The OSU team established contact with several companies and requested collaboration. Contrary to the OSU team’s belief, the trucking companies contacted showed resistance to the idea of allowing anyone outside of the trucking companies to track truck movement. Their concerns were that the intent of these studies was to justify raising taxes or to restrict street usage to trucks. The companies were also concerned that collaborating with the OSU team could lead to revealing their identity and sensitive information about their customers. As there was no support from companies for data collection, a suggestion was made to the PI by the staff at Port of Portland to contact Bob Russell, Executive Director of Oregon Truckers Association. The PI contacted Bob Russell to seek his help in identifying trucking companies in the Portland metro area that would be conducive to OSU team collecting GPS data on their trucks. A narrative detailing the project's goals and objectives, and the benefits for the State and the trucking companies in terms of potential improvements that can be made to the highway infrastructure in the Portland metro area based on the findings of this research was sent out to Bob Russell. This narrative was printed in the bi-weekly newsletter published by the Oregon Trucking Association, in the hope that some of the trucking companies would respond favorably to the OSU team's request for collaboration. Although the request for collaboration was printed twice in the newsletter, none of the trucking companies expressed their willingness to collaborate with the OSU team for data collection. The PI then talked with Bob Russell to have him identify a few trucking companies that he thought were the most favorable for the OSU team to contact and get their concurrence for data collection. Five companies were suggested by Bob Russell.

When these companies were approached for their participation, the initial reaction from them was similar to the experience the OSU team has had before. One trucking company indicated that if collaboration with the OSU team was not a requirement, they were not interested in investing any time into it. When these companies were approached, it was extremely difficult to find out who in the company had authority to let the OSU team install the GPS units and collect data. The companies that expressed an interest in collaborating with the OSU team were sent the signed Confidential Disclosure Agreement (CDA) for their signature, prior to installing the GPSs on their trucks. It turned out that in one company the staff in the legal department did not have the time to look over the CDA and sign on the company's behalf. Another company that agreed to let the OSU team install GPSs for data collection experienced reorganization of its staff. Subsequently, the company lost interest in collaborating with the OSU team in data collection.

Two of the five companies contacted showed some promise of collaborating with the OSU team. It took lot of effort to persuade one company to participate as they voiced their concerns, although they admitted to the potential benefits to them by collaborating on this project. A presentation was made at this company's site to outline the project's goals, objectives and benefits, and to put them at ease with regard to protecting their identity. The second company also took several weeks of conversations over the phone and correspondences via e-mail to decide to collaborate with the OSU team. This company turned out to be the most receptive of all, allowing the OSU team to install GPSs on ten of their trucks.

Experiences on Installing the GPS Units and Collection of GPS Data

The OSU team closely worked with the two companies above to carryout the installations of GPSs. The first company agreed to let the OSU team install GPSs on four of their trucks. However, on OSU team's first visit to the company's site, the GPSs were installed only on three of their trucks due to a miscommunication and one of the four trucks the GPS was intended to be installed on was not in the yard. These three-truck installations were performed on a Sunday because the trucks were in use most of the week and the OSU team was instructed by the company to use Sunday for GPS installations. The first installation was fairly time consuming, taking between 15 to 35 minutes for each truck that the units were installed on. There was no assistance available in the yard from the company personnel. The OSU team recognized that obtaining power for the unit from within the truck was necessary to complete installing the GPS. The truck drivers use the lighter socket to power their cell phones so this power supply was off limits. It meant power needed to be drawn from the fuse box on the truck, and finding the right fuse in the box on the truck to draw power from was no trivial task. The panels on the fuse box were removed to search for the right fuse in the box. The task at hand was finding a non-critical fuse (an example is the fuse that powers the dome light within the vehicle) that is the correct amps and connecting the live side of the power cord to the live side of this fuse opening and pressing the fuse back into place. This allows for proper functioning of the item the fuse is assigned for, as well as to draw power from the fuse box for the GPS unit. The process of finding the fuse box, finding the proper fuse to draw power from, and safely drawing power to feed the GPS unit can take 10 to 20 min.

After properly powering the GPS unit, the unit was attached to a safe place underneath the dashboard with large zip ties. The antenna was run up onto the dashboard where it was either held in place by a magnet attached to the antenna or zip tied to an air vent on the dashboard. The loose wires were then zip tied underneath the dashboard to keep them safe and out of the driver's way. This process could take an additional 5 to 16 min.

While the GPS data was collected for the first trucking company, the OSU team was able to reach an agreement with the second trucking company that allowed the team to install GPSs on ten of their trucks. The OSU team was aware of the need to install one more GPS unit on one of the trucks in the first company and uninstall the first set of installations that were placed with the first company. For this reason, the OSU team planned on installing the GPSs on the trucks at the second company on the same day that it planned on uninstalling the GPSs at the first company.

On the second trip to the Portland metro area, the OSU team uninstalled the first three installations at the first three trucks and installed the GPS on the fourth truck as it was then available for installation. This installation took 15 min. as the truck was similar to the one the GPS was previously installed on. After the uninstalling and the installation of GPSs were completed, the OSU team proceeded on to the second company to install ten units on their trucks. Again, the OSU team experienced unfamiliar new truck models that would take 15 to 35 min. to perform an installation on a truck. While the trucks that were similar to the ones that the OSU team previously installed on would take between 10 to 20 min. per truck. The OSU team also experienced an additional challenge in two of the newer trucks at the second company. The newer model trucks did not have fuse boxes at all but instead were using breaker boxes that the OSU team was completely unfamiliar with. Although the OSU team was able to carefully work on a power solution for about 30 min. in one of these trucks, the team determined that it was not safe to install GPS units on these trucks. The OSU team very much appreciates all of the help provided by the second trucking company, as they went beyond what was expected of them to select two more trucks that did not use the breaker system, thus allowing the OSU team to reach its original goal of installing GPSs on 10 trucks.

Experiences with Uninstalling the GPS Units

As noted above, the first trip made by the OSU team to uninstall GPSs was a joint trip to uninstall and install the GPSs at the same time in order to keep the unneeded trips from Corvallis, OR to the Portland area minimal. Uninstalling the GPSs turned out to be much quicker than installing them on trucks. The process of uninstalling GPSs involves clipping the zip ties to release the units and wires from where they had been secured and carefully removing the wiring from the ground and fuse box. Once the wiring was removed, care was exercised to make sure that the fuse was properly placed back into the fuse box and everything was left as it was during installation. This process would take between 5 to 10 min., depending upon whether or not the panels needed to be removed to get the fuse box. The final (fourth) GPS unit at the first trucking company was uninstalled the same day the 10 GPS units were installed at the second trucking company, the same way we performed both the installation at the second company and uninstallation at the first company on the same day to avoid unnecessary trips to the Portland area. The process of uninstalling GPSs on the second day went very smoothly. Uninstalling the units took between 5 to 10 min. per unit with most of the units taking closer to 5 min. to uninstall. Nine out of the 10 GPS units at the second company and the last unit from the first company were uninstalled. As the truck which had the last GPS unit installed needed some repair work done in a shop, it was inaccessible for uninstalling. However, the OSU team was able to retrieve this GPS from the truck on another day, following a meeting at Port of Portland. Thus, a total of 14 units were uninstalled from two trucking companies this year.

Transferring data from GPS's to the Laptop

The process of transferring the data from the GPS units to the laptop was fairly simple. It involved attaching the GPS unit to the laptop and configuring the GPS software to download all of the data from the GPS unit. This took between 5 and 10 min. There was one problem though with the installations made at the first company. The OSU team discovered that there was no data whatsoever in one of the GPS units uninstalled from the truck. The truck the GPS was installed on was replaced by a newer truck the day after the installation, which meant the truck with the GPS was parked in the yard for the two week duration intended for data collection. As GPS unit only collects data when the truck is in motion, no usable data was obtained from this installation.

Thus, the number of trucks from which the usable data was collected this year is equal to 3 from the first company and 10 from the second company, for a total of 13 trucks. With data collected from 10 trucks in the previous year, the OSU team has collected usable data from a total of 23 trucks in the two years.

Working with Data Compatibility Issues

When the data was first downloaded from the GPS unit it is stored in a program that came with the units. The process of getting the data into a usable form based upon the procedures developed in the previous year requires some effort. First the data must be exported into a text file and then converted into a Microsoft Access data base table. The programs previously written takes this file as input and runs a data placement algorithm to associate each point with a street segment, and then a duration stops algorithm is run to determine the number of stops and length of the stops taken by each truck each day. The OSU team ran into three major hurdles while analyzing the data. The first was dealing with bad data. The first attempt at running the algorithm did not give any results. When the data was carefully inspected using the original downloading program, there were a small number of bogus points that seemed to fall out of any reasonable area.

First these bogus data points were removed from the original data set. Even after this was done, there was still a problem of the data analysis algorithm not running on the data that was collected this year from the 13 trucks. After evaluation of the data that was used in the previous year, it was observed that the rows needed to be ordered exactly the same way as the previous tables were ordered, and a truck number field needed to be manually added to the data before running the data through the algorithm. With these changes in place, the data placement algorithm was successful in placing the points initially, but was still unable to run the duration stops algorithm. Further investigation revealed that unless the export program is instructed explicitly how to export the date and time fields as dates and times, the date and time formats would not be compatible with the algorithm. After getting through these three hurdles, all of the data collected from 13 trucks this year was converted into usable “cleaned up” data that the current placement and duration stops algorithms were able to handle.

Research Questions

The OSU team’s focus in the second year has been to address six different research questions, which are listed below. In the paragraphs that follow, the motivations for each research question, the procedure used for analyzing each research question, and the results obtained are described.

1. What is the daily average number of stops?
2. What is the expected travel time between stops?
3. What is the road usage of trucks?
4. Do trucks follow truck routes?
5. Do trucks deviate from truck routes to avoid congestion?
6. Do local less-than-truck-load trucks (LTLs) run relatively the same route every day?

1. *What is the daily average number of stops?*

The daily average number of stops is an important measure in this research, as it is an assessment of how busy each truck has been delivering and picking up commodities per day. For this purpose, a duration stop (i.e., for delivering and picking up commodities) by a truck is defined as any time that a truck does not move for more than 5 minutes. The use of over 5 minute time limit excludes stops associated with trucks waiting at traffic signals and stop signs during their daily route. Also excluded are the stops that occur overnight. Often trucks are driven 5 or 6 days of a week, and some on a given day may not have contributed to a full truck day. Based on the conversations with trucking companies, a truck is considered to have operated a full truck day if it was operational for more than 4 hrs on that day. If it was operational for more than 1 hr. and less than 4 hours in a day, it is considered to have operated for one-half truck day. Adjustments were made for those trucks that did not contribute to a full truck day on some days during the period the data was collected. A total of 238 truck days were contributed by 23 trucks from which data were collected in both years. Thirteen of these trucks represent the data collected in the second year, while the remaining ten represent that collected in the first year. The total number of duration stops contributed by these 23 trucks is 4376.

The average number of daily (duration stops) that a truck makes is 18.46 (4376/23), a measure representative of the LTL trucks driven in the Portland metro area for delivery and pick up of commodities.

2. *What is the expected travel time between stops?*

While individual trucks might have some idea as to the expected travel time between stops, its value for trucks representative of those driven in the Portland metro area is an important measure addressed by this research. The number of duration stops that a truck makes on a day is obtained from running the duration stops algorithm developed by the OSU research team. The number of travel segments contributed by the truck on that day is equal to the number of duration stops plus 1. The rationale for this can be explained as follows. Consider a truck that leaves the yard, makes two duration stops, and returns to the yard. Clearly, there are two duration stops and three travel segments, explaining the reason for this evaluation. Thus, the total number of travel segments (R_t) contributed by truck (t) over all days the data was collected is evaluated as its sum of the travel segments on each day. Next, to evaluate the expected travel time between stops, first the amount of travel time contributed by a truck on a day is needed. As the total operating time for a truck on a day is known from the GPS data collected, subtracting from it the total time the truck contributes to making duration stops, gives the amount of travel time contributed by the truck on that day. Adding these daily travel times for truck (t) on all days the data was collected gives the total travel time for truck t (TR_t). The expected travel time between stops for truck t (ATR_t) is thus TR_t/R_t. Finally, the expected travel time between stops for a truck (ATR) is evaluated as the sum of the expected travel time between stops for each truck divided by 23, the total number of trucks included in the study.

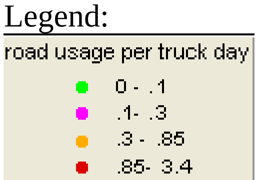
Based on the analysis performed and the computer runs made, the total amount of operational time and the total number of travel segments for all 23 trucks is 2457.11 hrs. and 4625, respectively. The average travel time between stops is evaluated as 32 min. ((2457.11/4625)*60).

3. *What is the road usage of trucks?*

This is an interesting research question from the perspective of the data collected from all 23 trucks. To answer this question, the OSU team decided to evaluate a measure that can be deemed as ‘street segment usage per day’ for each street segment in the Portland metro area. It is evaluated as the number of times each street segment is used (or traversed) by all 23 trucks included in the study. The OSU team obtained a digitized map from Portland Metro, which breaks up the metro area into distinct street segments. For the data collected in the study, the OSU team developed and implemented procedures to record what street segments each truck traveled for each day. The total number of times each street segment *s* was used during the entire data collection period (U_s) is evaluated by adding the street segment usage by trucks on each day. The street segment usage is thus evaluated as U_s/D, where D is the total number of truck operating days in the study.

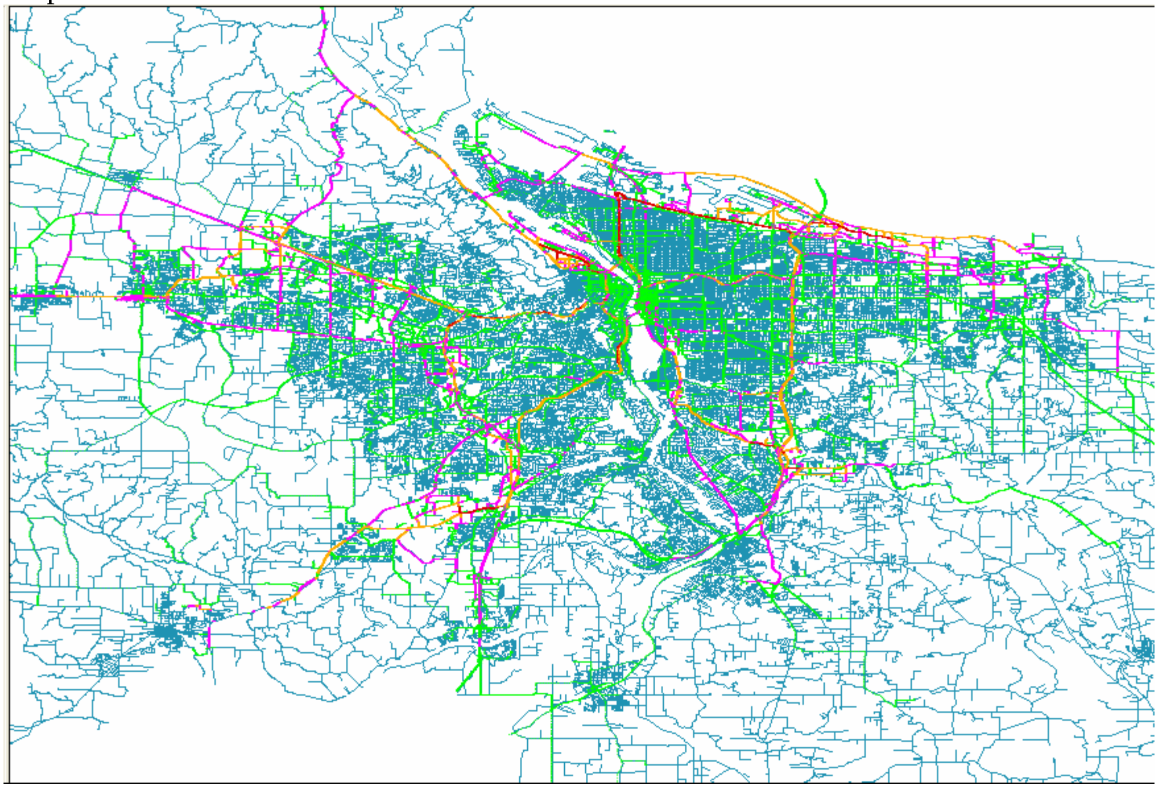
The following results were obtained from the analysis. The street segment (road) usage per truck day evaluated is shown in the legend below, with low usage of 0 – .1 in green and high usage of .85 – 3.4 in orange. For clarity, it should be pointed out that the high usage is denoted by orange while that next to the low usage is denoted by pink.

Legend:

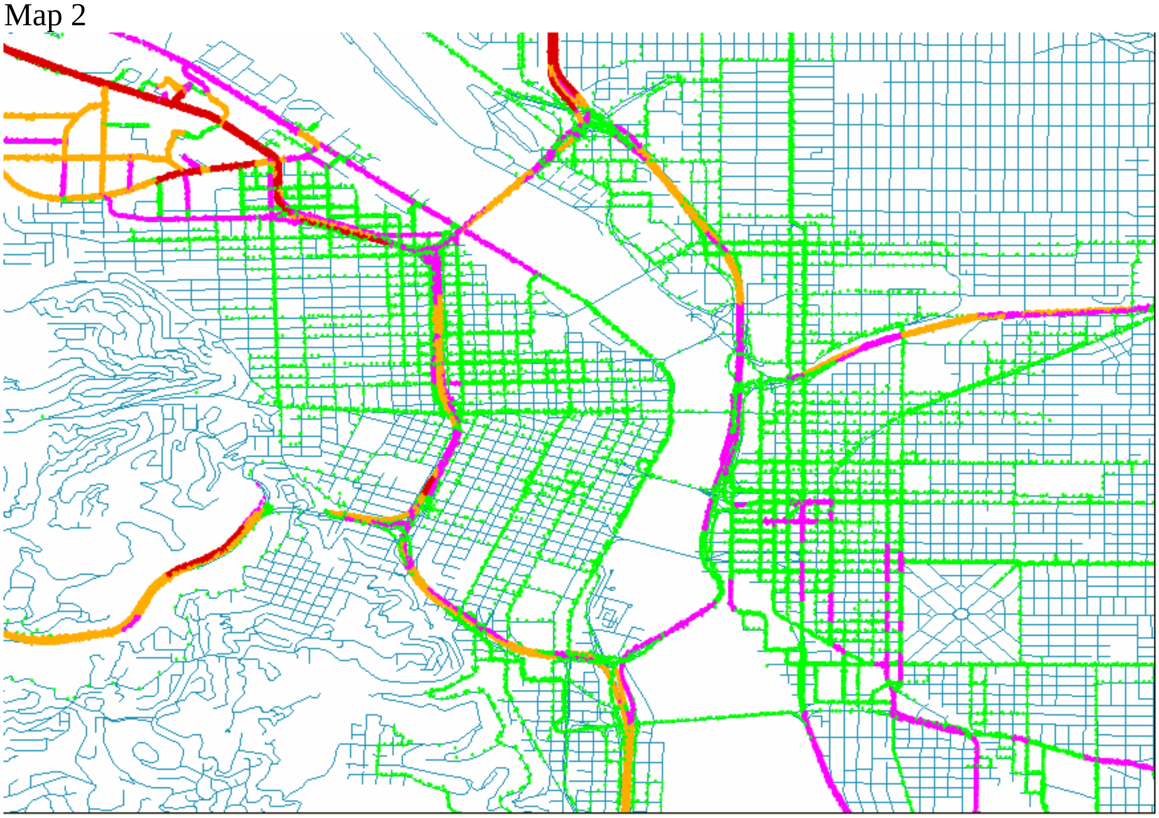


The first map (Map 1) on the next page shows the road usage for the Portland Metro area. Viewing the same map and zooming into an area of interest, enables identifying what roads get the most traffic and what areas on the map get a lot of traffic in general, as shown in the second ‘zoomed in’ map (Map 2).

Map 1



Map 2

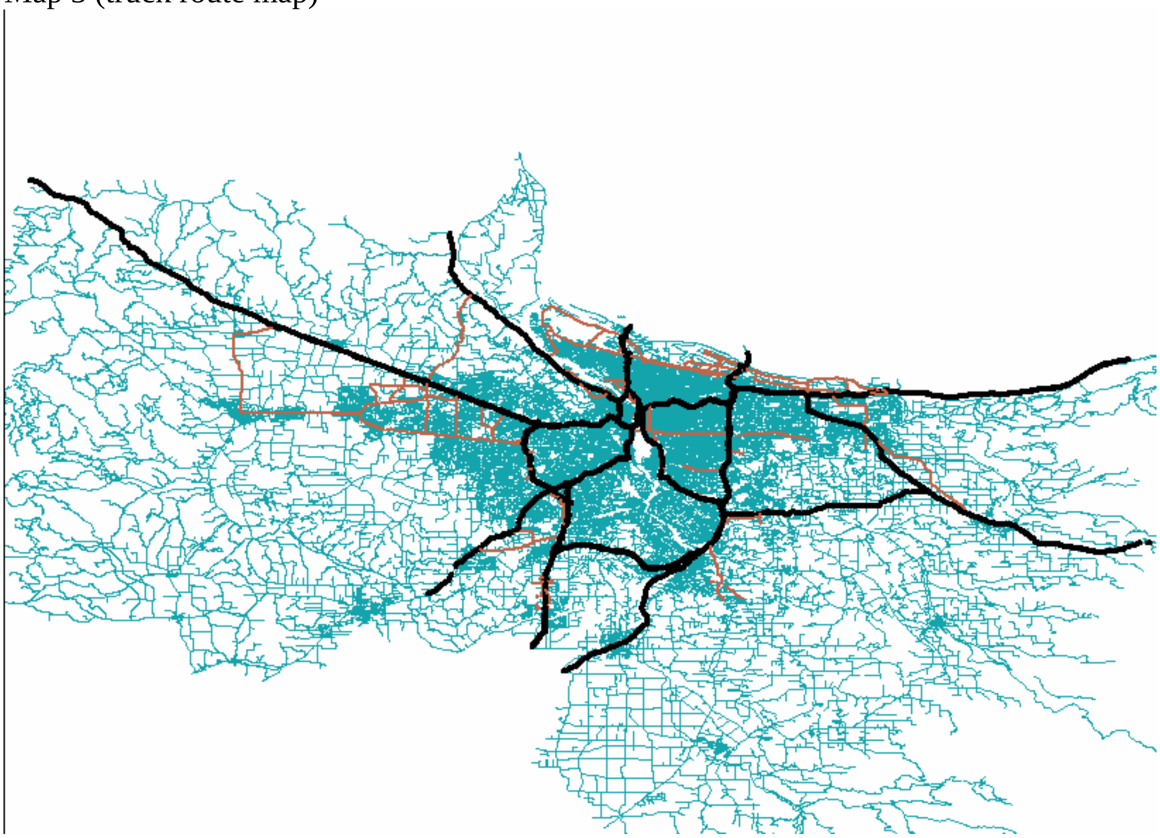


4. *Do trucks use truck routes?*

To answer this research question, it is necessary to know the designated truck routes in the Portland metro area. The OSU research team obtained the data for the truck routes map from Portland Metro, which shows the truck routes consisting of main roadways and intermodal connectors in the Portland metro area as shown in Map 3. The intermodal connectors are defined by USDOT as: "These are roads that provide access between major intermodal facilities and the other four subsystems making up the National Highway System." Thus, these connectors shown on the map are roads that accommodate and interconnect different modes of transportation such as main roadways, airports, and railroads.

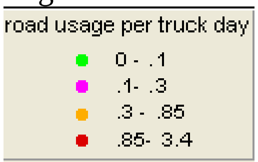
Legend:

Map 3 (truck route map)

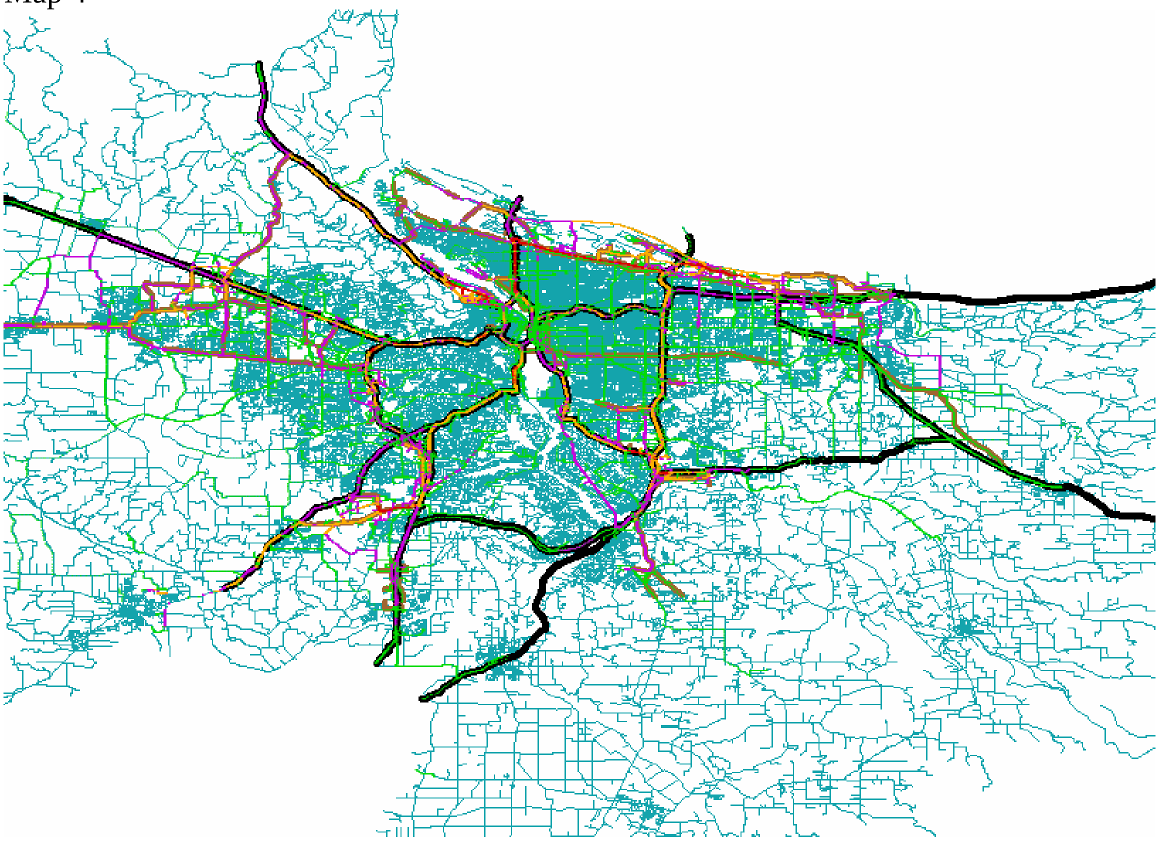


By plotting the road usage map over the truck routes map, an assessment on how well the truck routes are being used by trucks for making deliveries and pickups of commodities is made, as shown in Map 4. The map shows that trucks for the most part do follow the designated truck routes. Again, by zooming into a specific area of the map a better assessment of how well the trucks use the designated truck routes can be obtained (Map 5).

Legend:



Map 4



5. *Do trucks deviate from truck routes to avoid traffic?*

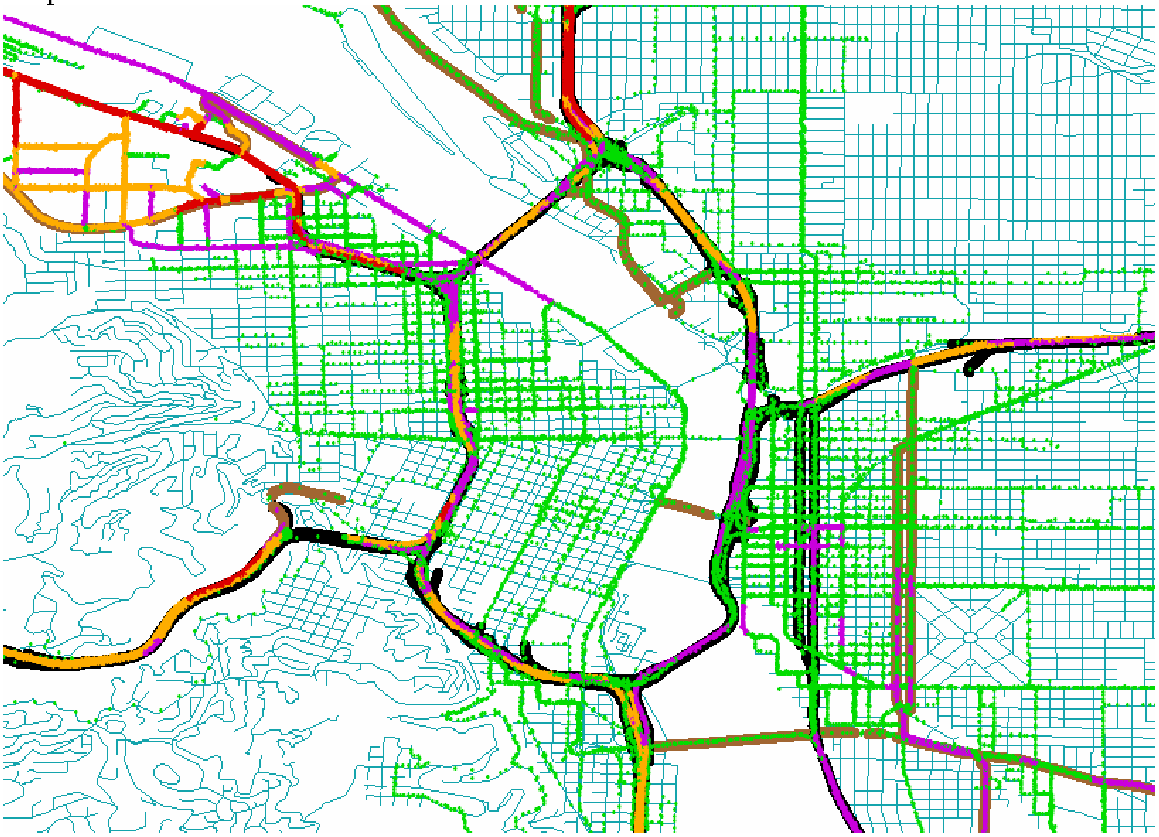
To gain some insight into answering this research question, the OSU team chose to overlay the road usage maps onto the truck routes maps for specific times of the day. By overlaying, one can observe if trucks seem to avoid certain routes in the Portland metro area due to rush hour traffic. The traffic was classified into two different categories as follows:

Non-Rush hour traffic: 9:00 am – 11:00 am & 1:00 pm – 3:00 pm

Rush hour traffic: 7:00 am – 9:00 am and 4:00 pm – 7:00 pm

Using these criteria, the adjusted road usage data obtained was plot over the truck route map. As expected, in the non-rush hour map the trucks do a fairly good job of staying on the truck routes as shown in Map 6. How the trucks are using the truck routes during non-rush hours can be seen clearly by zooming in on the non-rush hour map as shown in Map 7

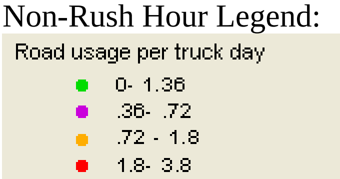
Map 5



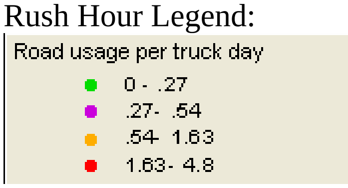
For the rush hour traffic, Maps 8 and 9 show that the trucks in the study did use the truck routes fairly well during the rush hour. This seems to answer the question quite well that trucks do not deviate from truck routes to avoid traffic.

Nevertheless, there was a noticeable difference in the amount of time that the trucks spend on the road during rush hour times and non-rush hour times. Trucks spend a good deal more time traveling during non-rush hour times than rush hour times, which reinforces the fact that trucks simply try to avoid traveling during rush hour times. In other words, even though trucks do not deviate from truck routes during the rush hour, the roads are most used by trucks during non-rush hour than rush hour.

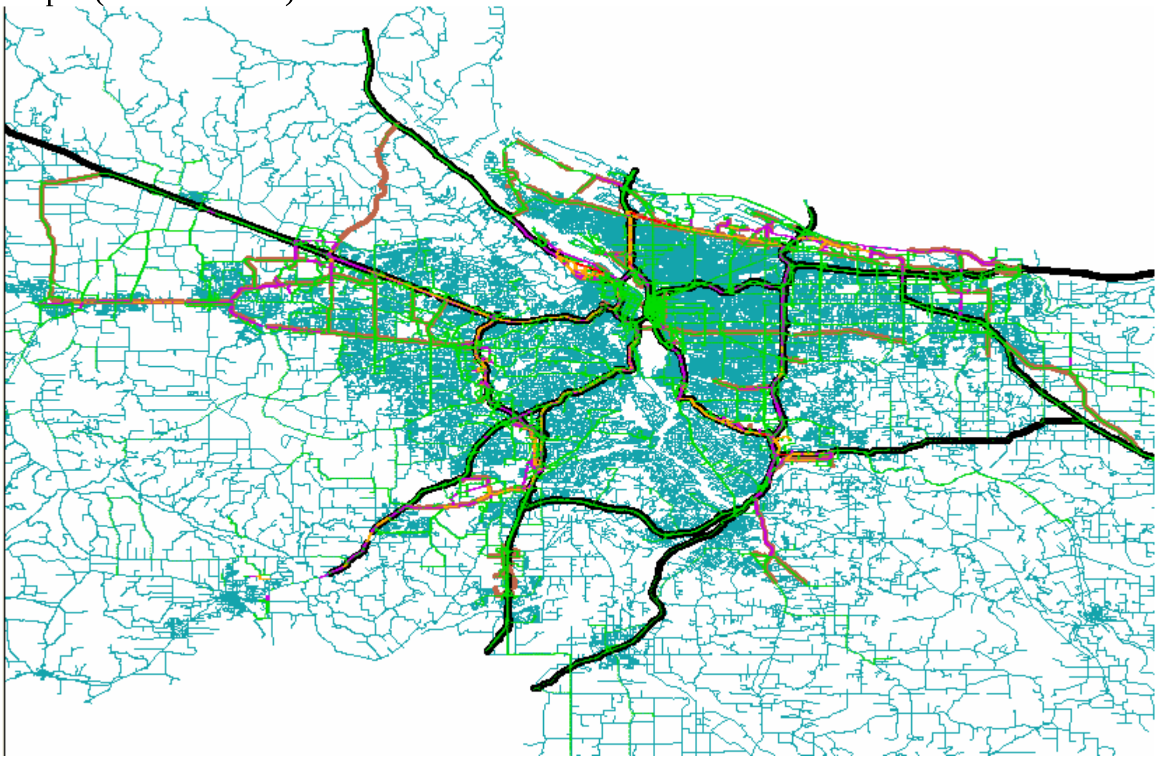
Non-Rush Hour Legend:



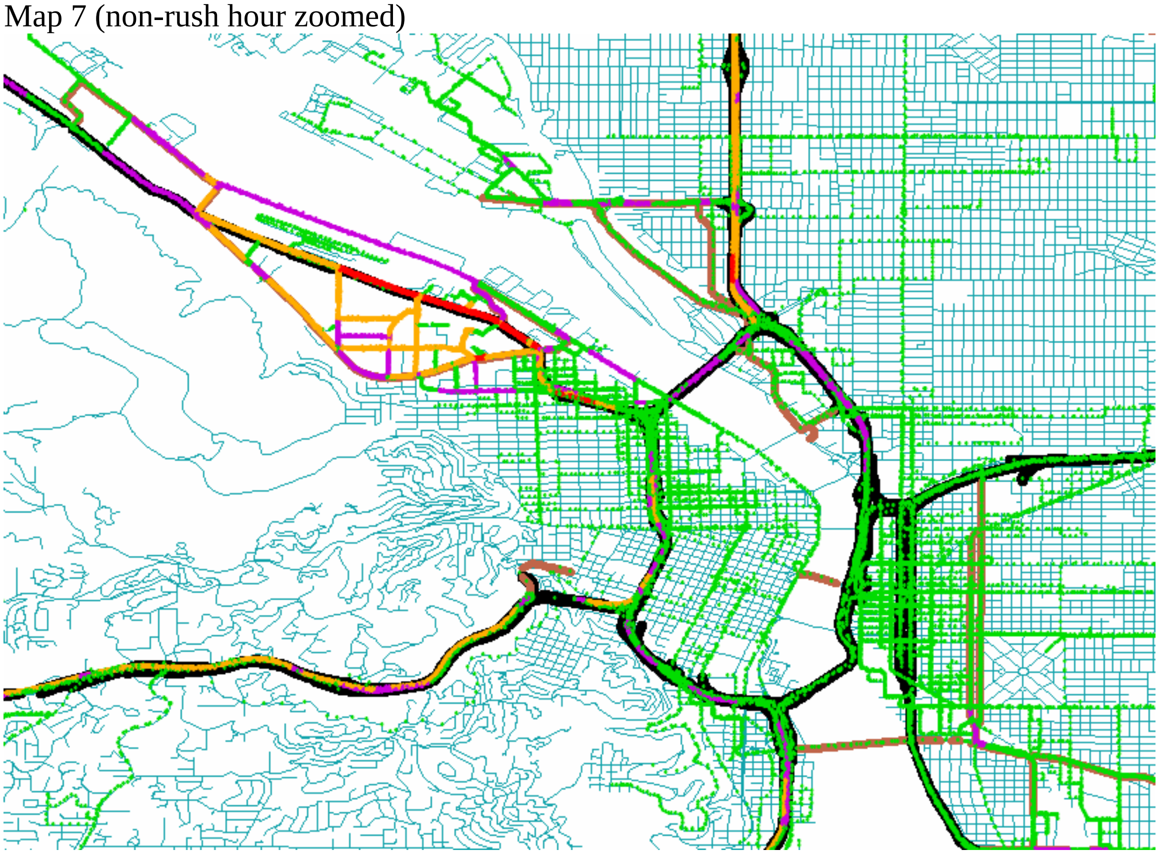
Rush Hour Legend:



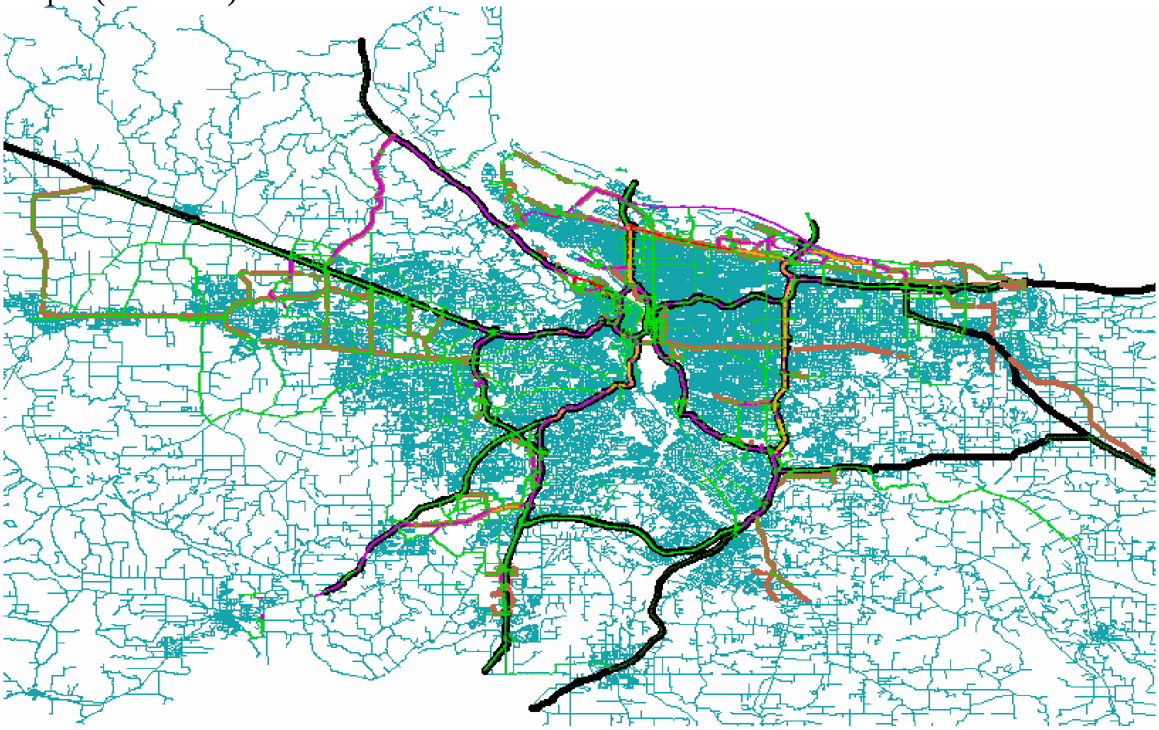
Map 6 (non-rush hour):



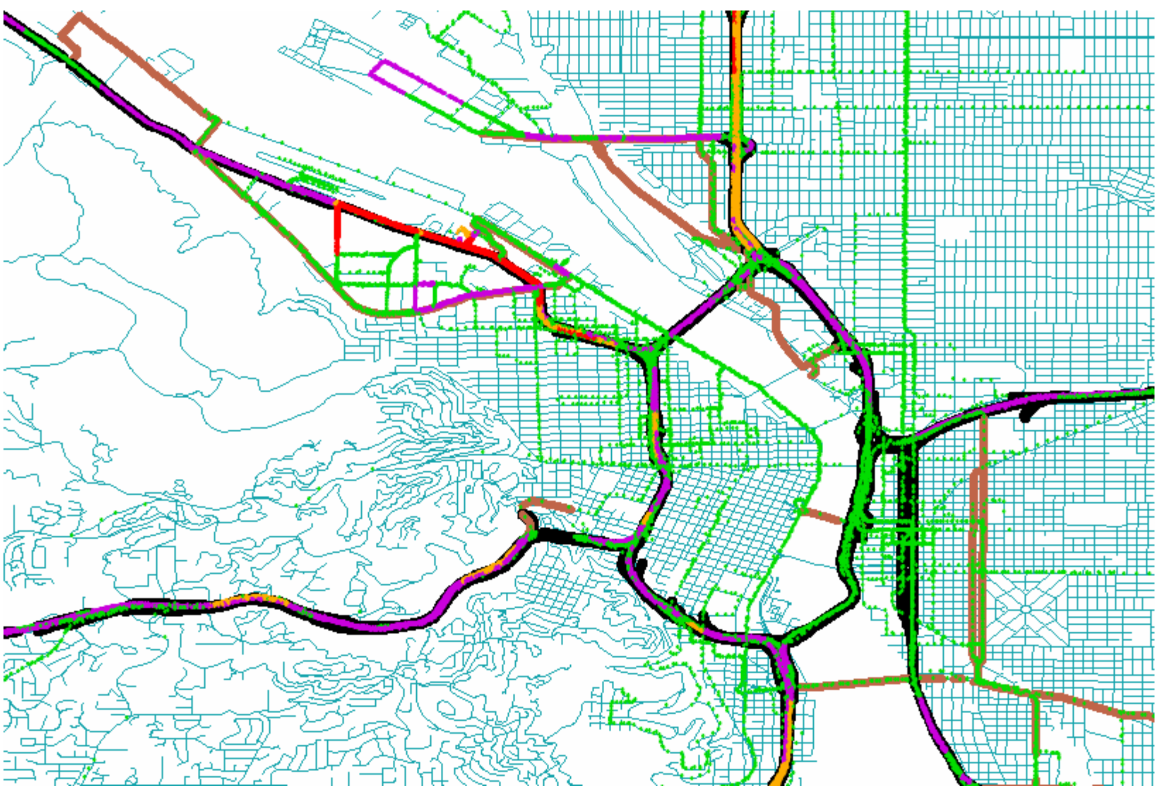
Map 7 (non-rush hour zoomed)



Map 8 (rush hour):



Map 9 (rush hour zoomed)



6. *Do local less-than-truck-load (LTL) trucks run relatively the same route every day?*

To completely answer this research question, each truck's route was mapped separately, giving each day a different color. Looking at each truck's routes individually on all operational days, a decision as to whether or not the truck follows the same route was made. Although a sample of only 23 trucks was used, the OSU team determined that 8 of the 23 trucks in the study follow a daily route. This means that 34.8% of the trucks in the study follow a daily route and 65.2% do not.

Conclusions

The road development is an expensive endeavor. The research performed and the questions addressed have shown that the information collected from trucks using GPSs give the capability to: 1. Forecast future traffic, and 2. Justify improvements to and developments of the highway infrastructure. The immediate beneficiaries of this project are Port of Portland, Portland Metro, Oregon Department of Transportation (ODOT), and the trucking companies. For the first three entities the benefits can be summarized as: 1. Identifying congested areas in terms of truck traffic, 2. Assessing if trucks use truck routes, 3. Examining if trucks deviate their routes to avoid congestion, and 4. Investing funds to improve commodity flow supported by research findings. The benefits for the trucking companies are: 1. Being able to see congested areas, 2. Monitoring their use of truck routes, 3. Seeing how their trucks deviate truck routes to avoid congestion, and 4. Road improvements made to improve commodity flow.

Contact information: Rasaratnam Logendran, OSU, logendrr@engr.orst.edu, 541-737-5239