Development of Tools for Processing Truck GPS Data and Analysis of Freight Transportation Facilities

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ABSTRACT

Increasing volumes of trucks on roadways cause increasing congestion and product delivery delays to the customers. Nowadays public and private stakeholders seek for efficient methodologies that may assist with identification of congested roadway segments and further allocation of the available monetary resources among the segments that require future improvements. This study presents two new applications that process the raw Global Positioning System data, collected from trucks, and efficiently calculate a wide range of performance measures. A case study is conducted to demonstrate how the developed applications may be used by decision makers in identification of the congested roadway segments, reliability of freight corridors, estimation of truck trips, analysis of rest areas and freight facilities, and freight transportation planning,

Keywords

Freight transportation, resource allocation, truck GPS data, freight performance measures

INTRODUCTION

Trucks remain an important transportation mode in the United States (U.S.) and around the world, as they deliver the majority of products to their final destinations. However, increasing amount of trucks on roadways may significantly increase the roadway congestion. The average travel delay increased by 6 hours on the U.S. roadways in 2014, as compared to 55 hour delay in 2009 (*1*). Travel speed at certain interstate segments of Los Angeles, which is ranked as the 1st congested city in the U.S. and the 3rd congested city in the world (*2*), can decrease up to 16 mph during peak hours (*1*). Increasing congestion may further cause the other negative externalities. For example, the Washington State Department of Transportation indicates that a 20% increase in the roadway congestion, caused by trucks, would increase the operational costs of freight-dependent industries, located in the Washington State, by more than $14 million (*3*). Approximately 60% of private sector freight-dependent industries pass those increasing costs to the consumers (*3*). Furthermore, the Washington State Department of Transportation underlines that a 20% increase in the roadway congestion would cause a net loss of 27,250 jobs and $3.3 billion in the State economic output.

Many alternatives have been investigated and implemented to reduce the roadway congestion, including the following (*4*): 1) prioritize and fund investments to improve signal timing and control; 2) limit peak-hour curbside parking on congested streets; 3) promote voluntary reductions in driving; 4) implement variable curb-parking charges in busy commercial and retail districts; 5) introduce transit fare discounts for employees; 6) implement fuel taxation schemes, etc. Public and private transportation agencies are still seeking for efficient alternatives to estimate performance indicators of busy freight corridors and identify the congested roadway segments. The latter information can be further used in prioritization of the congested roadway segments and allocation of investments to improve the level of service at those segments. Nowadays, many of freight stakeholders use Global Positioning System (GPS) devices to analyze truck travel patterns and to calculate freight performance measures (FPMs).

A number of methodologies have been developed in the past to process raw truck GPS data and calculate FPMs (*5-41*). However, many of those studies focus on estimation of a specific type of FPMs (i.e., either link-based FPMs or trip-based FPMs or parking-based FPMs, etc.). Nevertheless, decision makers may have to consider multiple FPM types in order to properly allocate the available monetary resources among congested roadway segments and other transportation facilities that require future improvements. This study proposes a standalone application for processing raw truck GPS data and a new ArcGIS toolbox for estimating various types of FPMs. The new applications, developed in this study, are expected to assist various stakeholders with freight transportation planning. The rest of the manuscript is organized as follows. The next section presents review of the literature with focus on the truck GPS data processing and FPM estimation, while the third section describes the developed tools. The fourth section presents a number of case studies to demonstrate how the proposed applications can be used for processing raw truck GPS data and calculating FPMs, while the last section provides necessary conclusions and outlines potential future research extensions.

LITERATURE REVIEW

Truck GPS data processing receives an increasing attention from the research community. The literature review presented herein will focus on published to date methodologies for processing raw truck GPS data and estimating FPMs. All of the collected studies have been classified based on the estimated FPMs into three groups: 1) Link-based FPMs; 2) Trip/tour-based FPMs; and 3) Parking-based FPMs. A detailed review of the collected studies is presented next.

Link-based FPMs

Quiroga and Bullock (*5*) presented a new methodology to computing travel time (TT) and travel speed (TS) on roadway segments using GPS and Geographic Information System (GIS) technologies. The GPS data were collected from the major metropolitan areas in Louisiana. It was found that increasing GPS signal frequency reduced the TS estimation error. Furthermore, the mean TS was affected with incidents, occurred during the peak hour. A similar study was conducted by Quiroga (*6*). The paper provided some additional performance indicators that could be used to quantify congestion, such as: segment TS, acceptable TT, delay, total delay, delay rate, and relative delay rate. Storey and Holtom (*7*) used the GPS data for estimating link TT and TS at the West Midlands highways (UK). The considered highways were divided in 50 m segments. The average TS was computed for each one of the highway segments. The study results indicated that the major links near the city center faced congestion issues. Jones et al. (*8*) proposed a new methodology for estimating FPMs of busy freight corridors based on the truck GPS data. The Alpha test was used to associate the GPS records with highway segments, while the Beta test aimed to calculate TT and TS values. A case study was performed to showcase estimation of the average TS at the busiest U.S. corridors.

Schofield and Harrison (*9*) used the truck GPS data, provided by the American Transportation Institute (ATRI), to calculate FPMs for the Texas highways. The authors highlighted that in some cases the GPS spatial error could reach ¼ mile. Findings indicated that travel patterns were significantly affected with the announcement of approaching Hurricane Rita. Liao (*10*) developed a methodology for processing raw truck GPS data, which was applied for analysis of the I-94/I-90 freight corridor between St. Paul (Minnesota) and Chicago (Illinois). Results demonstrated that TS was decreasing on the roadway segments, leading to Chicago. A number of studies focused on the estimation of TT and TT reliability in the State of Washington (*11-13*). It was underlined that the information from trucking companies could substantially improve accuracy of the estimated FPMs. Chien et al. (*14*) estimated link and path TT, variability of TT by departure time for 18 New Jersey highway corridors. The data were collected from the GPS enabled devices, installed into probe vehicles, traveling along considered highways between October 8, 2007 and April 21, 2008 from 6.15 am to 8.15 am during weekdays. It was found that TT on the most of roads followed a shifted log-normal distribution.

Figliozzi et al. (*15*) and Wheeler and Figliozzi (*16*) analyzed performance of the Oregon I-5 interstate using the GPS data. Significant differences in 50^{th}, 80^{th}, and 95^{th} percentile TT were reported for the urban areas. Furthermore, it was found that incidents substantially affected TS of trucks within the incident area throughout the day. Wang et al. (*17*) developed two methods for TT estimation based on the GPS data. The first method ("*naïve method*") calculated the average TS for each link individually, while the second method ("*mapping method*") analyzed truck trips for large segments, consisting of multiple links. Numerical experiments showed that the mapping method outperformed the naïve method.

Trip/tour-based FPMs

McCormack and Hallenbeck (*18*) used transponders and GPS devices for evaluation of freight mobility projects in the Washington State. The collected data were analyzed to determine trip TT, TT reliability, and congested roadway segments. Greaves and Figliozzi (*19*) evaluated performance of the freight corridor in the Greater Melbourne region (Australia) using the truck GPS data. The authors developed a Trip Identification Algorithm to estimate truck trips and tours. Findings indicated that TS decreased during the AM and PM peak periods. Bassok et al. (*20*) proposed an algorithm for identification of trip ends based on the GPS data for the Washington State highway corridors. Computational experiments, conducted for the Puget Sound region, demonstrated that each truck on average made 9 tours and 10 trips per tour. Golias et al. (*21*) and Mishra et al. (*22*) used the truck GPS data, provided by ATRI, to estimate various performance measures of highway segments, traffic analysis zones, and freight facilities (including warehouses, distribution centers, and intermodal facilities) in Tennessee. Golias and Mishra (*23*) conducted a study to assess the impact of the new Hours of Service (HOS) rule for Commercial Motor Vehicle drivers on travel conditions along the Tennessee roadway network. Existing conditions were evaluated based on the available GPS data, while the future conditions were forecasted using the Highway Capacity Manual methodology. Results demonstrated that new HOS rule would cause additional delays on the roadways.

Pinjari et al. (*24-26*) focused on the analysis of freight corridors in the State of Florida using the truck GPS data, provided by ATRI. A Trip Origin Destination Identification algorithm was developed for identification of truck trips and further estimation of the trip length and trip duration distributions. Kuppam et al. (*27*) proposed a methodology for identification of truck tours in the Phoenix area (Arizona) based on the truck GPS data. The study presented several tour-based models, including the following: tour generation, stop generation, tour completion, stop purpose, stop location, stop time of day choice. It was found that incompletion of truck tours was mostly caused by increasing number of stops. Furthermore, the purpose of the preceding stop could affect duration of the succeeding stop. Flaskou et al. (*28*) developed the Direction and Outlier Identification and Trip Detection Algorithms to estimate bi-directional link-based and trip-based FPMs based on the truck GPS data, provided by ATRI. Numerical experiments indicated that the developed algorithms could assist public and private stakeholders in freight transportation planning.

Parking-based FPMs

Several methodologies have been used in the past for truck parking analysis, including the following: 1) surveys (*29, 30*); 2) regression models (*21, 31*); 3) parking demand models (*32*); 4) discrete choice models (*33, 34*); and 5) IT technologies (*35-37*). Only a limited number of studies used the GPS data for estimating truck parking based FPMs. Maze et al. (*38*) discussed parking issues encountered in the State of Minnesota. The study focused on the analysis of supply and demand of parking facilities along the major corridors. A new concept "*IPark*" was described, when truck drivers were able to receive the information regarding the parking availability in rest areas via GPS enabled smartphones. Ma et al. (*39*) developed a GPS data processing application for analysis of truck trips. The proposed tool was able to identify trips ends and truck parking locations. Liao (*40*) presented a methodology for estimating the utilization of rest areas using the GPS data, provided by ATRI, in the Twin Cities Metro Area. The study provided distribution of parking space utilization by time of day. Zanjani (*41*) developed an Origin-Destination Matrix Estimation algorithm for analysis of truck trips within the State of Florida. It was underlined that the proposed algorithm could be used in identification of trip ends in rest areas.

Contribution

Review of the literature suggests that truck GPS data processing is an evolving area of research. Many of researchers and practitioners developed a number of algorithms that could be used for processing raw truck GPS data and FPM estimation. However, the majority of those algorithms are able to produce only a limited number of FPMs. To address the latter drawback this study proposes two new applications for processing raw truck GPS data and calculating a wide range of FPMs, which can further assist decision makers with freight transportation planning and efficient resource allocation.

DEVELOPED TOOLS

The following tools were developed in this study: 1) GPS Data Processing and Extracting Tool – a standalone application for importing raw tuck GPS data, processing raw truck GPS data, and extracting the data for certain time periods specified by the user; and 2) GPS-based FPMs Estimation – an ArcGIS toolbox for calculating various FPMs. Description of both tools is presented next.

GPS Data Processing and Extracting Tool

The raw truck GPS data are typically provided in a CSV format for the whole year or multiple years (*21-26*, *28*). However, FPMs should be estimated for specific time periods in order to accurately analyze a given transportation facility (e.g., AM vs. PM peak hour volumes, weekday vs. weekend volumes, etc.). The GPS Data Processing and Extracting Tool (see Figure 1A), developed under this study, is able to import the CSV file with raw truck GPS data, process the data, and extract certain portions of the data based on time periods specified by the user.

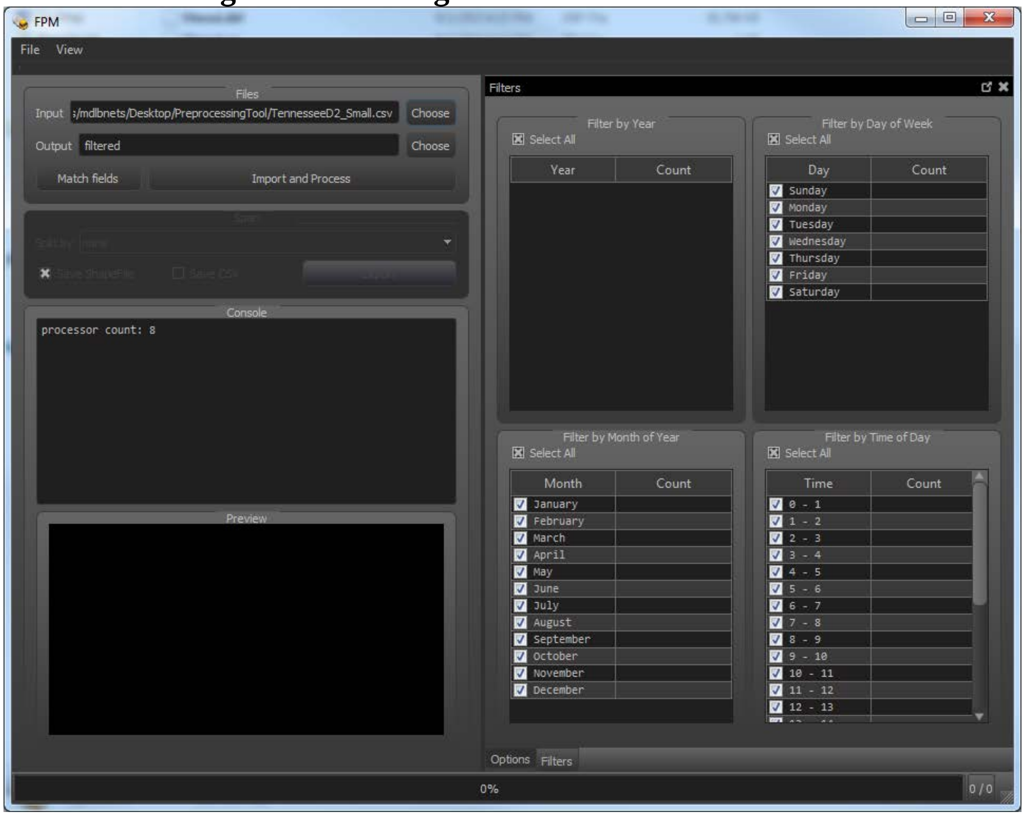
The procedure for GPS data processing and extracting includes the following steps:

Step 1: The user has to select the file with raw GPS data using the input panel, and specify the desired name and directory for the output file using the output panel;

Step 2: The user should press button "*Import and Process*", and the tool will process the imported raw GPS data. An example of processing the raw GPS data, collected from trucks traveling in the State of Tennessee (TN), is presented in Figure 1B. Once the imported data are processed, the tool will display the GPS records on the map at the bottom left corner. Furthermore, on the right side of the application the tool will show the number of records available by year, month, day of week, and time of day;

Step 3: The user should specify the time period to analyze and press button "*Export*" (see Figure 1B). By default, the tool will extract the GPS records, obtained for the selected time period, and save them in a shapefile (SHP format). The user can also request the output file in a CSV format and extract the processed data by month, day, and hour. Before exporting the file, the user can assign field names for the output file using button "*Match Fields*", located at the top left corner of the application.

1A: GPS Data Processing and Extracting Tool Interface



2A: Example of Raw GPS Data Processing

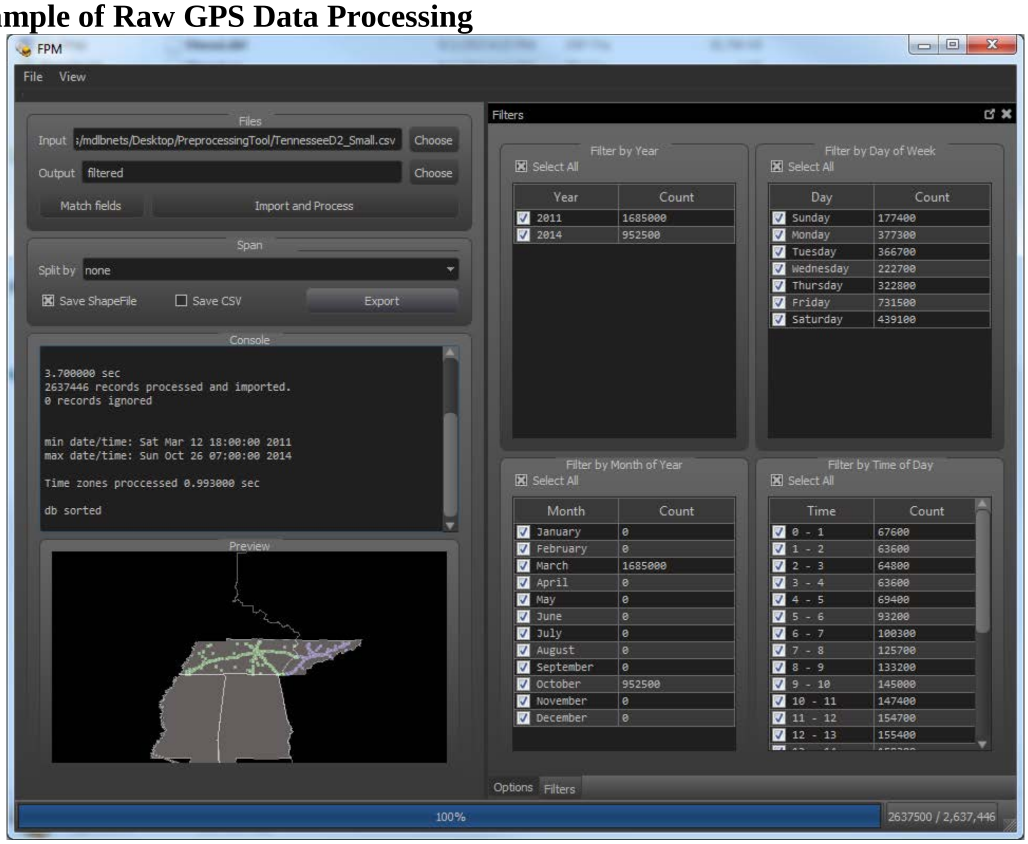


FIGURE 1 GPS Data Processing and Extracting Tool.

GPS-based FPMs Estimation Toolbox

The ArcGIS toolbox "*GPS-based FPMs Estimation*" has a total of 7 scripts (see Figure 2) for estimating various FPMs within the ArcGIS environment, including the following: 1) Link FPMs ("*LinkFPMs*"); 2) Trip FPMs ("*TripFPMs*"); 3) Average FPMs ("*AverageFPMs*"); 4) Congested lane miles ("*CLM*"); 5) Hours of delay ("*HOD*"); 6) Truck parking FPMs ("*TruckPark*"); and 7) Freight facility turn time statistics ("*TurnTimeStat*"). Description of each one of the scripts is presented next.

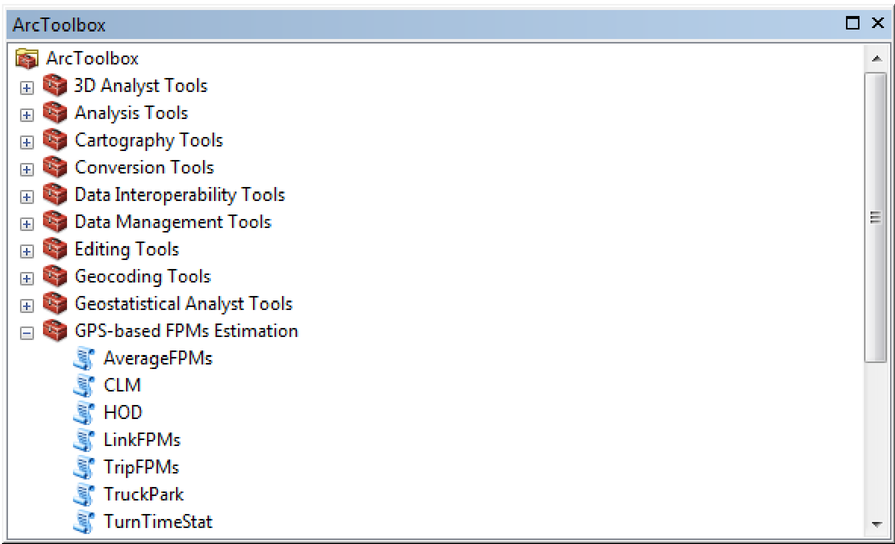


FIGURE 2 GPS-based FPMs Estimation Toolbox.

1) Script "*LinkFPMs*" has 7 input data fields (see Figure 3). The user is required to select the GPS data shapefile or folder with GPS data shapefiles, if multiple GPS data shapefiles are to be analyzed. Next, the shapefile with transportation network should be loaded. The user is able to perform the analysis for a given time period by assigning start and end hours. By default, start and end hours are set to 0 and 24 respectively (i.e., the tool will use all the GPS data available for a given day). Based on the available literature (*8*, *9*), the default value of snapping radius for associating GPS records with the network was set to ¼ mile. The user can modify the radius value, if accuracy of the GPS devices is available. The default value for joining the estimated FPMs with links of the network was set to "KEEP_COMMON" (i.e., keep only links that have FPMs). Last, the user should select the folder, where the output shapefiles with links and associated FPMs will be exported. The following bi-directional link-based FPMs are produced by script "*LinkFPMs*" for each roadway segment of the given transportation network: 1) volume; 2) average TS; 3) average TT; 4) 90^{th} percentile TT; 5) 95^{th} percentile TT; 6) buffer TT; 7) buffer TT index; 8) TT standard deviation; 9) TT coefficient of variation; 10) TT range; and 11) mean to median TT ratio.

2) Script "*TripFPMs*" has 6 input data fields (see Figure 3). Similar to "*LinkFPMs*" input, the user is required to select the GPS data shapefile or folder with GPS data shapefiles. Next, the shapefile with Traffic Analysis Zones (TAZs) should be loaded. Start and end hours should be assigned to perform the analysis for a specific time period. The default value for joining the estimated FPMs with TAZs was set to "KEEP_COMMON" (i.e., keep only TAZs that have FPMs). Last, the user should select the folder, where the output shapefiles with TAZs and associated FPMs will be exported. The following trip-based FPMs are produced by script

"*TripFPMs*" for each TAZ: 1) number of truck trip origins; 2) number of truck trip destinations; 3) average TT of originated/destined trips; 4) 90th percentile TT of originated/destined trips; 5) 95th percentile TT of originated/destined trips; 6) buffer TT of originated/destined trips; 7) buffer TT index of originated/destined trips; 8) TT standard deviation of originated/destined trips; 9) TT coefficient of variation for originated/destined trips; 10) TT range of originated/destined trips; and 11) mean to median TT ratio of originated/destined trips.

3) Script "*AverageFPMs*" has 5 input data fields (see Figure 3). The user is required to load the shapefile with transportation network or TAZs. Next, the folder containing shapefiles with links and associated FPMs or TAZs and associated FPMs should be selected. After that, the user is required to select type of FPMs to be analyzed (i.e., either link-based FPMs or trip-based FPMs). The default value for joining the estimated FPMs with links of the network or TAZs was set to "KEEP_COMMON" (i.e., keep only links or TAZs that have FPMs). Last, the user should select the folder, where the output shapefiles with links and associated FPMs or TAZs and associated FPMs will be exported. The script produces the average bi-directional link-based FPMs or the average trip-based FPMs.

4) Script "*CLM*" has 3 input data fields (see Figure 3). The user is required to load the shapefile with links and associated FPMs. Next, the shapefile with links and associated FPMs for the off peak period should be loaded. This study assumes that the travel conditions under the off-peak period are similar to the free-flow travel conditions (*14*). Last, the user is required to input the number of congested lane mile levels to be considered. Note that grouping of roadway segments will be performed based on ratios of the actual TS at those segments and the free-flow TS (FFTS). For example, if 5 levels are requested by the user for estimating the congested lane miles, the first group will include the roadway segments that have TS = [0.8×FFTS; 1.0×FFTS] (i.e., between 80% of FFTS mph and 100% of FFTS mph), while the last group will include roadway segments that have TS = [0; 0.2×FFTS] (i.e., between 0 mph and 20% of FFTS mph). Note that the roadway segments that have TS ≥ FFTS will be assigned to the group "0". Script "*CLM*" will return the bi-directional congestion levels for each roadway segment of a given transportation network.

5) Script "*HOD*" has 2 input data fields (see Figure 3). The user is required to load the shapefile with links and associated FPMs. Next, the shapefile with links and associated FPMs for the off peak period should be loaded. Script "*HOD*" will provide the bi-directional hours of delay (measured in vehicles·hours) for each roadway segment of a given transportation network.

6) Script "*TruckPark*" has 5 input data fields (see Figure 3). The user is required to select the GPS data shapefile. Next, the shapefile with rest area polygons should be loaded. The user has an option to use the average hourly truck observations of all the days provided in the shapefile. By default, truck observations in truck rest areas are estimated hourly for every day. The user is able to perform the analysis for a given time period by assigning start and end hours. By default, start and end hours are set to 0 and 24 respectively (i.e., the tool will use all the GPS data available for a given day). Last, the user should select the folder, where the output shapefiles with polygons and hourly truck observations will be exported. Script "*TruckPark*" will produce hourly truck occupancy for each one of the considered rest areas by time of day. Furthermore, the script is able to determine the number of trucks parked on- and off-ramp within the vicinity of a given rest area.

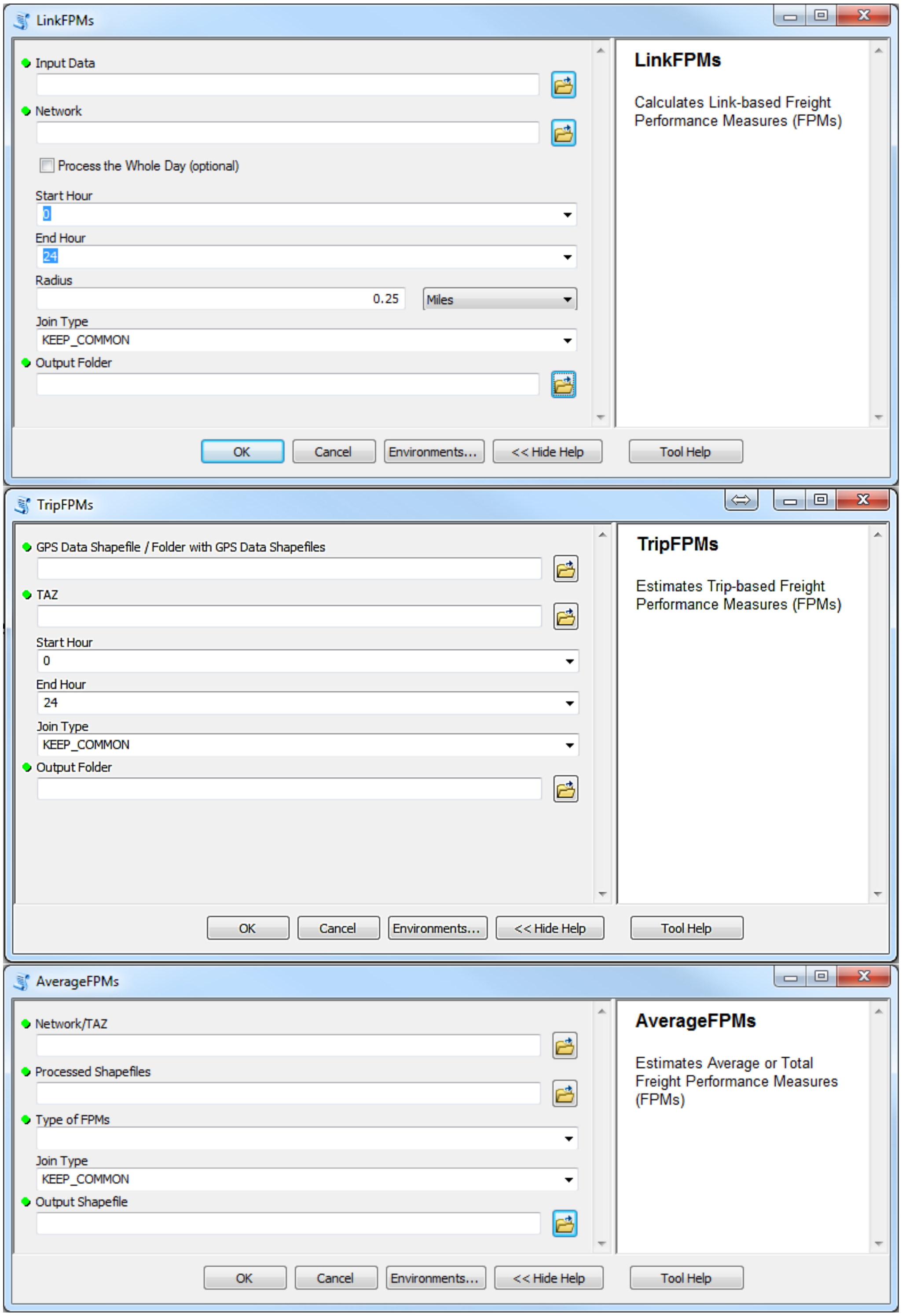


FIGURE 3 GPS-based FPMs Estimation Toolbox Scripts.

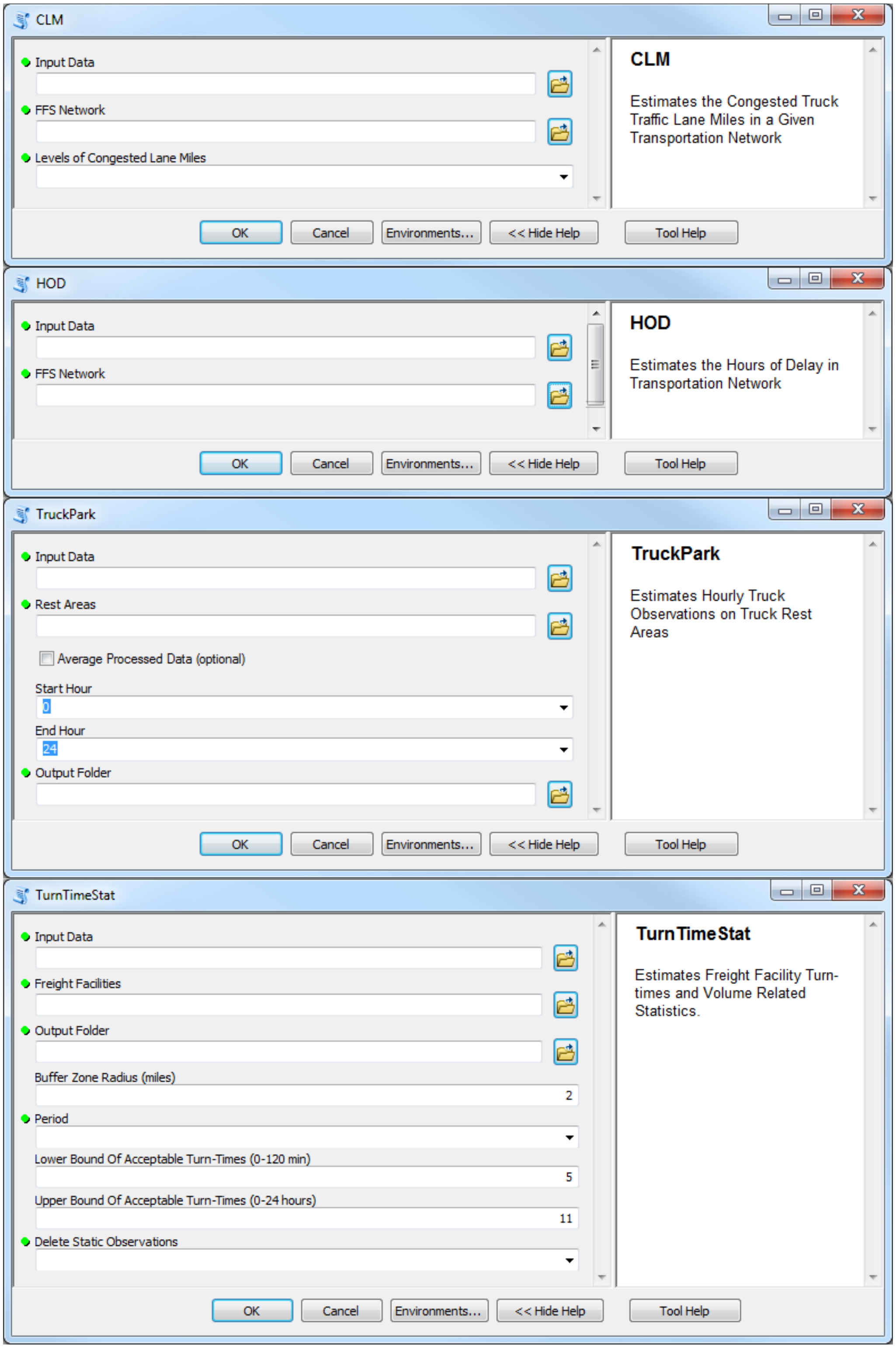


FIGURE 3 GPS-based FPMs Estimation Toolbox Scripts (Continued).

7) Script "*TurnTimeStat*" has 8 input data fields (see Figure 3). The user is required to select the GPS data shapefile. Next, the folder with freight facility polygon shapefile(s) should be loaded. Third, the user should select the folder, where the output shapefiles will be exported.

Fourth, the buffer zone radius (in miles) should be specified. In some cases the truck turn time at a given facility may be suspiciously large (e.g., the truck is staying overnight) or suspiciously small (e.g., there are missing GPS records). To avoid estimation of misleading truck turn times, the user is able to set lower and upper bounds for acceptable truck turn times. The developed script will filter out all truck turn time values, falling outside the assigned region of acceptable turn times. Last, the user may select an option of deleting static truck observations (the spot speed of a truck was <5 mph throughout the whole analysis period). Script "*TurnTimeStat*" will produce the following freight facility FPMs: 1) distribution of the freight facility occupancy by time of day; 2) distribution of the average truck turn time by time of day; 3) total freight facility occupancy; 4) average freight facility occupancy; 5) freight facility occupancy standard deviation; 6) freight facility occupancy variance; 7) minimum and maximum freight facility occupancy; 8) average truck turn time; 9) truck turn time standard deviation; 10) minimum and maximum truck turn times; and 11) truck turn time variance.

Examples of how the developed "*GPS-based FPMs Estimation*" toolbox can be used for estimating various FPMs will be presented in the next section. More details regarding the algorithms, used within the ArcGIS toolbox for calculating FPMs, are provided in Mishra et al. (*22*) and Flaskou et al. (*28*).

CASE STUDY

A case study was conducted for the State of TN using the truck GPS data, provided by ATRI, for Mondays-Wednesdays-Fridays of March 2014. The GPS data were retrieved using the GPS Data Processing and Extracting Tool. A total of 2,920,043 GPS records were available for 24,039 trucks. Next we present several examples of FPMs that can be produced using the developed "*GPS-based FPMs Estimation*" toolbox.

Link-based FPMs

The first analysis aimed to estimate link-based FPMs for the roadway segments in TN. The Freight Analysis Framework (FAF) was used as a transportation network. The FAF network has 3,393 roadway segments with the average link length of 2.66 miles. Two time periods were considered (*22, 28*): AM peak period (6 am – 9 am) and PM peak period (2 pm – 6 pm). Scripts "*LinkFPMs*", "*CLM*", and "*HOD*" of the developed ArcGIS toolbox were executed using the retrieved GPS data for the AM and PM peak periods to calculate the average travel speeds, congested lane miles, and hours of delay respectively. Results are presented in Figures 4 and 5 for all roadway segments of the FAF network in TN. Link-based FPMs were not calculated for 32.4% and 26.9% of links for AM and PM peak periods respectively, as the GPS data were not available (those links are colored in black, see Figures 4). We observe that traveling speeds at the major TN freight corridors (i.e., I-24, I-40, I-65, and I-81) are greater than 60 mph and are close to FFTS. Furthermore, hours of delay for the most of links do not exceed 2.00 vehicles·hours. However, reduction in travel speeds and increase in hours of delay are observed at links in the vicinity of large metropolitan areas (i.e., Memphis, Nashville, Knoxville, and Chattanooga).

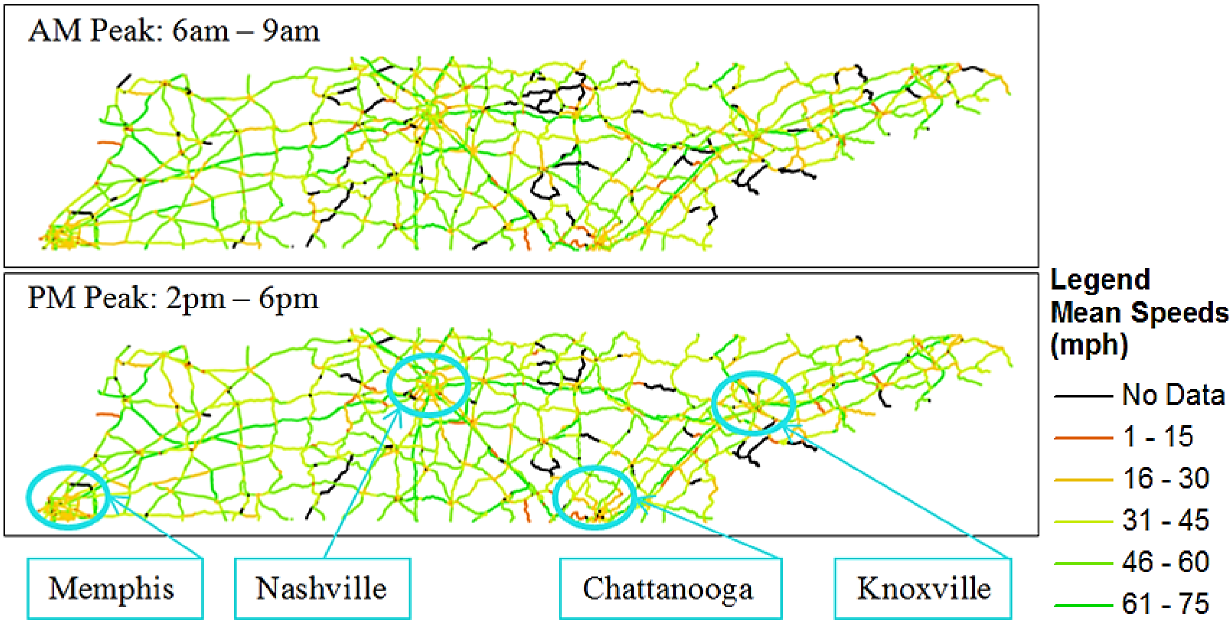
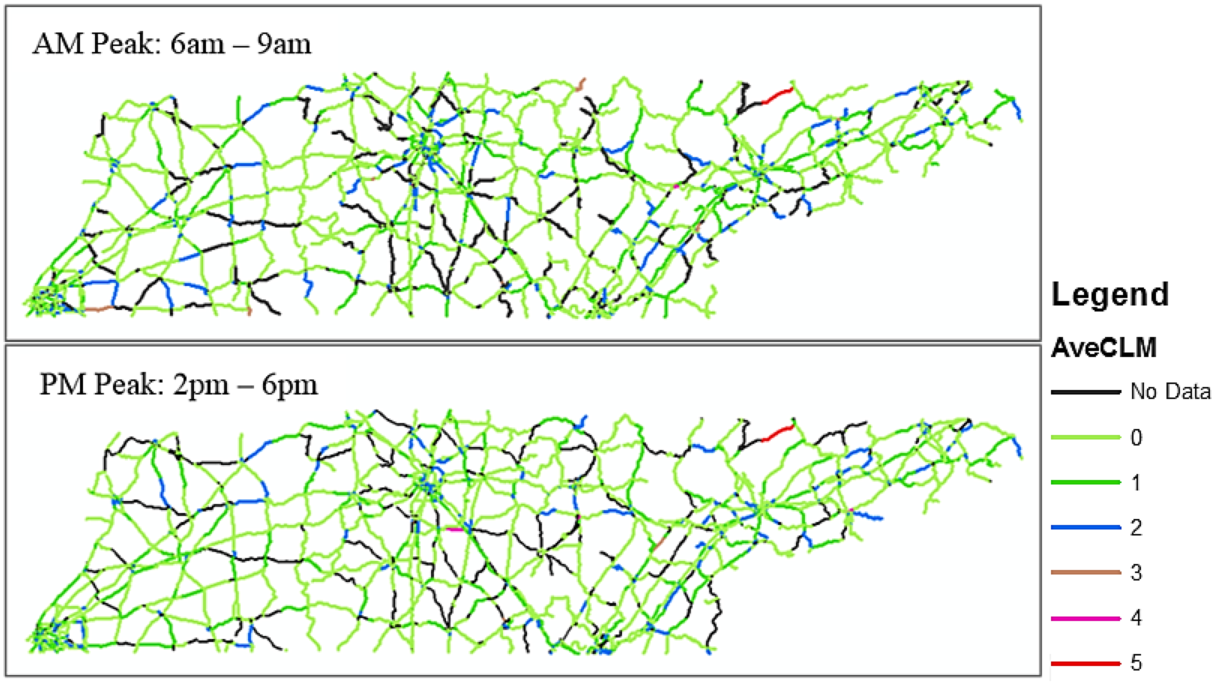


FIGURE 4 Average TS for AM and PM Peak Periods.

Trip-based FPMs

The second analysis aimed to estimate the number of truck trip origins and destinations for each TAZ in TN. The State of TN was divided into 6,095 TAZs. Script "*TripFPMs*" of the developed ArcGIS toolbox was executed using the retrieved GPS data for Mondays-Wednesdays-Fridays of March 2014, and calculated truck trip origins and destinations are presented in Figure 6 for each TAZ. We observe that large metropolitan areas (i.e., Memphis, Nashville, Knoxville, and Chattanooga) produce and attract more truck trips. A significant amount of truck trip origins and destinations was estimated for TAZs, located near the major freight corridors. The latter can be explained by the fact that due to lack of commodity data script "*TripFPMs*" defines truck stops, which do not involve loading/unloading of cargo, as destinations (e.g., refueling stops, rest stops, etc.).

6A: Congested Lane Miles



6B: Hours of Delay

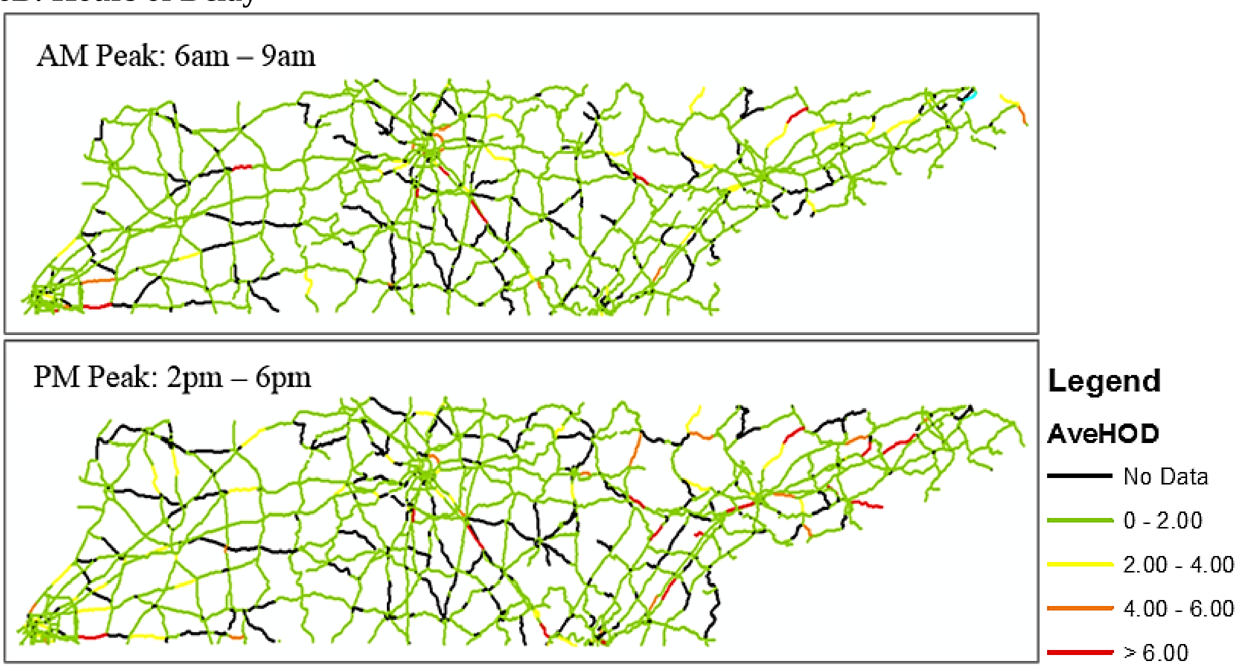


FIGURE 5 Congested Lane Miles and Hours of Delay for AM and PM Peak Periods.

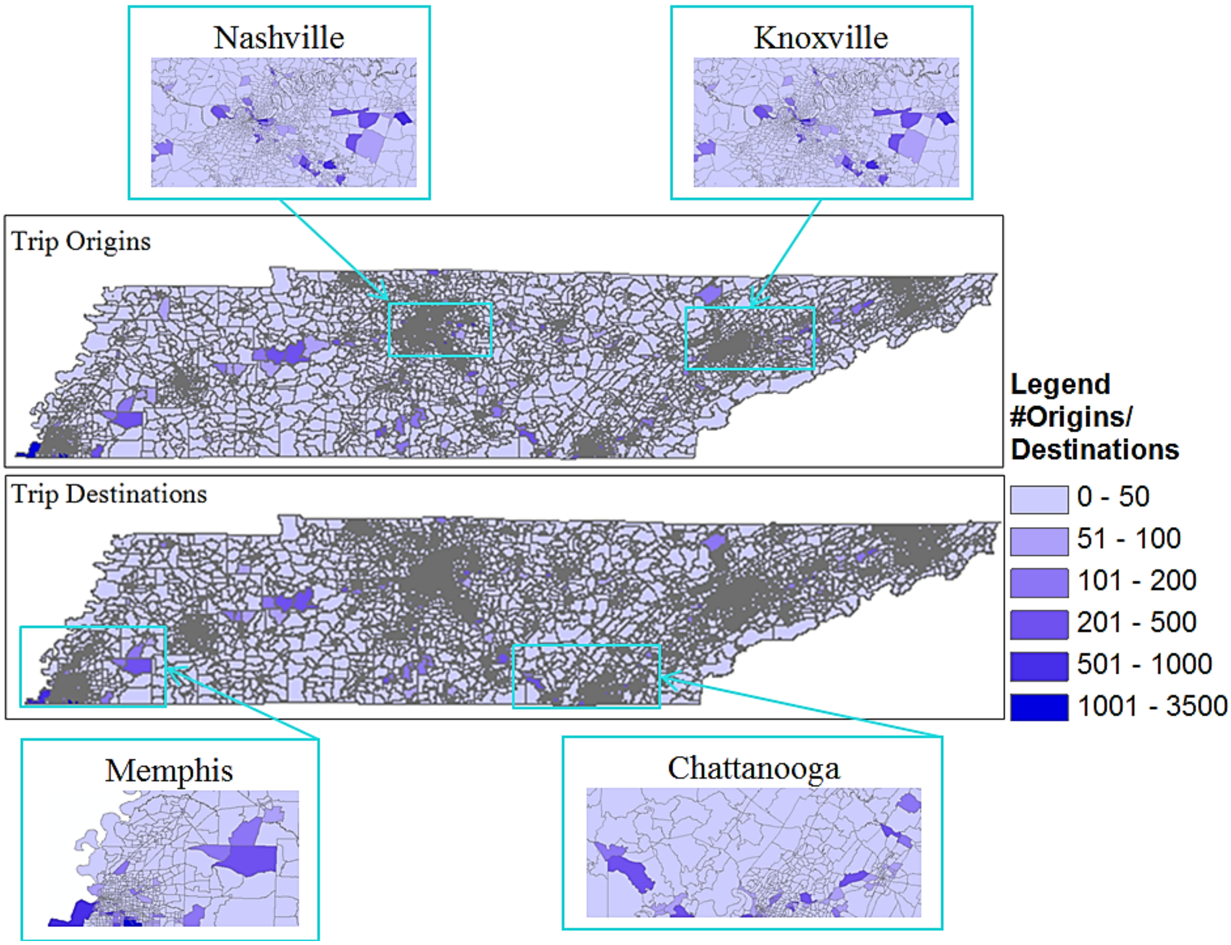


FIGURE 6 Number of Truck Trip Origins and Destinations by TAZ.

Parking-based FPMs

The third analysis aimed to evaluate utilization of TN rest areas. Two rest areas were randomly selected for the analysis. The first rest area (RA1) is located on the I-65 corridor close to Nashville, while the second rest area (RA2) is located on the I-75 corridor between Knoxville and Chattanooga. The average number of trucks by time of day is presented in Figure 7 for each one of the rest areas. It can be observed that rest area RA1 has a higher truck occupancy for a period between 12 am and 4 pm as compared to the period between 4 pm and 12 am, while the truck occupancy for rest area RA2 has multiple spikes (i.e., between 5 am and 11 am, between 12 pm and 2 pm, between 3 pm and 5 pm, etc.).

Freight Facility Analysis

The fourth analysis aimed to estimate the average truck turn times at freight facilities, located in the Greater Memphis Area (TN). Two freight facilities that will be referred to as FF1 and FF2 respectively were randomly selected for a detailed analysis. The average truck turn times by time of entrance are presented in Figure 8 for each one of the freight facilities. For example, the average turn time of trucks, entering freight facility FF1 between 6 pm and 7 pm, comprises 55.5 min. Figure 8 indicates that there are GPS records for certain trucks at FF1 between 12 am and 4 am. The latter can be explained by the fact that those trucks arrived to the facility the day before and were staying overnight. Distribution of truck turn times by time of day can be used by freight facility operators and freight transportation planners in evaluation of the facility performance and bottleneck identification.

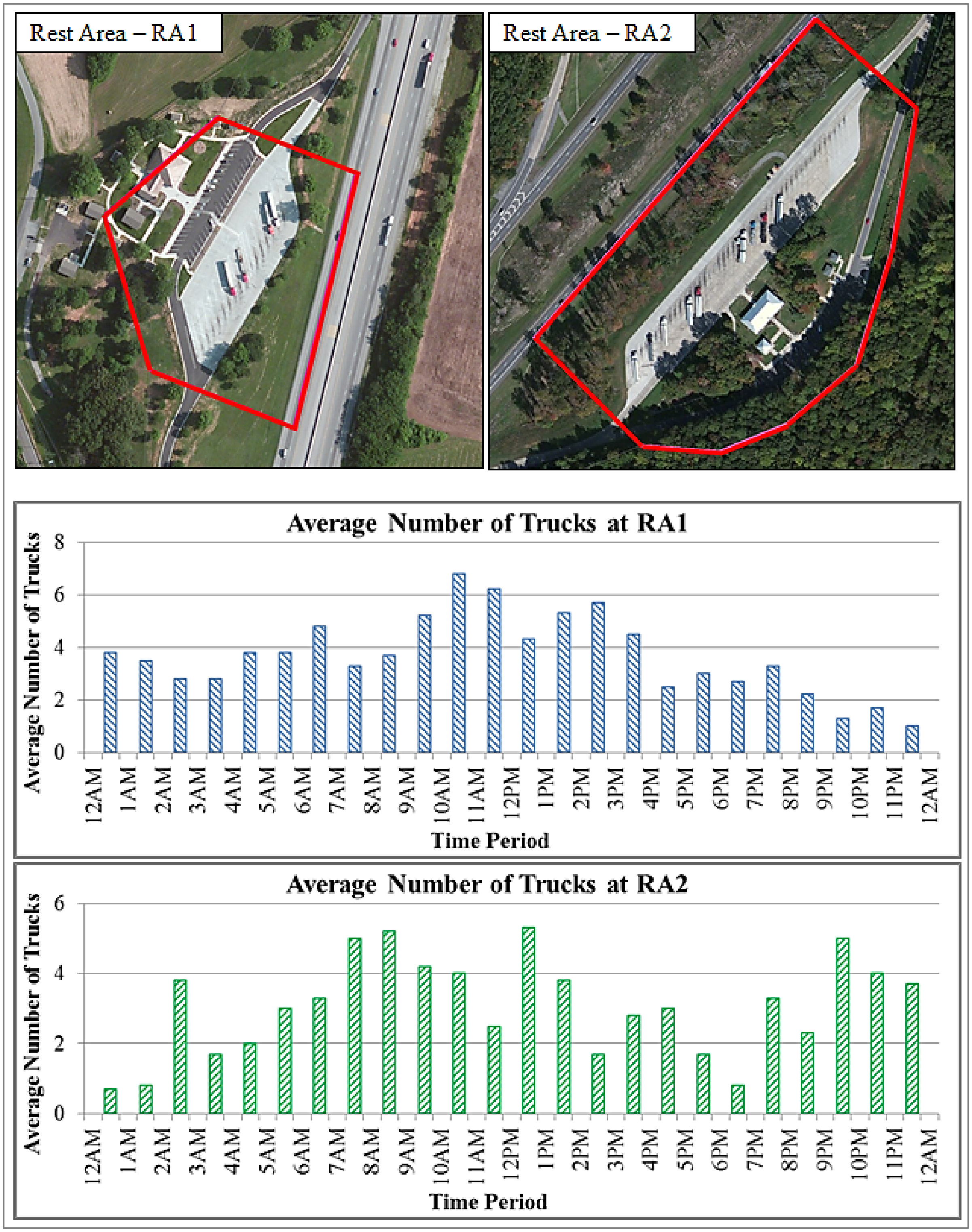


FIGURE 7 Average Number of Trucks at Rest Areas.

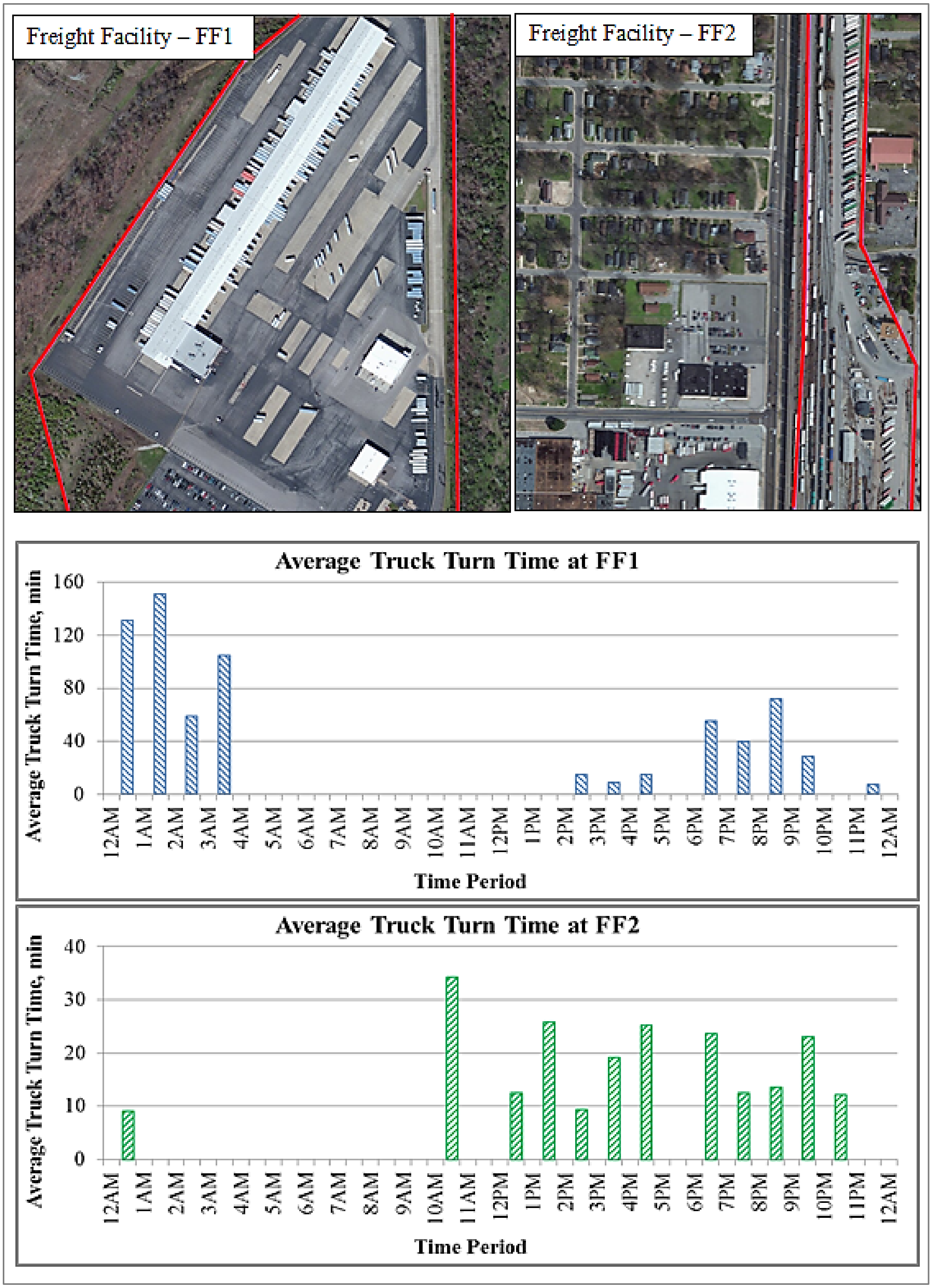


FIGURE 8 Average Truck Turn Times at Freight Facilities.

Discussion

This study presents a standalone application for processing raw truck GPS data and a new ArcGIS toolbox for estimating various types of FPMs. The developed tools can assist private and public stakeholders with bottleneck identification, TT reliability assessment, identification of peak hours, analysis of rest areas and freight facilities, resource allocation between highway segments that may need future improvements, and freight transportation planning. Furthermore, the developed ArcGIS toolbox allows producing colored-theme maps within the ArcGIS environment, which can significantly facilitate evaluation of roadway segments, TAZs, and other freight transportation facilities. The accuracy of computed FPMs can be improved if additional information is provided, including accuracy of GPS devices, commodity data, etc.

CONCLUSIONS AND FUTURE RESEARCH

Considering an increasing congestion issues due to increasing number of trucks on roadways, public and private agencies seek for efficient methodologies and tools that can assist with estimation of performance measures for various transportation facilities and allocation of monetary resources among the roadway segments that may require future improvements. To achieve the latter objective this study proposes two applications which compute performance measures based on the Global Positioning System data, collected from trucks. The first tool allows the user processing raw truck GPS data and extracting the data for certain time periods. The second tool enables the user to load the processed GPS data and calculate a wide range of performance measures within the ArcGIS environment. A case study, performed for transportation facilities located within the State of Tennessee, demonstrate that the developed tools may facilitate bottleneck identification, travel time reliability assessment, identification of peak hours, analysis of rest areas and freight facilities, resource allocation between highway segments that may need future improvements, and freight transportation planning. The scope of future research may focus on the following extensions: 1) apply the developed tools within various U.S. regions; 2) automate production of colored-theme maps; 3) develop a guidebook describing how the developed tool can be used by decision makers in freight transportation planning; and 4) integrate the GPS Data Processing and Extracting Tool and "*GPS-based FPMs Estimation*" Toolbox.

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