

Truck Demand Modeling with ArcInfo 9.0

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Abstract

Linear regression models have been created to estimate truck volumes based on information collected through state traffic monitoring programs and to fill the gap created by the limited availability of observed truck traffic data. Results of such models may be exported into a database and then imported into a GIS framework for visualization and utilization. This procedure creates difficulties in database management and increases the workload and the potential of error. Using ArcObjects, the Center for Advanced Infrastructure in Transportation at Rutgers University has developed an add-on tool that enables the user to perform statistical modeling within ArcView 9 using Linear and Stepwise Regression and Least Squares Optimization. The development of this tool is presented, along with a case study demonstrating its use.

Keywords: ArcInfo, GIS, vehicle-based freight modeling, truck volumes, least squares optimization, linear regression.

INTRODUCTION

Metropolitan Planning Organizations, transportation planners and researchers have attempted to address the issue of forecasting freight supply and demand to estimate future needs. The successful implementation of this type of analysis is held back due to the lack of appropriate freight transportation modeling methodologies, models and data, and due to the complexity of the freight transportation system. According to the Institute of Transportation Engineers (ITE) there are three major widely reported approaches to estimate truck trip data: a) Estimation of simple rates, b) Linear regression models, and c) Commodity flow models. Linear regression models are mainly vehicle-based methods, and can be considered rather simple and straightforward.

This paper, based on a study (Boilé, 2001) conducted by the Center for Advanced Infrastructure and Transportation (CAIT) at Rutgers University, describes a GIS-based tool for estimating truck volumes and flows based on classification counts and socioeconomic data using Linear and Stepwise Regression and Least Squares Optimization. State DOTs may obtain information on truck activity on state highways through their traffic monitoring systems. These systems typically include information on traffic counts taken at various locations throughout the state. Although these counts usually provide a good geographic and temporal coverage for the overall traffic, there are a limited number of classification counts, providing information explicitly on truck volumes. In the future, the increasing use of Intelligent Transportation Systems such as global positioning systems for vehicle tracking, a wider use of Weight-In-Motion stations and better video imaging, have the potential to lessen the problem of limited and insufficient data. These additional data would provide a better geographic coverage in terms of truck volumes on state highways. To improve the current situation, the proposed GIS-based tool will enable state transportation planners to

estimate truck volumes on sections of the highway system where such information is not currently available.

The proposed dynamic tool, linked to a state DOT's traffic monitoring database system would allow for the update of the models and the display of truck volumes (both observed and estimated) on state highways, whenever new data enters the DOT's database. The tool described in this paper is an easy to use, in-house application, which gives state transportation planners the ability to develop truck volume, flow and percentage profiles for any highway in the state and obtain an estimate of truck activity throughout the state. This information could be part of a statewide freight network modeling effort, which state DOTs typically outsource to their consultants. The proposed approach loses some of the functionality of typical freight models in terms of their ability to perform future forecasts and "what-if" type of analyses. On the other hand, however, the proposed approach requires much less data to be available, avoids the series of assumptions made in typical freight models and is an easy to use, in-house application which yields fairly accurate results.

The following section describes the GIS-based tool and its functionality. Results of the application to the estimation of truck volumes on New Jersey highways are also presented. The paper ends with some concluding remarks.

GIS APPLICATION

The main goal of the application is to use statistical techniques to create predictive models for truck volumes on New Jersey roadways, based on nearby land use activities and observations of traffic volumes on some sections of the roadway network. The steps of the modeling approach (fig-1), described in detail in this section, can be summarized as: a) define roadway sections, b) develop the socioeconomic data tables, c) estimate new or update current models, d) predict truck volumes on selected highway sections, and e) create truck volume and percentage profiles for each highway or selected section. The final product is a GIS add-on feature that automates most of the modeling steps and minimizes user modeling efforts. The main desktop tool for this application is ArcView (ESRI) while Matlab is used to create the statistical algorithms and export them into a format suitable for use with Visual Basic for Applications (VBA). VBA (fig. 2) is used to create the GIS add-on feature interface. The rest of this section presents the seven steps of the procedure using snapshots of the application's interface and describes the tool's functionality.

Step 1: Highway Section Definition

The first step of the process is to segment each highway into uniform sections. Econometric data associated with these sections can then be extracted and used as input in the model estimation process. Uniform sections may be defined based on a set of criteria such as major interchanges, changes in roadway functionality and changes in roadway geometry. Provided that these data are available in an electronic format, the user would be able to choose among a set of criteria and create sections for a selected highway or the full road network. If for any of the user defined criteria data are not available in an electronic form, visual observation may be used along with a manual procedure to define the roadway segments.

The length of the sections is highly dependent on the amount of observed counts (the more counts available the smaller the length of the sections). One of the advantages of automating this process is that roadway sections can be re-defined, with a decreased length, whenever a larger dataset of truck classification counts becomes available. Creating smaller sections would produce more accurate estimates and profiles. This part of the tool is under development.

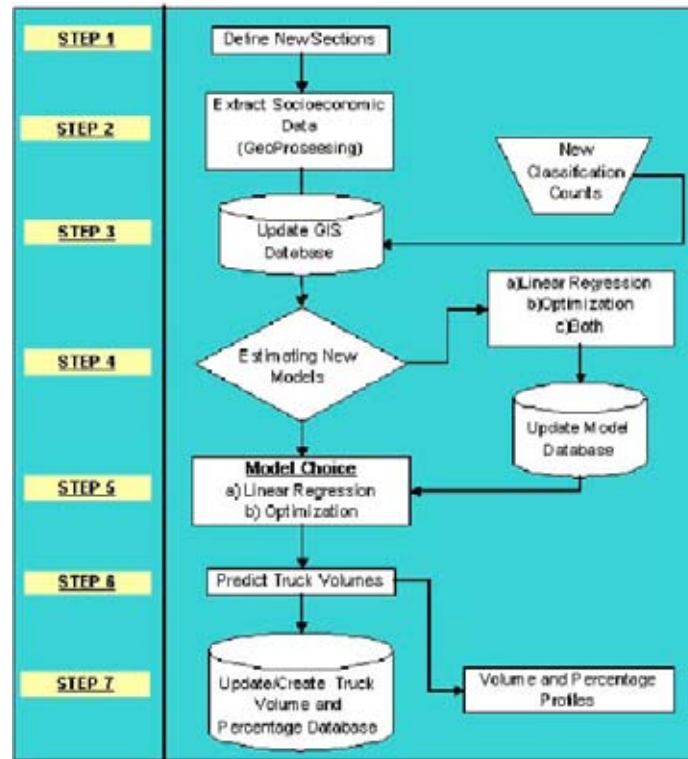


Figure 1: Overall Tool Framework

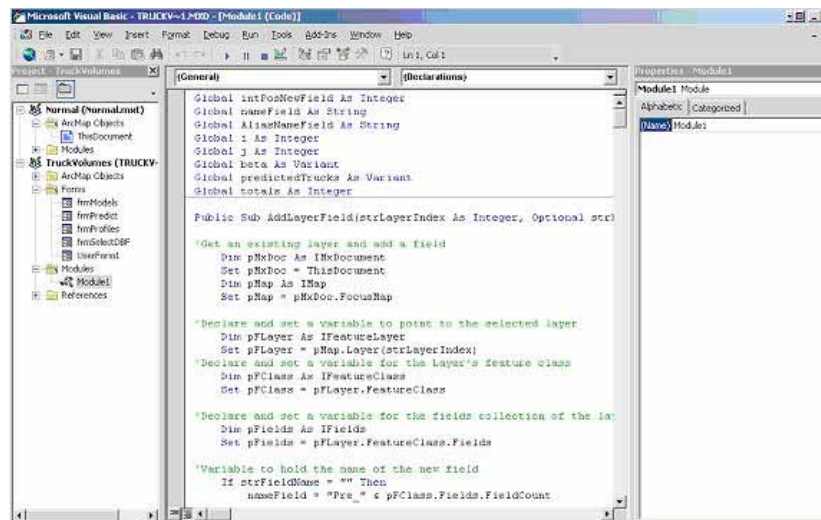


Figure 2: ArcInfo 9.0 VBA Environment

Step 2-3: Input Data

New Jersey DOT has developed a traffic data collection program, through which classified traffic counts are taken at certain locations throughout the state each year. An effort is made to provide good geographic, temporal and spatial, coverage through these counts. It is expected that in the future a larger amount of truck classification counts would be available, which would provide a better geographic coverage in terms of truck volumes on New Jersey state highways.

Socioeconomic data, which are also used as input in the modeling process, are available in electronic form. Related databases are easily updateable whenever new or additional data become available.

Step 4: Model Estimation

Once the necessary input data are obtained the option of updating existing models or estimating new models based on the new data becomes available (fig-3). Three different statistical techniques can be used: a) Linear Regression, b) Stepwise Regression and c) Constrained Least Squares Optimization. Both models assume a linear relationship between truck volumes and socioeconomic data (Eq. 3.1).

$$Y_j = b_0 + b_1 X_{1j} + b_2 X_{2j} + \dots + b_i X_{ij} \text{ (Eq. 3.1)}$$

Where: Y_j = Truck Volume on link j , b_i = linear model coefficients,

X_{ij} = Socioeconomic Data of Variable i on link j

The independent variables that were considered in these models and which are typically used for these types of applications (NCHRP Synthesis 298) are: a) number of employees, b) sales volume, and c) number of establishments, for different Standard Industrial Classification (SIC) categories.

Sensitivity analysis may be performed, according to which truck-generating activity within a band of varying width around each selected roadway link is considered. One of the advantages of incorporating this procedure within the GIS environment is that there is no limitation on the number and type of independent and dependent variables to consider when estimating new models. Furthermore, the tool provides the ability to easily choose among different band sizes for the independent variable dataset, estimate the new models and perform sensitivity analysis.

The models take into account the impact of the roadway functional class (FC) by using clustered data and estimating different models for each class. This clustering considers the fact that different roadways attract different types of truck traffic. In this study a total of 6 different categories were considered: a) Rural interstate and major arterials (FC=1-2), b) Rural minor arterials, collectors, and local (FC=6-9), c) Urban interstate (FC=11), d) Urban expressways and parkways (FC=12), e) Urban major arterials (FC=14), and f) Urban minor arterials, collectors, and local (FC=16-19).



Figure 3: Estimating New Models

Once the model has been trained the regression coefficients can then be saved into a dbf file. The user has two different options: a) update an older model (fig. 4), or b) create a new model (fig. 5). The new model automatically appears in the table of contents.

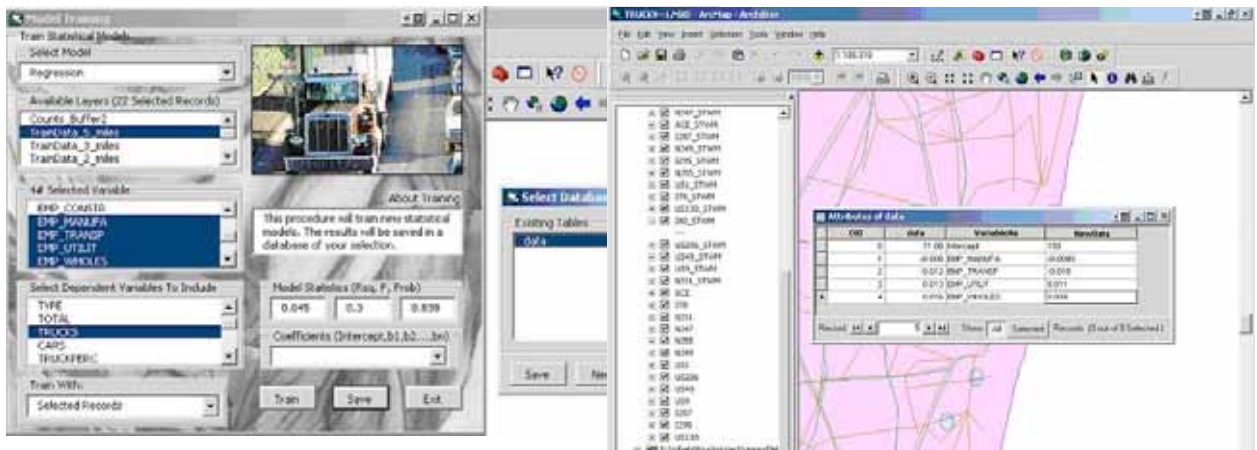


Figure 4: Updating Old Models



Figure 5: Saving New Models

Step 5-6: Prediction

The next two steps of this process is to use the estimated models to predict truck traffic volumes on sections of the NJ street network. The user may select an existing or a newly estimated model to predict truck volumes and generate truck percentage profiles. In figure 6 the model "data" has been selected and 4 independent variables will be used as predictors of truck traffic volumes. The user is asked to enter the name for the new field that will contain the prediction (fig. 7) and the new volumes are added to the attribute table of the layer (fig. 8).



Figure 6: Predicting Truck Volumes

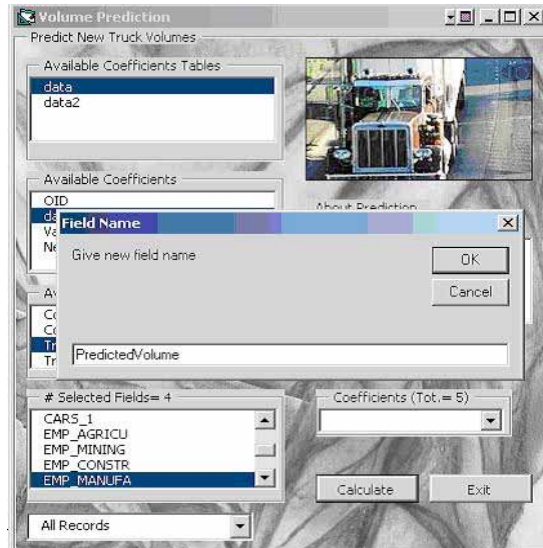
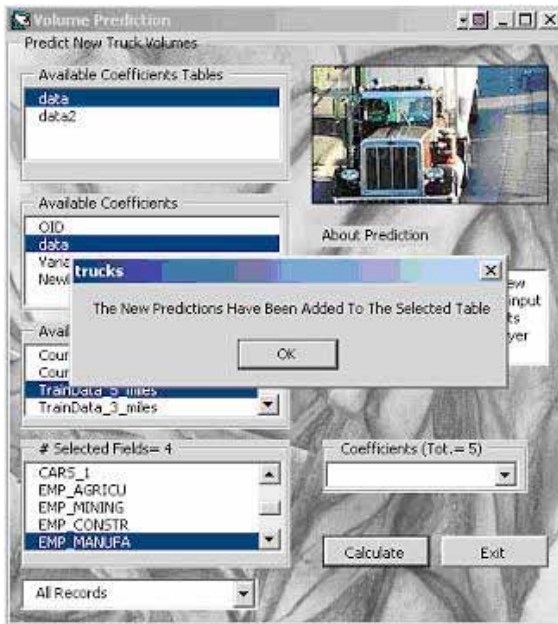


Figure 7: Inserting New Predictions Field Name



COUNT_REAL	COUNT_SERV	estPredict	Predicted%
254	1040	123450	85.18
271	109	81444	94.267
242	862	881181	72.504
32	279	52269	52.269
336	4793	308338	108.181
278	3238	172128	124.571
14	176	19199	68.204
38	721	83296	73.786
18	381	83364	78.601
47	388	8318	88.888
270	3724	183318	98.764
143	2714	181188	82.544
40	181	83289	82.822
3	89	78288	72.338
38	271	9332	89.888
182	2884	158384	185.088
38	278	113238	88.158
10	188	74432	82.118
380	8188	2888	102.82
480	8812	888388	178.818
8	78	72238	72.488
48	488	83178	78.482
38	188	83382	74.182
17	288	117388	70.027
180	112	18882	38.078

Figure 8: Updated Attribute Table with Truck Volume Predictions

Step 7: Visualization

After model estimation and truck volume prediction have been completed, the user may select a highway and view the observed and estimated truck volumes on each defined section, model information for each section (R-square value, band width, etc.), and the profiles of truck volumes and percentages. Figure 9 shows information on the functional class, roadway type, predicted and observed truck volume for each section of Interstate 80, as these are stored in the system's database.

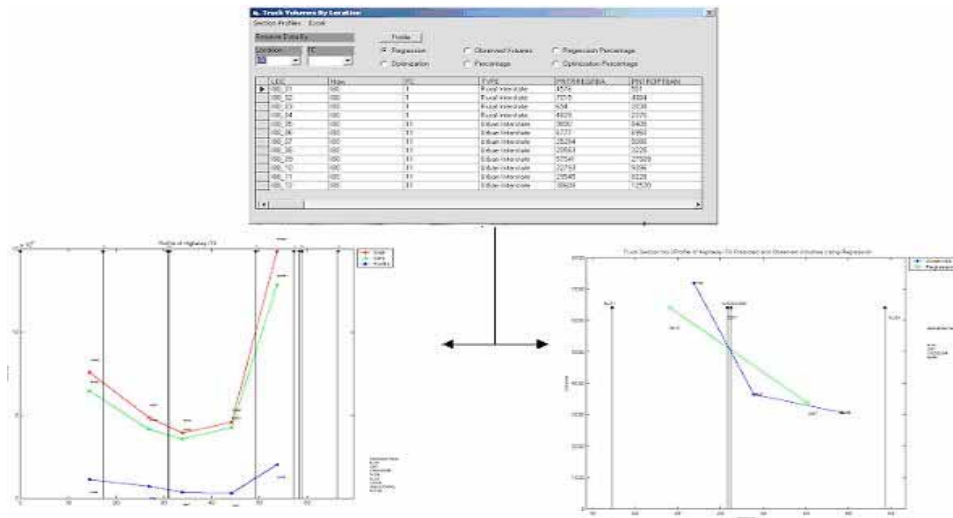
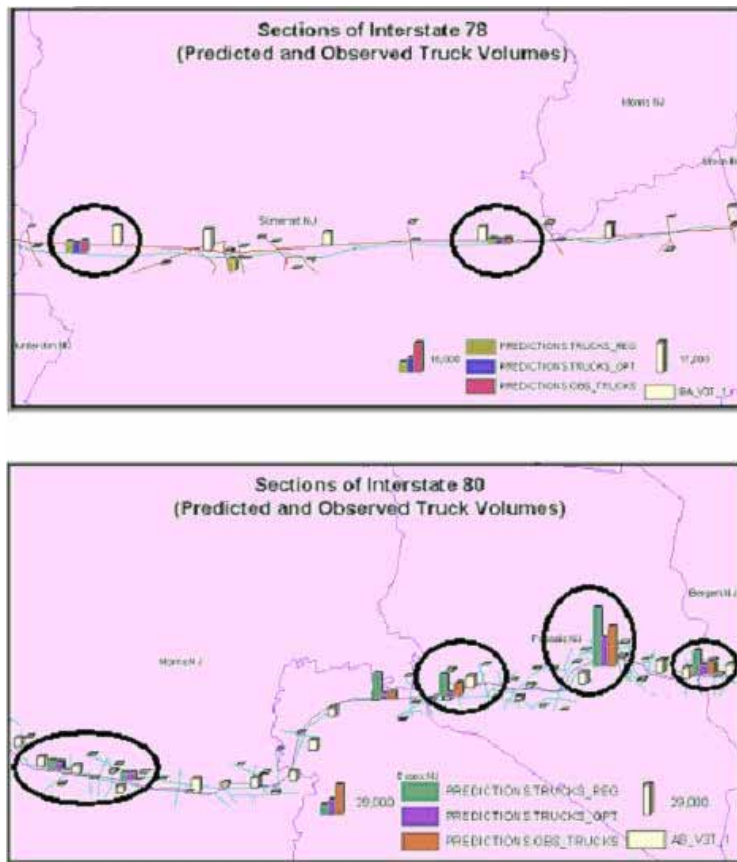


Figure 9: Predicted, Observed Truck Volumes and Profiles Display

In addition, several profiles may be displayed for each roadway, including Predicted Truck Volume Profile (PTVP) using the Regression Model, PTVP using the Optimization Model, Observed Truck and Car Volumes, and Percentages. The user may select a section on a roadway and view the predicted and the observed truck volumes and a comparison of the truck volume on that section of the highway with those on adjacent sections.

MODEL APPLICATION AND RESULTS

Figure 10 shows results of the application of the modeling approach to sections of highways I-78 and I-80. The results indicate that both the ordinary least squares (OLS) and the optimization approach produce estimates that are in the same order of magnitude with the observed volumes. For the purpose of comparison, the volumes produced by the statewide truck model are also included in the figure. A general observation is that the proposed method yields better estimates compared to the statewide truck model.



Trucks_Reg=Predicted Truck Volumes (PTV) using OLS Model, Trucks_Opt=PTV using Optimization Model
 Obs_Truck =Observed Truck Volumes, AB_V3T_1=PTV from SWTM

Figure 10: Observed and Predicted Truck Volumes on I-78 and I-80

The proposed modeling approach relates the truck volume on a roadway section to the truck generating activity in adjacent land. The fact that different roadway classes attract different type of truck traffic (through or local) is accounted for since different models are being developed for different roadway

categories. However, if additional information were available on the amount of through traffic vs. local traffic using the state highways, it could be accounted for in the proposed process and better results could be expected. The through traffic would be subtracted from the vehicle classification counts in the appropriate locations and the models would be re-estimated based only on local traffic, which is better explained by local truck generating activity and land use, compared to through traffic.

The models would also further improve if additional classification counts were available throughout the state. Since a bigger number of such counts are to be taken in the future, it is expected that the model accuracy will further improve.

CONCLUSIONS

This paper presented the implementation of a statistical analysis tool within the ArcMap environment. Using Arc-Objects the Center for Advanced Infrastructure in Transportation at Rutgers University has developed an add-on tool that enables the user to perform statistical modeling within ArcView 9.0 using Linear and Stepwise Regression and Least Squares Optimization. The resulting application allows the estimation of truck volumes on state highway sections and the visualization of the results in terms of estimated and observed truck volumes and percentages. The proposed tool could provide state transportation planners the ability to perform truck volume estimation in-house, using this GIS-based tool which is updated dynamically whenever new traffic counts and socioeconomic data become available. Having access to a tool with this functionality is very important for a state DOT, since truck volume data availability is required for a big number of applications, and having the ability to estimate these data in-house would save both money and time.

ACKNOWLEDGEMENT

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