한정된 O-D조사자료를 이용한 주(州)전체의 트럭교통예측방법 개발

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DEVELOPMENT OF STATEWIDE TRUCK TRAFFIC FORECASTING METHOD BY USING LIMITED O-D SURVEY DATA

by

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1 Summary

The objective of this research is to test the feasibility of developing a statewide truck traffic forecasting methodology for Wisconsin by using Origin-Destination surveys, traffic counts, classification counts, and other data that are routinely collected by the Wisconsin Department of Transportation (WisDOT). Development of a feasible model will permit estimation of future truck traffic for every major link in the network. This will provide the basis for improved estimation of future pavement deterioration.

Pavement damage rises exponentially as axle weight increases, and trucks are responsible for most of the traffic-induced damage to pavement. Consequently, forecasts of truck traffic are critical to pavement management systems. The pavement Management Decision Supporting System (PMDSS) prepared by WisDOT in May 1990 combines pavement inventory and performance data with a knowledge base consisting of rules for evaluation, problem identification and rehabilitation recommendation. Without a reasonable truck traffic forecasting methodology, PMDSS is not able to project pavement performance trends in order to make assessment and recommendations in the future years. However, none of WisDOT's existing forecasting methodologies has been designed specifically for predicting truck movements on a statewide highway network.

For this research, the Origin-Destination survey data available from WisDOT, including two stateline areas, one county, and five cities, are analyzed and the zone-to-zone truck trip tables are developed. The resulting Origin-Destination Trip Length Frequency (OD TLF) distributions by trip type are applied to the Gravity Model (GM) for comparison with comparable TLFs from the GM.

The gravity model is calibrated to obtain friction factor curves for the three trip types, Internal-Internal (I-I), Internal-External (I-E), and External-External (E-E). Both "macro-scale" calibration and "micro-scale" calibration are performed. The comparison of the statewide GM TLF with the OD TLF for the macro-scale calibration does not provide suitable results because the available OD survey data do not represent an unbiased sample of statewide truck trips. For the "micro-scale" calibration, "partial" GM trip tables that correspond to the OD survey trip tables are extracted from the full statewide GM trip table. These "partial" GM trip tables are then merged and a partial GM TLF is created. The GM friction factor curves are adjusted until the partial GM TLF matches the OD TLF. Three friction factor curves, one for each trip type, resulting from the micro-scale calibration produce a reasonable GM truck trip model.

A key methodological issue for GM calibration involves the use of multiple friction factor curves versus a single friction factor curve for each trip type in order to estimate truck trips with reasonable accuracy. A single friction factor curve for each of the three trip types was found to reproduce the OD TLFs from the calibration data base. Given the very limited trip generation data available for this research, additional refinement of the gravity model using multiple friction factor curves for each trip type was not warranted.

In the traditional urban transportation planning studies, the zonal trip productions and attractions and region-wide OD TLFs are available. However, for this research, the information available for the development of the GM model is limited to Ground Counts (GC) and a limited set of OD TLFs. The GM is calibrated using the limited OD data, but the OD data are not adequate to obtain good estimates of truck trip productions and attractions. Consequently, zonal productions and attractions are estimated using zonal population as a first approximation. Then, Selected Link based (SELINK) analyses are used to adjust the productions and attractions and possibly recalibrate the GM.

The SELINK adjustment process involves identifying the origins and destinations of all truck trips that are assigned to a specified "selected link" as the result of a standard traffic assignment. A link adjustment factor is computed as the ratio of the actual volume for the link (ground count) to the total assigned volume. This link adjustment factor is then applied to all of the origin and destination zones of the trips using that "selected link".

Selected link based analyses are conducted by using both 16 selected links and 32 selected links. The result of SELINK analysis by using 32 selected links provides the least %RMSE in the screenline volume analysis. In addition, the stability of the GM truck estimating model is preserved by using 32 selected links with three SELINK adjustments, that is, the GM remains calibrated despite substantial changes in the input productions and attractions. The coverage of zones provided by 32 selected links is satisfactory. Increasing the number of repetitions beyond four is not reasonable because the stability of GM model in reproducing the OD TLF reaches its limits. The total volume of truck traffic captured by 32 selected links is 107% of total trip productions. But more importantly, SELINK adjustment factors for all of the zones can be computed. Evaluation of the travel demand model resulting from the SELINK adjustments is conducted by using screenline volume analysis, functional class and route specific volume analysis, area specific volume analysis, production and attraction analysis, and Vehicle Miles of Travel (VMT) analysis.

Screenline volume analysis by using four screenlines with 28 check points are used for evaluation of the adequacy of the overall model. The total trucks crossing the screenlines are compared to the ground count totals. LV/GC ratios of 0.958 by using 32 selected links and 1.001 by using 16 selected links are obtained. The %RMSE for the four screenlines is inversely proportional to the average ground count totals by screenline. The magnitude of %RMSE for the four screenlines resulting from the fourth and last GM run by using 32 and 16 selected links is 22% and 31% respectively. These results are similar to the overall %RMSE achieved for the 32 and 16 selected links themselves of 19% and 33% respectively. This implies that the SELINK analysis results are reasonable for all sections of the state.

Functional class and route specific volume analysis is possible by using the available 154 classification count check points. The truck traffic crossing the Interstate highways (ISH) with 37 check points, the US highways (USH) with 50 check points, and the State highways (STH) with 67 check points is compared to the actual ground count totals. The magnitude of the overall link volume to ground count ratio by route does not provide any specific pattern of over or underestimate. However, the %RMSE for the ISH shows the least value while that for the STH shows the largest value. This pattern is consistent with the screenline analysis and the overall relationship between %RMSE and ground count volume groups.

Area specific volume analysis provides another broad statewide measure of the performance of the overall model. The truck traffic in the North area with 26 check points, the West area with 36 check points, the East area with 29 check points, and the South area with 64 check points are compared to the actual ground count totals. The four areas show similar results. No specific patterns in the LV/GC ratio by area are found. In addition, the %RMSE is computed for each of the four areas. The %RMSEs for the North, West, East, and South areas are 92%, 49%, 27%, and 35% respectively, whereas, the average ground counts are 481, 1383, 1532, and 3154 respectively. As for the screenline and volume range analyses, the %RMSE is inversely related to average link volume.

The SELINK adjustments of productions and attractions resulted in a very substantial reduction in the total in-state zonal productions and attractions. The initial in-state zonal trip generation model can now be revised with a new trip production's trip rate (total adjusted productions/total population) and a new trip attraction's trip rate. Revised zonal production and attraction adjustment factors can then be developed that only reflect the impact of the SELINK adjustments that cause increases or decreases from the revised zonal estimate of productions and attractions.

Analysis of the revised production adjustment factors is conducted by plotting the factors on the state map. The east area of the state including the counties of Brown, Outagamie, Shawano, Winnebago, Fond du Lac, Marathon shows comparatively large values of the revised adjustment factors. Overall, both small and large values of the revised adjustment factors are scattered around Wisconsin. This suggests that more independent variables beyond just population are needed for the development of the heavy truck trip generation model. More independent variables including zonal employment data (office employees and manufacturing employees) by industry type, zonal private trucks owned and zonal income data which are not available currently should be considered. A plot of frequency distribution of the in-state zones as a function of the revised production and attraction adjustment factors shows the overall adjustment resulting from the SELINK analysis process. Overall, the revised SELINK adjustments show that the productions for many zones are reduced by a factor of 0.5 to 0.8 while the productions for a relatively few zones are increased by factors from 1.1 to 4 with most of the factors in the 3.0 range. No obvious explanation for the frequency distribution could be found. The revised SELINK adjustments overall appear to be reasonable.

The heavy truck VMT analysis is conducted by comparing the 1990 heavy truck VMT that is forecasted by the GM truck forecasting model, 2.975 billions, with the WisDOT computed data. This gives an estimate that is 18.3% less than the WisDOT computation of 3.642 billions of VMT. The WisDOT estimates are based on the sampling the link volumes for USH, STH, and CTH. This implies potential error in sampling the average link volume.

The WisDOT estimate of heavy truck VMT cannot be tabulated by the three trip types, I-I, I-E (E-I), and E-E. In contrast, the GM forecasting model shows that the proportion of E-E VMT out of total VMT is 21.24%. In addition, tabulation of heavy truck VMT by route functional class shows that the proportion of truck traffic traversing the freeways and expressways is 76.5%. Only 14.1% of total freeway truck traffic is I-I trips, while 80% of total collector truck traffic is I-I trips. This implies that freeways are traversed mainly by I-E and E-E truck traffic while collectors are used mainly by I-I truck traffic. Other tabulations such as average heavy truck speed by trip type, average travel distance by trip type and the VMT distribution by trip type, route functional class and travel speed are useful information for highway planners to understand the characteristics of statewide heavy truck trip patterns.

Heavy truck volumes for the target year 2010 are forecasted by using the GM truck forecasting model. Four scenarios are used. For better forecasting, ground count-based segment adjustment factors are developed and applied. ISH 90 & 94 and USH 41 are used as example routes. The forecasting results by using the ground count-based segment adjustment factors are satisfactory for long range planning purposes, but additional ground counts would be useful for USH 41.

Sensitivity analysis provides estimates of the impacts of the alternative growth rates including information about changes in the trip types using key routes. The network-based GM can easily model scenarios with different rates of growth in rural versus urban areas, small versus large cities, and in-state zones versus external stations.

2 Conclusions

First of all, a gravity model (GM) for forecasting truck trips statewide is developed by using limited Origin-Destination survey data and classification count data for a limited number of selected links. Thus, the primary objective of this research is fulfilled. The model is validated by comparing estimated link volumes with ground counts through analysis of % Root Mean Square Error (%RMSE), screenline comparisons, functional class and route specific volume comparisons, area specific volume comparisons, vehicle miles of travel (VMT) comparisons, and some example routes including ISH 90 & 94 and USH 41.

The first advantage of the fulfilling the primary objective of this research is that forecasting heavy truck traffic both for the total volumes and volumes by trip type is possible for all links while the conventional extrapolation of individual ground counts can provide only estimates of total truck volumes for the limited number of links where ground count data are available. Considering that pavement deterioration is caused by the number of repetitions of axle loads and pavement repairing or rehabilitation is planned on a link basis, truck traffic forecasting on a link by link basis can be critical information for statewide highway pavement management.

Second, the GM forecasting model can provide information about the impacts of the alternative growth rates. The trip types of the truck traffic traversing each route are not similar. Some routes are traversed by External-External (E-E) trips predominantly and some other routes are used by Internal-Internal (I-I) trips or Internal-External (I-E) trips mainly. The alternative growth impacts and trip type information can be obtained by sensitivity analysis using the GM truck forecasting model as demonstrated for the example routes, ISH 90 & 94 and USH 41. Understanding the impacts of the alternative growth rates is important information for the highway planner, because this can be related to the impacts of future economic development and land use.

Third, estimation of heavy truck VMT by trip type, functional class and speed range is an additional advantage for this research. WisDOT has computed statewide heavy truck VMT, but VMT by trip type, functional class and speed range has not been available. The GM truck forecasting model provides the detailed information. The information on heavy truck VMT by trip type, functional class and speed range can be used for statewide highway planning, highway safety analysis, travel trend analysis, and air quality analysis.

Fourth, the GM truck model can be used to identify and classify uniform truck volume segments for traffic monitoring purposes. Only a single count station is needed for all the links within the uniform truck volume segment, even though the length of this uniform segment may be relatively long. In contrast, if the truck volume is not uniform and the volume fluctuation is great, the length of a uniform segment may be very short. In this case, more frequent traffic count stations corresponding to the number of uniform segments will be required. This kind of information is available from the GM truck forecasting model. If there are two count stations in the same uniform segment, one of them can be eliminated or moved to another necessary segment. These uniform segments provide the basis for "ground count-based segment adjustment factors". By using these, better projections of future truck traffic are possible. This is validated for the example routes ISH 90 & 94 and USH 41.

Finally, the analyses of the productions and attractions resulting from the selected link-based (SELINK) adjustments reveal that the truck trip productions and attractions model based on population alone is inadequate. More independent variables such as zonal employment data (office employees and manufacturing employees) by industry type, zonal private trucks owned and zonal income data are needed to estimate truck trip productions and attractions more accurately. The base year 1990 truck productions and attractions from the GM model as adjusted by the SELINK analysis process can be used as a foundation for the development of improved truck trip productions and attractions models in the future when additional independent variables at the zonal level are available.

3 Recommendations for Additional Research

This research was constrained by data limitations. GM calibration was conducted using limited OD survey data. The macro-scale calibration and validation showed that the available OD data are not an unbiased sample for the entire state. Consequently, the GM friction factors were developed based on micro-scale calibration and validation. Potential bias in the development of the friction factors can't be eliminated completely, but the bias is thought to be small compared to other sources of bias. Further research is needed to identify the extent to which more OD survey data would contribute to improving the accuracy of the estimation of truck trips statewide. More OD survey data should decrease the potential bias in the friction factor curves.

The selected link (SELINK) analysis is conducted manually. In order to load selected links, a list of links to be analyzed must be specified in the TRANPLAN software. Trips traversing a listed link will be loaded on the network. The total number of selected links traversed may not exceed 10 in each TRANPLAN run. Thus, using 32 selected links for the SELINK analysis requires four runs of "load highway selected link" (LHSL). In addition, the creation of the production and attraction adjustment factors is performed by using the results of SELINK analysis. Conducting this procedure manually is time consuming and requires patience. Thus, automation of this procedure is recommended to expedite further research.

The classification count data needed for the SELINK analysis process are obtained for locations that have a three year count cycle. Further research is needed on the benefits of having more frequent classification counts at key locations. Also, more data on seasonal variations of truck trips and seasonal variations in the proportion of truck trips is needed.

The different types of heavy trucks have different axle loads, and cause different damage to the pavement. The GM truck forecasting model developed in this research estimates heavy truck trips overall regardless of the type of truck. More detailed models could not be developed in part because there are inconsistencies in the heavy truck classifications between the OD survey data and the vehicle classification count data. Further research is needed to develop a standard distribution of heavy truck types by each route and each segment and to be able to apply it to compute the appropriate axle load.