EXPRESS BUS RIDERSHIP MODELING IN EMME SOFTWARE

Md. Shahid Mamun[(1)]

[(1)]Department of Civil Engineering, Ahsanullah University of Science and Technology, Tejgaon, Dhaka, Bangladesh.

Email:smamun93@hotmail.com, mamun.ce@aust.edu

ABSTRACT

EMME software is extensively used in the planning of urban roads and transit networks. But unfortunately, current EMME-based models are not capable of properly representing express bus services in the Greater Toronto Area (GTA). This study focuses on finding a solution to this problem. Three approaches are investigated. First, different combinations of user adjustable parameters of EMME are explored to see if they result in improved express bus assignments. Second, adjustments to the representation of the express bus attributes (artificially decreasing speeds and increasing headways for the express bus routes) are investigated. Finally, a sub-mode split model is developed in which original demand matrix is split into two demand matrices (one for express bus and other for local bus) and assigned separately to the GTA transit network in EMME. For this purpose logit mode choice models are developed and estimated to predict express bus and local bus demand.

Key Words: EMME, Express bus, GTA, Mode choice, logit model.

1.0 INTRODUCTION

Computer-based models are extensively used in the planning of urban roads and transit networks. Estimating the demand for transportation facilities and services is one of the most important analysis tasks in this area. In order to facilitate this analysis, planners use a variety of software. EMME ("Equilibre Multimodal, Multimodal Equilibrium") is one such package. It is designed to provide a flexible modeling environment for the specification, implementation and efficient application of urban and regional urban transportation methods. Some of the main purposes of this software are travel demand modeling, multimodal network modeling and analysis, and as an evaluation procedure to determine the effectiveness of an existing transportation network.

A computer network (road and transit) for the Greater Toronto Area (GTA) has already been developed and implemented in EMME. Travel demand origin-destination (O-D) trip matrices for 1986, 1991, 1996 and 2001 are also available from Transportation Tomorrow Survey (TTS) data. So, one should be able to use this network for different purposes. But unfortunately it has been found that EMME does not provide good prediction of express bus (e.g. GO bus) ridership with the current transit networks and demand matrices. In particular, express bus ridership tends to be significantly over predicted in the current models. Because the characteristics of express buses (e.g. GO bus) are different from regular buses. They have lower frequency but higher speed. At the same time, their fares are much higher than regular buses. Frequency and speed are used in the current route choice algorithm of EMME. However, there is no direct way to incorporate the higher fare of the GO bus mode into the EMME assignment algorithm. As a result it is not surprising that EMME predicts much more ridership for each individual GO bus route than originally recorded by TTS. So, this research focuses on finding a solution to overcome the problem. The original intention was to evaluate and model all type of express buses. But due to the lack of data and available time this work is limited only to GO buses.

2.0 DESCRIPTION OF THE DATA

Three data files are used in this research to develop the proposed model. These three data files are originally extracted from the 1996 TTS (1) to support updating the GTAModel (2) to incorporate the 1996 TTS information. For the GTAModel, three separate files were created according to three trip purposes (work trip, school trip and other trip). Thus, collectively, the three files contain all the trips made during the morning peak-period (6:00 a.m. to 8:59 a.m.) whose origins and destinations are within the GTA. The 1996 TTS consisted of 5% sample (total households of 115,193) of all households which was randomly selected from the survey area. Since the data represented a small portion of the actual population in the survey area, an expansion factor was then applied to the data to achieve the total population.

3.0 PERFORMANCE OF THE CURRENT METHOD

In this section, we present the current performance of EMME regarding GO bus demand forecasting. For this purpose, the 1996 GTA network is loaded in EMME. Then peak-time (6:00 a.m. to 8:59 a.m.) transit demand (without GO Rail) whose origins and destinations are within the GTA is assigned to the network. The standard aggregate EMME transit assignment is used. The peak time (6:00-8:59) boardings of GO bus obtained from EMME run are compared with TTS records. But, in EMME the line descriptions are not always identical to the actual line descriptions found in TTS. Sometimes, a single line is subdivided into several routes in EMME according to their respective frequencies. This is why the ridership (boardings) of sub routes are added before comparing the result. On the other hand, the TTS 1996 Data Guide provides only 24 hour ridership (boardings). As a result, peak time ridership (boardings) for transit was extracted directly from the TTS database using the iDRS data retrieval system. Moreover, TTS divides every transit lines into five sub-routes. So ridership (boardings) of each sub-route was extracted and then, finally, all five routes are added. So, some discrepancies were found between EMME and TTS line descriptions. Some transit lines appear in TTS but those are missing in EMME and vice versa. For our comparison purpose we simply ignored these lines.

3.1 Current Assignment Results

In order to run standard transit assignments in EMME several user-adjustable parameters (boarding times, wait time factors, wait time weight, auxiliary transit time weight & boarding time weight) are required. Results from EMME runs more or less depend on these parameters. Finding the best set of parameters to use, however, is a difficult process. Modelers generally rely on trial and error process to determine these parameters. As this research is concerned only with the GTA, as a basecase, the assignment parameters currently used in the GTAModel (2) were used.

The current GTAModel assignment parameters are as follows: Boarding time (min) = 0, Wait time factor = 0.5, Wait time weight = 1.23, Auxiliary transit time weight=2.65, Boarding time weight = 0. Active transit and auxiliary transit modes for assignment: Mode(s) = w t b m g s l (as our demand matrix does not contain GO rail riders, the mode r for GO rail was not used in the assignment).

The output results using these parameters, the base GTA 1996 transit network and observed 1996 TTS transit O-D flows are presented in Figure 1. Peak time (6:00-8:59) boardings of each individual GO bus lines obtained from EMME are compared with TTS counts. For this base case (with GTA Model parameters) EMME predicts two to eighteen times higher boardings for different lines (except 8= Yonge Service, 11= Newmarket-Yorkdale EX and 12= Bradford-Newmarket). Total boardings predicted by EMME are 32705, compared to the TTS count of 9607. The Global Relative Error (GRE) is 2.72. That means error between real count and EMME is 272%. As EMME drastically over-predicts GO bus usage (compared to reported TTS counts) for this base case, the result is absolutely unusable.

$$GRE= \frac{\sum abs(boardings_{observed} - boardings_{predicted})}{\sum boardings_{observed}})$$

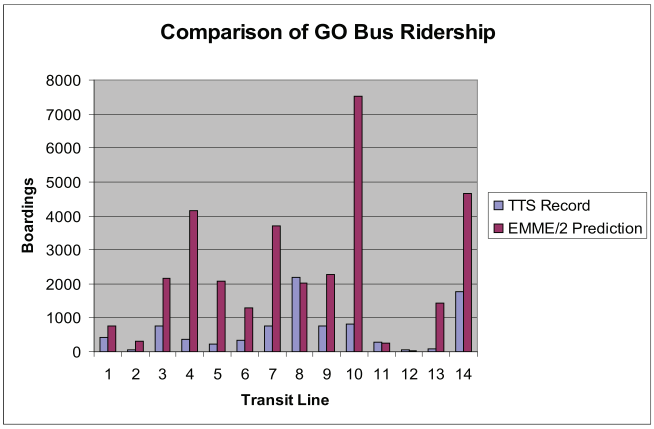

Fig-1: Comparison of GO Bus Ridership (Original Demand Matrix)

3.2 Adjustment to the Assignment Parameters

One possible cause of this over prediction of GO bus ridership is that the current GTAModel assignment parameters are not optimal. So, various arbitrarily chosen sets of parameters were tested to see if they could improve the performance of EMME regarding GO bus ridership prediction. Fourteen trial sets were tested. The wait time factor was kept fixed at 0.5 (for constant inter-arrival time of the vehicles), while other parameters were varied from 0 to 3. Their performances are judged on the basis of total boardings and the Global Relative Error (GRE) in predicted versus observed boardings.

The values of the trial parameters set and their results are presented in Table 1. From the results it can be seen that, while some parameter sets resulted in some modest improvements in GO bus predictions, all sets tested still yielded significant, systematic over-predictions of GO bus ridership. Total boardings obtained from the best trial parameter set are 16653, with a GRE of 0.96. That means predicted boardings are still far from actual counts. Further, change in assignment parameters did not necessarily improve overall transit assignment results. It is concluded that change in transit assignment parameter values alone cannot resolve the GO bus over-prediction problem

Table-1: GO Bus ridership for Different Sets of Parameters

Trial No.	Assignment Parameters					Result		
	Board-ing Time	Wait Time Factor	Wait Time Weight	Aux. Transit Time Weight	Board-Time Weight	TTS Record (Total Boardin	EMME Prediction (Total Boarding)	GRE (Global Relative Error)
1	2.5	0.5	2.00	2.00	2.0	9607	19422	1.32
2	0.5	0.5	1.23	2.65	1.0	9607	30482	2.52
3	0.5	0.5	1.23	2.65	2.0	9607	29016	2.36
4	0.5	0.5	1.23	2.65	3.0	9607	27557	2.23
5	1.0	0.5	1.23	2.65	3.0	9607	24602	1.92
6	2.0	0.5	1.23	2.65	3.0	9607	22062	1.68
7	3.0	0.5	1.23	2.65	3.0	9607	19917	1.45
8	3.0	0.5	1.00	2.65	3.0	9607	20612	1.54
9	3.0	0.5	2.00	2.65	3.0	9607	18612	1.30
10	3.0	0.5	3.00	2.65	3.0	9607	17395	1.11
11	3.0	0.5	3.00	2.00	3.0	9607	17195	1.08
12	3.0	0.5	3.00	3.00	3.0	9607	17450	1.13
13	3.0	0.5	3.00	1.50	3.0	9607	16841	0.99
14	3.0	0.5	3.00	1.00	3.0	9607	16653	0.96

3.3 Adjustment to GO Bus Attribute

The transit assignment algorithm is based on the optimal strategy (3). In this algorithm route choice depends on the overall expected travel time (i.e. sum of wait time, in-vehicle travel time, auxiliary transit time, etc.) of the given transit route. As, in every case, EMME over-predicts GO bus riders, the attempt was made to make GO buses less attractive to the assignment algorithm. By artificially increasing the overall travel time of every GO bus route. The rationale is to use a time penalty on GO bus routes to compensate for their higher fares and lower frequencies. Two different methods are used to achieve this goal. First, the speeds of all GO bus routes were decreased by a specified percentage (10%, 20% & 30%) from their original speeds. Second, headways of all routes were increased by 10%, 20% and 30% from their original values. These changes were performed (using Module 2.2) one at a time and analyzed separately. In every case the base (GTAModel) parameter set was used. The performance of these adjusted attributes is again judged on the basis of total boardings and Global Relative Error (GRE). A short tabulated result is presented in Table 2. Details results of these changes are presented in Figures 2 and 3. From the results it can be seen that decreasing GO bus speed results in a slight improvement. And increasing GO bus headway also results in some improvements. These improvements, however, are very small. A GRE of 1.86 (the best among our trial changes) is obtained when speed is reduced by 30%. Further improvement could be achieved by reducing the more percentage of speed. But it is not rational to use abnormally low speed of GO buses. So it is clear that current method of EMME is unable to handle expresses (GO bus) in the GTA.

Table-2: GO Bus Ridership for Different Speeds and Headways

Trial No.	Feature (For every GO bus routes)	TTS Record (Total Boarding)	EMME Prediction (Total Boarding)	Global Relative Error (GRE)
1	Speed decreased by 10%	9607	29696	2.39
2	Speed decreased by 20%	9607	27273	2.14
3	Speed decreased by 30%	9607	24397	1.86
4	HDWY increased by 10%	9607	31368	2.53
5	HDWY increased by 20%	9607	29773	2.35
6	HDWY increased by 30%	9607	27669	2.14

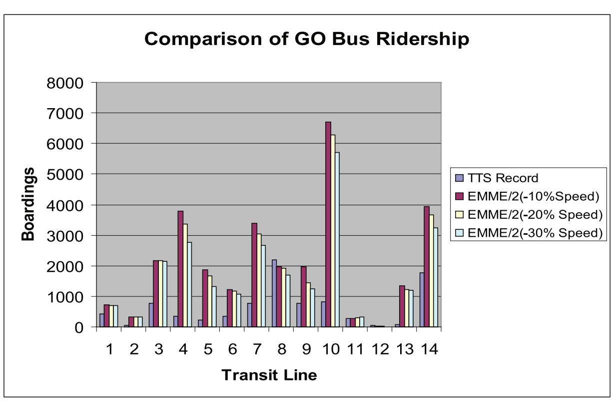

Fig-2: Comparison of GO Bus Ridership (For Different Speeds)

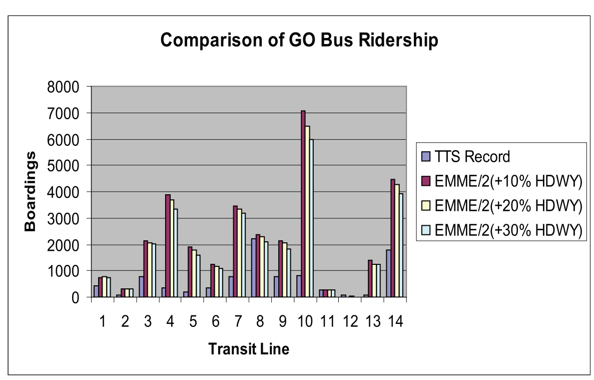

Fig-3: Comparison of GO Bus Ridership (For Different Headways)

4.0 SUB-MODE CHOICE MODEL

It was found that current method of EMME is not capable of properly handling express buses in the GTA. Therefore, a sub-mode choice model is proposed as an alternate solution to overcome this problem. Logit models were developed and estimated to model the sub-mode choice. Logic behind the sub-mode choice and a short description of the process are also presented in this section.

4.1 Logic behind the Sub-mode Choice Model

The current method of EMME predicts much more GO bus ridership than actually occurs. Different methods were tried without success to overcome this problem. In every case, the total predicted boardings were found to be two to four times higher than actual boardings as recorded in TTS. So, it is assumed that the origin of this problem lies in improper modal split between GO bus and regular bus. As the differences are huge, it is assumed that current EMME mode choice algorithm is mistakenly assigning almost all the demand to GO buses. If this is the case, there is no way to get reasonable performance of EMME regarding GO bus by utilizing the conventional methods. But this can be solved in another way. If we have a demand matrix for only GO bus mode and assign this demand in EMME then we should get correct GO bus predictions, as EMME will assign all the demand to this mode. On the other hand, if we have a demand matrix for regular bus (local bus) and assign this demand in EMME without including “g” (GO bus) mode for active transit mode(s) then we should get proper prediction of local bus. After running the first assignment (with GO bus demand), the second assignment (demand for other modes) can be run as an additional demand on the existing network to obtain the fully loaded network. To achieve the above stated goal, an attempt is made to split the total demand matrix into GO bus demand and regular bus demand. For this purpose, a disaggregate logit model is used to model the GO bus/local bus modal split. As trip-making behavior varies considerably from one trip purpose to another, three different sub-mode choice models are developed for different trip purposes (work, school and “other”).

4.2 Model Development

Data Generation

We have already mentioned that three different models are developed for different trip purposes (work, school and other purposes). So, three logit input files are made from input files (originally extracted from TTS) generated by the GTAModel and EMME runs. Most of the attributes are taken from the TTS data, with only the travel time attributes are generated from EMME runs. Our original data files contain records for all individuals whose origins and destinations are within the GTA. But our research is concerned with modal split between GO bus and regular bus (local bus) only where the GO bus option is available. That means we needed data for those origins and destinations which are feasible for GO bus routes. So, our task was to find the feasible O-D’s for GO bus within the GTA. This was done by "select line analysis" module of EMME. At the same time, travel times (in-vehicle travel time, auxiliary travel time and wait time of GO bus as well as regular bus) for all the feasible O-D’s were calculated from EMME and saved in a predefined file. After identifying the feasible O-D’s and their corresponding travel time components, TTS data for these O-D’s were extracted from the original data files. Then, travel time components are added with the sorted data and saved in a file according to the input format of the logit software.

Parameter Estimation

Three logit models were estimated to split the total transit demand (without GO Rail) into GO bus and local bus for three different trip purposes. For estimation purposes, many trial models were estimated based on the guidelines provided in the literatures ((4)-(7)), but only the final model for each trip purpose is presented below. All the three models are quite satisfactory. All the parameters have correct signs and significant t-statistics. Travel time components obtained from EMME are also significant. The alternative specific constant value is, however, relatively large. This may be due to not considering some important variables (i.e. fare, comfort) in the utility functions.

The models' goodness of fit statistics are very good (work trip: expected percent right of 85.2% and adjusted rho-square of 0.611; school percent right is 90.1% and adjusted rho-square is 0.7361; other trip: expected percent right of 86.9% and adjusted rho-square of 0.6529).

Final work trip model:

V_{gobus} = 0 – 0.1059*ivttg – 0.2430*auttg – 0.1586*waitg

$V_{localbus}$ = 2.5215 - 0.1059*ivttl - 0.2430*auttl - 0.1586*waitl + 0.4465* occu1 + 0.5565*occu2 + 0.4266*age

Final school trip model:

V_{gobus} = 0 – 0.0844*ivttg – 0.2139*auttg – 0.1655*waitg

$V_{localbus}$ = 2.0366 - 0.0844*ivttl - 0.2139*auttl - 0.1655*waitl + 0.9151* occu3 + 1.1087*pdes1

Final other trip model:

V_{gobus} = 0 – 0.0317*ivttg – 0.5349*auttg – 0.0430*waitg

$V_{localbus}$ = 2.4313 - 0.0317*ivttl - 0.5349*auttl - 0.0430*waitl + 1.0749*pdes1

Where,

Vgobus = Utility of GO Bus mode

Vlocalbus = Utility of local Bus mode

ivttg = In-vehicle travel time, GO Bus mode

auttg = Auxiliary travel time, GO Bus mode

waitg = Wait time, GO Bus mode

ivttl = In-vehicle travel time, local bus

auttl = Auxiliary travel time, local bus

waitl = Wait time, local bus

occu1 = 1 if occupation is General office/Clerical

= 0 otherwise

occu2 = 1 if occupation is Manufacturing/ Construction/Trade

= 0 otherwise

occu3 = 1 if occupation is unemployed

= 0 otherwise

age1 = 1 if age is ≤ 50

= 0 otherwise

pdes1 = 1 if planning district of destination other than 1

= 0 otherwise

New Demand Matrices

Once their parameters were estimated, the models were used to calculate the probability of GO bus mode choice for each observation. This probability was then multiplied by the expansion factor for the given trip to generate GO bus demand. The demands for all observations were combined to obtain the demand matrix for GO bus. Then the GO bus demand was deducted from the original demand to obtain local bus demand. Both demand files were saved in EMME batchin format (Module 3.11).

We have to note that some of the feasible O-D pairs contain only GO Bus mode. As there is no local bus, the demands for those O-D's should be fully assigned to GO bus. Therefore, the probability of GO Bus mode choice was adjusted to 1 where there was no local bus option. Moreover sometimes it was found that the obtained GO bus demand was more than total demand. In that case a check was introduced to limit the GO bus demand up to total demand

The overall process is illustrated in Figure 4.

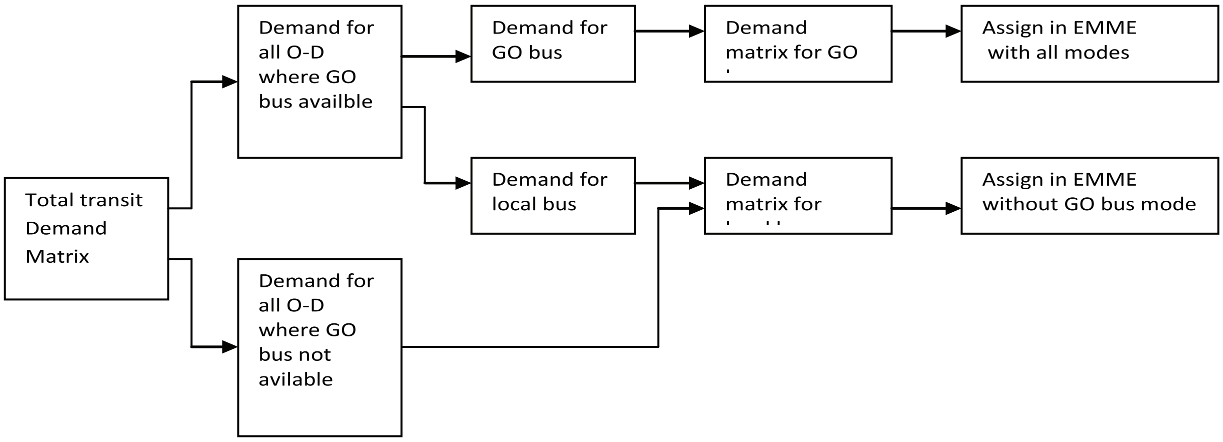

Fig-4: Flow Diagram of Transit Demand Matrix Split

4.3 Model Testing

The GTA transit network was loaded into EMME. Then two demand matrices were assigned. First, GO bus demand was assigned to the network. During this assignment all active transit mode(s) were used in the scenario preparation. According to our assumption (EMME assigns all demands to GO bus) the whole demand should be assigned to the GO Bus. Second, local bus demand was assigned to the network as an additional demand on the existing demand. During this assignment, the GO bus mode ("g") was not used in active transit mode(s) in the scenario preparation. If there is no GO bus mode in the active transit mode(s) EMME will not assign any demand to GO bus.

So it is seen that, according to our proposed approach, EMME is assigning GO bus demand to only GO bus mode and local bus demand (other than GO bus) to only local bus mode. This network should represent the GTA network loaded with full transit demand. GTA Model

parameters were used during the scenario preparation of these new assignments. After running the assignment the ridership predicted by EMME was compared with TTS records for validation purposes. The results are presented in Figure 5. The results are also compared with the previous output of EMME (base case).

From the table and figure it can be seen that performance of new procedure regarding GO bus prediction is much better than with the original approach. Total predicted boardings from EMME are now 9624 compared with TTS recorded total boardings of 9607 yielding a GRE of only 0.56. This result can be compared with the previous prediction of 32705 (GRE of 2.72). Thus the model provides a fit to the observed data that is almost five times better.

Despite this very significant improvement, our result is not fully satisfactory. Poor predictions still exist for three of the GO bus lines. "Yonge C Service" predicted much less boardings than TTS records, while "Newmarket-Finch B" and "Sutton-Yorkdale" predicted much more boardings than TTS records. But, if we add the boardings of these three lines together (note that these are parallel lines within the same general travel corridor) and compare with the similarly summed value from TTS, it is found to be almost same. Thus, this unexpected result might be caused from some combination of improper modal split and/or "untuned" assignment flows among these lines. If we ignore these three lines, then our result is quite satisfactory. GRE was found to be 0.24 without considering these three lines which is the half of the overall value.

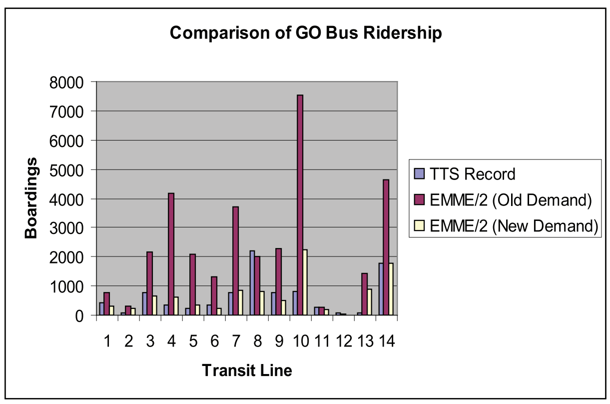

Fig-5: Comprison of GO Bus ridership (new dimand matrices)

5.0 SUMMARY AND CONCLUSION

5.1 Summary of the Work

The research contained in this paper dealt with the solution to an observed over-assignment of transit trips to express bus services in EMME within the GTA. The solution efforts can be summarized as follows:

First, different arbitrary sets of EMME parameters (boarding times, wait time factors, wait time weight, auxiliary transit time weight & boarding time weight) were tried to overcome the assignment problem of GO bus in EMME. But no good result regarding GO bus ridership prediction was achieved. The total peak time boardings predicted by EMME (from the best arbitrary parameter set) were 16653, which was almost double of the real counts (9607). And the results were found to be generally sensitive to parameter changes. Using unreasonable higher values of the parameters might slightly improve the result for GO bus, but at the same time the results for other modes would become worse.

Second, in order to make GO bus less attractive, artificial adjustments to GO bus speeds and headways were performed by decreasing the speeds and increasing the headways of every GO bus route. But this effort was also proven fruitless. The total peak time boardings of GO bus predicted by EMME (when speed of each GO bus route was decreased by 30%) was 24397, which was almost three times higher than real count (9607). This was the best result within reasonable adjustment ranges.

Finally, the original total demand matrix was split into two matrices (one for GO bus and the other for all other transit trips) and assigned to the network separately. This process consisted of three parts: data generation, model development and parameter estimation, and creating new demand matrices for assignment. Data were generated from two sources: general attributes from TTS data and travel time attributes from EMME runs. Then three logit models were estimated for work, school and "other" trip purposes. Finally, new demand matrices were created using the estimated logit models.

The results obtained from the new demand matrices were reasonably good. The total peak time boardings of GO bus predicted by EMME were 9624, which was almost the same as actual count (9607) by TTS.

Given this satisfactory result, an EMME macro was written to put all the pieces of work together and make it easier for the users to use the proposed models and procedures.

5.2 Conclusion

This study concluded with developing a procedure to properly handle GO bus trips in EMME. The results obtained from our proposed models are much better than the existing methods. For the convenience of users, an EMME macro was developed. After running this macro one will get the fully loaded GTA transit network. This will allow planners and policymakers to use the EMME-based GTA network to analyze all types of transit modes (except GO rail which is handled separately within the GTAModel in a more credible and useful way).

5.3 Recommendations for Future Works

This research used the 1996 transit network and the 1996 TTS data. The modeling procedure should be tested on the 2001 transit network with the 2001 TTS data. Our research started with the intention to model all types of express buses. But due to time constraints and lack of information, it was limited to only GO buses. So, future work could be extended to model all types of express buses within the GTA. Time can be invested on improving the overall performances of the logit models. This could be done by including more variables in the model's utility functions to capture currently unobserved characteristics of the trips. Overall performance of the work was satisfactory. But the results from three GO bus routes ("Yonge C Service", "Newmarket-Finch B" and "Sutton-Yorkdale") were not acceptable. These routes should be investigated in detail in order to determine the source of these errors. Currently, there is no way to incorporate some important route choice attributes (fare, comfort, etc.) into EMME assignment calculations. Methods for doing so should be investigated. Currently, EMME considers all transit services in the same way. A procedure for dealing with different services appropriately, either with the assignment procedure itself, or through extensions to the mode choice model developed in this thesis, should be investigated

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