REGIONAL AND EXTRA - REGIONAL HIGHWAY TRAFFIC IN ATLANTIC CANADA: A REVIEW AND PRELIMINARY MODEL

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Introduction

There is a need for a regional and extra - regional model to estimate highway traffic movement between provinces within Atlantic Canada, to and from the central Canadian provinces of Quebec and Ontario, and to and from each of the New England states. Such a model would help to evaluate various pertinent and key policy, planning and operating issues facing transportation engineers and planners today including: energy shortages, environmental concerns (vehicle emissions and climate changes), sustainable transportation, capacity and level-of-service, and safety. Most model development requires origin-destination information; however, regional origin-destination surveys are prohibitively expensive to complete. The last comprehensive roadside survey within the Atlantic Region was completed in 1979. A review of the origin and destination tables produced from this survey was completed in this research to recap the activity in the region from an historical perspective. The relative distribution of traffic was also considered to be potentially helpful in verifying the effectiveness of any traffic model developed from the present research.

In the present study a preliminary aggregate - based modelling exercise was completed to determine the feasibility of developing a regional highway transportation model based upon border traffic counts (essentially cordon counts) in conjunction with basic demographic characteristics associated with each of the relevant provinces and states,

and using travel time as the measure of impedance. An aggregate, gravity-based model was developed in this case rather than concentrating on a more detailed data-intensive dis-aggregate modelling approach. The intent was to determine the practical feasibility of developing a regional traffic model, to evaluate the relative effectiveness in estimating the distribution of the highway traffic throughout the study region and to identify various means of verifying the results generated from the model.

Historical Review of Traffic Activity

The 1979 origin-destination survey represents the last comprehensive roadside survey of all the highway traffic occurring in the Atlantic Region. It encompassed all four Atlantic Provinces, and it was intended to capture activity related to both passenger and goods movements. The present research examines the traffic in aggregate, combining both traffic types. The intent therefore is to review the aggregate activity that occurred in 1979, and try to relate it to what is presently happening in the Atlantic Region.

It is important to note that each survey is completed to capture particular segments of the highway traffic. In the 1979 survey particular emphasis was on capturing longer distance traffic; thus short-distance, local traffic was not necessarily captured. This approach was taken to satisfy the major purpose for the survey: to evaluate road user benefits to the travelling public resulting from major upgrading or rehabilitative projects on the primary highway system in the Atlantic Region which services longer - distance inter- and intra-provincial traffic. This included benefits accruing to the trucking industry from strengthened major sections and resulting efficiencies through more uniform vehicle size and weight regulations and standards. Efficiency and effectiveness of the primary highway system was a concern in 1979 and continued

efficiency and effectiveness remains a concern today.

Table 1 shows the traffic distribution in the Atlantic Region based upon the 1979 origin destination survey, particularly the results of the surveys completed in New Brunswick and Prince Edward Island. The origin-destination tables from the Nova Scotia and Newfoundland surveys were not readily available. Therefore, there are no estimates available for the 1979 traffic between Nova Scotia and Newfoundland.

As expected the major long-distance activity in the region is between New Brunswick and Nova Scotia with an annual average daily traffic (AADT) of 2884. The survey station capturing this activity was located at the intersection of routes 2 and 15 near Moncton; thus a significant amount of local activity between New Brunswick and Nova Scotia was not captured. One can correct for this. To quote from the New Brunswick Department of Transportation (1980) report:

> "A permanent counter at the border indicated an average annual daily traffic figure of 6830. The origin-destination table indicated a value of approximately two-thirds of the 6830 figure. It appeared the local traffic represented one-third of the average daily traffic figure".

Given the above, local traffic would represent approximately 2276 AADT. Therefore, the total traffic between New Brunswick and Nova Scotia in 1979 was approximately 5160 AADT.

This example serves to indicate the relative importance of so-called local traffic. This is also important when looking at the traffic estimates for New Brunswick-Quebec and New Brunswick-Maine, both of which were significantly underestimated because none of the survey stations were located at the borders. They could not, as a result, be relevant when evaluating the effectiveness any regional highway traffic model, other

than to expect considerably higher AADT's than presented in Table 1.

Table 1 Distribution of Traffic in 1979

Origin-Destination Pair	AADT 2-Way Trips
New Brunswick - Nova Scotia	2884*
New Brunswick - Prince Edward Island	1286
New Brunswick - Newfoundland	18
Newfoundland - Prince Edward Island	9
Nova Scotia - Prince Edward Island	834
New Brunswick - Quebec	1407*
New Brunswick - Ontario	332
New Brunswick - Maine	1268*
New Brunswick - New Hampshire	23
New Brunswick - Vermont	12
New Brunswick - Massachusetts	121
New Brunswick - Rhode Island	15
New Brunswick - Connecticut	8
New Brunswick - New York	18
Prince Edward Island - Quebec	76
Prince Edward Island - Ontario	32
Prince Edward Island - Maine	60
Prince Edward Island - New Hampshire	3
Prince Edward Island - Vermont	1
Prince Edward Island - Massachusetts	24
Prince Edward Island - Rhode Island	1
Prince Edward Island - Connecticut	1
Prince Edward Island - New York	2
Nova Scotia - Quebec	195
Nova Scotia - Ontario	118
Nova Scotia - Maine	195
Nova Scotia - New Hampshire	9

Cont'd Table 1 Distribution of Traffic in 1979

Origin-Destination Pair	AADT 2-Way Trips
Nova Scotia - Vermont	2
Nova Scotia - Massachusetts	36
Nova Scotia - Rhode Island	0
Nova Scotia - Connecticut	6
Nova Scotia - New York	5
Newfoundland - Quebec	3
Newfoundland - Ontario	3
Newfoundland - Maine	1
Newfoundland - New Hampshire	0
Newfoundland - Vermont	0
Newfoundland - Massachusetts	0
Newfoundland - Rhode Island	0
Newfoundland - Connecticut	0
Newfoundland - New York	0

Source: 1979 Atlantic Provinces Highway Origin - Destination Survey

* No survey station located at the border; therefore AADT excludes the local traffic between provinces/states.

Traffic between New Brunswick - Prince Edward Island, 1286 AADT, and Nova Scotia - Prince Edward Island, 834 AADT, was captured at the ferries to Prince Edward Island. Therefore, all traffic was included in these estimates. The AADT of 332 between New Brunswick and Ontario should be all inclusive as well. Extra - regional traffic between each of the Maritime Provinces of Nova Scotia and Prince Edward Island and Central Canada was fairly substantial also, and should be all inclusive. This addresses the major traffic activity within the Atlantic Region and to/from Central Canada.

Other than for the state of Maine, extra - regional activity related to the New England states appears to be substantially lower, particularly when the relative population sizes and displacement (as measured in travel time) are compared. The majority of activity occurs between the Maritime Provinces and Massachusetts with a 1998 population of 6,147,132 (US Government Census, 1999). New York with three times the population of Massachusetts generates considerably less activity. This could be explained to some extent by the additional travel time of almost three hours. But an additional point to note is the relative difference in traffic activity generated in Ontario as compared to New York. New York, with a population of about 18 million and an approximate travel time of 10.5 hours to New Brunswick, generated an AADT of 18 while Ontario, with a population of only about 11 million and a corresponding travel time of 14 hours, generated an AADT of 332. This indicates that two separate models may be appropriate; one for trips to/from the New England states and another for trips within Canada.

Preliminary Highway Traffic Model

Various efforts have been made to develop a transportation model based on traffic counts. One of the more recent models in the Canadian context was developed by Leore (1996) based on an intervening opportunity model and various traffic counts throughout Canada and the United States. Major urban centres (approximately 148) in Canada and an additional 60 in the United States) were considered to be the generator of the majority of inter-provincial and provincial-state traffic; minimum traffic counts along routes between the urban centres were considered to be representative of the measure of this traffic activity. Independent explanatory variables included various demographic characteristics in conjunction with travel time as the measure of impedance. Reasonable success was noted with this approach, but not considered as appropriate in the present study where cordon counts at provincial and state borders are being used to account for all traffic

activity between provincial-provincial and provincial-state pairs. In this case, both the local activity as well as long distance travel is captured.

The approach taken in the present study is to incorporate basic demographics (population) at coarse grained zonal levels, and therefore consideration is given to all the population, not just the major urban centres. County level zones are used within the Atlantic Provinces, within Quebec east of Quebec City and within the state of Maine. Because of the greater distance from the Atlantic Region, the remainder of Quebec is considered a single traffic zone with the city of Montreal as the zonal centroid. Similarly, Ontario is divided into only two zones; one centroid is Toronto, and the other is Ottawa. For the states other than Maine the whole state is considered to be a traffic zone.

Based on the observations noted in the historical review of activity observed from the 1979 origin-destination survey, a preliminary aggregate, gravity-based model was calibrated for Canadian based activity, and a model of similar structure was calibrated for United States related activity. The effective model form is:

$$T_{ij} = \left[C_{ij}\right]\left[ao \frac{\left(P_i \times P_j\right)^{a1}}{I_{ij}^{a2}} \right] + \left[C_{ij} \neq 1\right]\left[a3 \frac{\left(P_i \times P_j\right)^{a4}}{I_{ij}^{a5}} \right]$$

where, C_{ij} = country activity code; 1 = inter-Canadian activity, 0 = Canadian-United States activity for each pair of zones i and j

P_i and P_j = population of zone i and j, respectively

I_{ij} = travel impedance between zones i and j as measured in travel time between zonal centroids

a0, a1, a2, a3, a4 and a5 = non-linear regression coefficients to

be solved for using an optimization routine

The Quattro Pro spreadsheet package was used for data compilation and analysis. The spreadsheet optimization solver was used to determine the values of the regression coefficients by minimizing the sum of the squares of the error in the cordon counts. These results are summarized in Table 2 and are discussed in the following section.

Model Verification

The initial model verification is based upon a comparison of observed and estimated cordon counts shown in Table 2. As a point of clarification the individual cordon counts presented are not border point counts, but rather the sum of the average annual daily traffic determined at each of the various points along the whole border defining a particular province or sub-region area. For example, the cordon count relating to traffic activity to and from Prince Edward Island is the sum of the AADT using the Confederation Bridge at the Prince Edward Island - New Brunswick border plus the AADT using the ferry service at the Prince Edward Island - Nova Scotia border. From Table 2 it can be seen that the relative errors in estimating the cordon counts is quite small, ranging between zero percent for trips between the United States and the Atlantic Provinces to the highest of 13 percent (or 465/3625) for trips to/from Prince Edward Island. The generalized coefficient of determination, R-squared has a value of 0.995. This indicates that, for the optimization, 99.5 percent of the variation in the observed cordon counts has been explained.

However, the model results should also be evaluated in terms of the estimated AADT activity between provincial O-D pairs and between provincial and state O-D pairs. Table 3 presents the AADT estimates for trips to and from each of the Atlantic Provinces. Two primary sources of data can assist in this evaluation: the Canadian Travel Survey (Statistics Canada, 1997) and the report Trade and Traffic Across the

Eastern US - Canada Border (Taylor, 1997).

Table 2 RESULTS OF THE NON-LINEAR REGRESSION ANALYSIS

Cordon Count Locations	Cordon Counts at the Borders			
	ESTAADT	OBSAADT	ERROR	SOERROR
To/From PEI+NS+Nfld	14819	14346	473	224138
To/From NS+Nfld	12203	11721	482	231929
To/From PEI	3160	3625	-465	215885
To/From NS	12719	12245	474	224679
To/From Nfld	516	540	-24	556
Oue/Ont To/From Atlantic Provinces	16888	17830	-942	887069
USA To/From Atlantic Provinces	23572	23572	-0	0
MINIMIZED SUM SQERROR			SUM=	**1796707**
			GENERALIZED R-SQR =	**0.9952089**
Model Coefficients:				
a0 =	**1.79E-07**			
a1 =	**1**			
a2 =	**-2.5**			
a3 =	**8.47E-07**			
a4 =	**1**			
a5 =	**-4**			

Table 3 EXTRA- & INTRA-REGIONAL TRAFFIC (ATLANTIC REGION)
(Travel time, hrs / Estimated AADT)

1998	**Population**	753000	136500	934200	543800
Population	**Prov./State(Activity centroid)**	N B	P E I	N S	Nfld
543800	Nfld (ST. JOHN'S)	22.43 /**42**	21.6 / **8**	19.95 /**81**	
934200	N S (HALIFAX)	4.73 /**6154**	3.9 /**979**		19.95 /**81**
136500	P E I (CHARLOTTETOWN)	3.93 /**1296**		3.9 /**979**	21.6 / **8**
753000	N B (FREDERICTON)		3.93 / **1296**	4.73 /**6155**	22.43 /**42**
7334500	Que (MONTREAL)	8.02 /**9740**	11.83 /**458**	12.68 /**2401**	30.47 /**186**
11413700	Ont (TORONTO)	14 / **2298**	17.8 / **243**	18.65 /**1386**	36.47 /**178**
1244250	Me (AUGUSTA)	4.37 /**20295**	8.22 / **38**	9.02 /**163**	26.8 / **2**
1185048	N H (CONCORD)	6.93 /**197**	10.8 / **10**	11.6 /**49**	29.38 /**1**
590883	Vt (MONTPELIER)	8.7 / **48**	12.55 /**3**	13.35 /**14**	31.13 /**1**
6147132	Mass (BOSTON)	7.02 /**983**	10.87 /**53**	11.68 /**251**	29.47 /**5**
988480	R I (PROVIDENCE)	7.88 /**102**	11.73 /**6**	12.55 /**30**	30.33 /**1**
3274069	Conn (HARTFORD)	8.47 /**259**	12.32 /**17**	13.13 /**83**	30.92 /**2**
18175301	N Y (NEW YORK)	10.52 /**643**	14.37 /**50**	15.18 /**258**	32.97 /**10**

The Canadian Travel Survey is representative of only passenger traffic by all modes in the domestic travel market. As such it cannot be used directly. Air traffic can be subtracted using information from Air Passenger Origin and Destination, Domestic Report (Statistics Canada, 1997). This results in only highway passenger traffic in the Atlantic Region. This then has to be converted to vehicle trips by dividing by an estimate of the vehicle occupancy rate (available from Atlantic Region ferry statistics and border crossing statistics). This number has to be further adjusted to account for the percentage truck traffic (available from ferry statistics, border crossing statistics and various department of transportation statistics). As such traffic flows based upon the Canadian Travel Survey are really estimates themselves. Table 4 presents the comparison of the AADT based upon the Canadian Travel Survey to both the modelled traffic flows and the 1979 O-D traffic flows.

A review of the results presented in Table 4 indicate that the preliminary traffic model has estimated some of the traffic activity reasonably well, particularly within the Atlantic Region itself. The activity for Nova Scotia appears a little high; on the other hand the AADT at the New Brunswick-Nova Scotia border has increased from 6830 in 1979 to 10800 in 1997 which tends to support the model estimate. But there appears to be substantial error in estimating traffic to and from Quebec and Ontario. The report Trade and Traffic Across the Eastern US-Canada Border (Taylor, 1997) only provided enough information to adequately estimate traffic of about 20,000 AADT between New Brunswick and Maine. The model estimate is 20295. The overall evaluation indicates that other explanatory variables should be included in the model, perhaps some of those identified by Leore (1996) such as a language factor. There should also be a separate model developed for each of the classes of traffic, one for passenger traffic and one for truck traffic. Perhaps a multi-objective optimization procedure should be incorporated to minimize, not only the error in the cordon counts, but also the error in available O-D activity.

Table 4
Comparison of the 1997 Canadian Travel Survey AADT,
the Modelled AADT and 1979 O-D AADT
(for selected O-D pairs where sufficient data was available)

O-D Pair	1997 Canadian Travel Survey AADT	Modelled AADT	1979 O-D AADT
Nfld-NB	42	42	18
PEI-NB	1295	1296	1286
NS-NB	3947	6155	2884 (5160*)
Ont-NB	372	2298	332
PEI-NS	1122	979	834
Que-NS	82	2400	195
Ont-NS	235	1386	118
Que-PEI	105	458	76
Ont-PEI	279	243	32

* The long distance activity is adjusted to include short distance local activity

Conclusions and Future Research

The optimization procedure itself was successful, validating the feasibility of the basic approach of using cordon traffic counts in conjunction with demographic statistics and travel time data. The verification of the estimated AADT for various O-D pairs indicates that the model performed reasonably well within the Atlantic Region itself, but not quite as well for estimating activity to and from central Canada. There was good agreement between the model estimate of activity between New Brunswick and the state of Maine and the estimate of activity indicated in the Taylor (1997) report; however, there was not enough information available to make a reliable comparison for the other New England States.

Future research is required to improve the performance of the model. Additional demographics, such as language, will have to be examined. A finer grained zonal structure, at the parish level, might also help. Separating the traffic into two homogenous groups, passenger traffic and truck traffic, would probably improve the model performance as well. An effort is also required to improve the information available from on-going surveys such as the Canadian Travel Survey microdata, which is now being produced on an annual basis by Statistics Canada. A multi-objective optimization procedure could then be employed which would simultaneously minimize both the error in the cordon traffic counts and the error in O-D pair traffic.

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