EVALUATING ALTERNATE TRANSIT OPTIONS IN HALIFAX USING TRAVEL DEMAND FORECASTING MODEL INFORMED BY A STATED PREFERENCE SURVEY

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Introduction

Alternative options of public transportation have evolved around the world. Bus Rapid Transit (BRT) is a popular option in some cities. Commuter rail is a viable option especially in cities that are equipped with track infrastructure. Similarly, cities that have a proximal water body or harbour have the advantage of considering fast ferry service as an option. Fortunately all of these are available for the Halifax region, which is the capital of Nova Scotia, Canada.

For more than a decade, the HRM has been investigating the possibility of enhancing commuter service between Bedford and the Halifax Peninsula, and has considered a BRT system, a commuter rail service, and a ferry service. According to the Regional Municipal Planning Strategy (RMPS) adopted by the HRM in 2006, the suburban communities of Bedford West and Bedford South are each expecting a population increase of over 15,000 people in the next twenty years even with lower growth rate. (*1*). In order to accommodate the large increase in the number of commuters to the Halifax Peninsula and reduce automobile congestion along major commuter corridors, the current public transit system needs to be improved. Therefore the study has great significance at present context of Halifax.

Travel demand forecasting models have been playing a crucial role in transportation planning particularly to evaluation of transport and land use policies, programs and projects. Both the state-of-the-art and the state-of-the-practice of travel demand modeling have advanced considerably over the past few decades. This paper proposed the use of a Multinomial Logit (MNL) model, which is estimated on the

Stated Preference (SP) survey to update the O-D trip matrix. The updated matrix was used in Halifax model. Different scenarios were generated in the model with BRT, rail and ferry to compare between those options.

The paper is organized as follows: first, a review of the literature. Then a brief discussion on future transit options in Halifax is provided. The next section describes the model development and validation for the study, followed by a discussion of the model results. The paper concludes by providing a summary of contributions and future research directions.

Literature Review

The availability of travel demand forecasting models has provided planners with powerful and flexible tools for the transport studies. Kriger et al. (*2*) reviews travel demand forecasting models of Canada's nine largest urban areas: Québec City, Montréal, Ottawa-Gatineau, Toronto, Hamilton, Winnipeg, Calgary, Edmonton and Vancouver. Their finding suggested that well-developed travel demand forecasting models available in each of the nine urban areas which provided a unique opportunity for local authorities to use the models in policy decisions. But for Halifax there was no travel demand forecasting model developed. Rahman and Habib (*3*) recently develops a four stage based multimodal travel demand forecasting model for Halifax.

Most of the recent studies use forecasting techniques or revealed preference studies to determine future modal split. It is common for researchers to use growth factor, trip generation models or reveled preference study data to calculate the O-D matrix .In the case of implementing new alternatives, this approach can be improved by using the road users' choice preference when new options are exposed to them. This indicates a literature gap of not incorporating of a trip maker's opinion directly to determine future modal split. This study contributes in the field by introducing the use of a SP survey based model to calculate future mode choice in the travel demand forecasting model.

Stated preference methods were introduced to transportation in the early 1970s, but did not become popular among researchers until the early to mid 1980s, when SP surveys were used to investigate travellers' behaviour (*5-8*). Since the late 1980s, many researchers have employed SP studies and choice experiments for applications in transportation research. One of the benefits of an SP survey, as outlined by Loo (*8*), is its ability to be easily repeated for any transportation corridor, providing context specific results.

In applications of SP methods for transportation mode choice, respondents choose their preferred future transit alternative from a set of transit alternatives presented to them on a series of hypothetical scenario cards (*7-9*). Each scenario card includes a bundle of attributes for each transportation alternative.

Though SP methods have been used as the base of mode choice models there is no such effort found to incorporate these model results to update the trip matrices, which can be used in the forecasting model. Richardson and Habib (*4*) developed a multinomial logit model based on stated preference survey data in their study on transit users of Halifax and discovered that travel cost, travel time and travel frequency are the significant determining factors of mode choice. This study addressed the literature gap and provided the methodology to use stated preference survey data, discussed in the following section.

Future Transit Alternatives for Halifax

Halifax is the capital of the province of Nova Scotia, Canada. The Halifax Regional Municipality (HRM) had a population of 390,096 in 2011 and the urban area had a population of 297,943 . Halifax, the largest population center in Atlantic Canada, is one of the world's largest natural harbor with extensive international shipping.

The proportion of commuters in Halifax using public transit to get to work has continued to rise in recent years. In the HRM, 11.9% commuters used public transit in 2006 compared to 9.9% in 2001. Meanwhile, in 2009 the HRM emphasized its potential growth of transit users in the 5-year strategy plan. They have adopted a transportation strategy, which further emphasizes the need for increased reliance on transit. To accommodate a greater portion of transportation trips, the HRM strives to increase to as high as 26% of overall trips by 2031 and 18% within next five years. The HRM addresses this issue with greater emphasis on public transit and the ability to handle a major portion of the future growth of transportation (10).

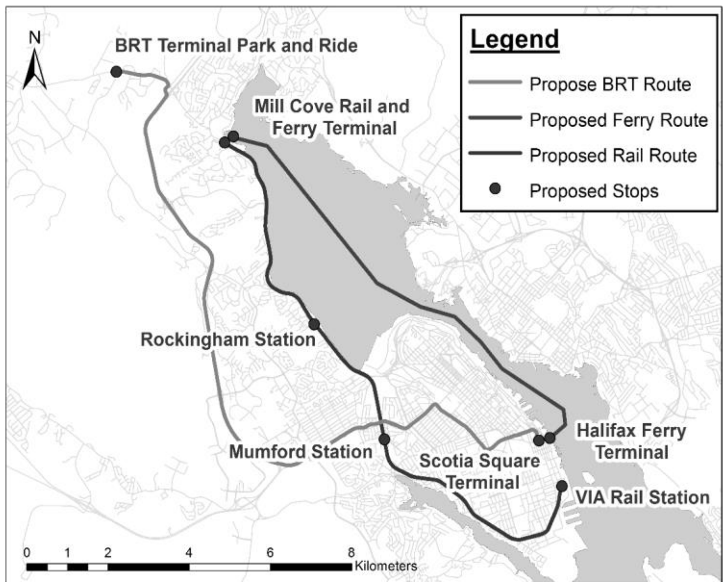

FIGURE 1 Proposed BRT, Ferry and Rail Route.

Figure 1 shows the proposed BRT, Rail and ferry routes in Halifax. The proposed BRT line starts at from the Park and Ride facility at the BMO Centre in Bedford and ends at Scotia Square in Downtown Halifax. The proposed Ferry route if from Mill Cove, Bedford to Halifax ferry terminal. Meanwhile the proposed commuter rail stats at Mill cove and runs through Rockingham to VIA rail station.

Model Development and Validation

A new travel demand forecasting model for Halifax was developed in this stage. The main three steps for model developments are building the network, creation of O-D matrix and running the assignment model. The transit network for this scenario uses the data of the current municipal street layout, bus and ferry routes, transit schedules, and relevant vehicle information, which were acquired from various sources, including the HRM. This study generated a business-as-usual scenario for the HRM transit system. (*6*)

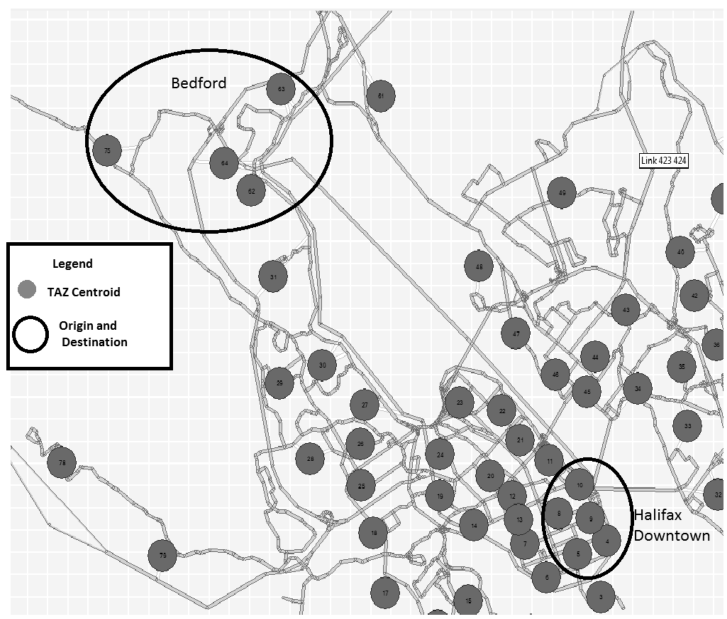

FIGURE 2 Traffic Analysis Zones of Bedford and Halifax Downtown in Demand Forecasting Model

The HRM is subdivided into 87 traffic analysis zones according to the census tracts. The alternate transport improvements of the Bedford-Halifax corridor zones in close proximity to the corridor present the highest potential to show changes in transit demand. Figure 2 shows the zones that were considered in this study, with Bedford as the origin and downtown Halifax, the destination. All the other zones were active in the model but their demand matrices remained the same during the length of the study. Journey to Work data acquired from the HRM for 2006 was used to prepare the O-D pair data adopted in this study.

All trips in EMME/3 begin or end at zone centroids; this includes transit trips. During the transit assignment, it will calculate the optimal strategy from every zone to every other zone; but will only assign volume to those O-D pairs with non-zero demand. Thus, the resulting travel time component matrices will always be the same for the same network and the same parameters, even while demand changes. Completing a strategy-based assignment in EMME/3 involves preparing a scenario and running the assignment.

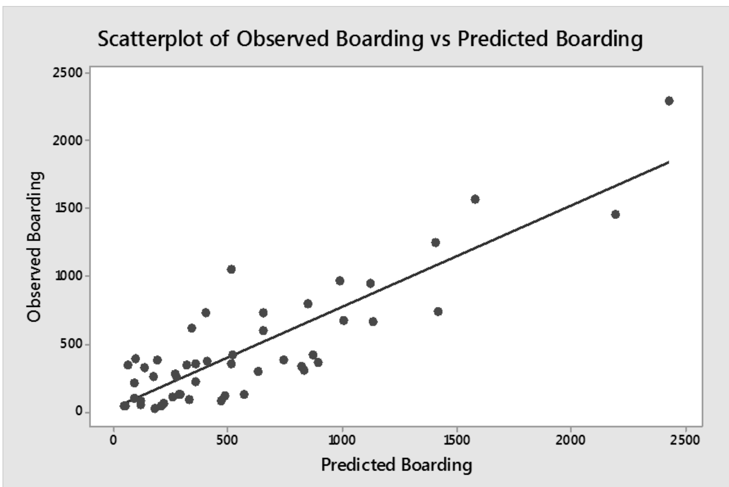

FIGURE 3 Model validation with passenger boarding.

The transit demand forecasting model validation is conducted to compare the transit assignment results with the real world service condition from two aspects: total boarding on each line during peak hours and total time taken by each itinerary**.**

The model also predicts the itinerary time of each route, which is compared with the scheduled itinerary time, shown in Figure 4. Both of the figures imply that the model results are consistent with real traffic data.

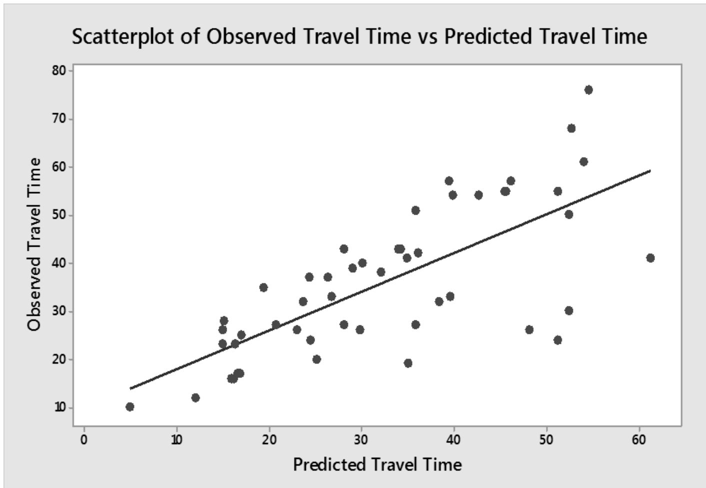

FIGURE 4: Model validation with Travel time

MNL model based on SP survey

Origin destination trip matrix need to be updated to represent any future scenario in travel demand forecasting model. However it is challenging to update the O-D matrix in future model. This becomes more critical when multiple options are proposed as future alternatives.

Richardson and Habib (*4*) performed a stated preference survey to investigate user preference for three proposed transit alternatives, bus rapid transit, commuter rail and ferry connecting Bedford and Halifax. The survey design used for the study considers three attributes: travel time, travel cost, and service frequency for each transit alternative, each with two levels. A fractional factorial design is considered for the SP survey, which generates 12 choice scenarios. They developed multinomial logit (MNL) model using SP survey data with random utility-based discrete choice modelling techniques. The majority of stated preference experiments employ a MNL model as it allows more than two alternatives (*11-12*).

Let P_i be the probability of choosing an alternative "i" from a set of "j" alternatives, Then the multinomial logit model is given by McFadden (*13*)

$$P_i = \frac{\exp(U_i)}{\sum_{j=1}^{j} \exp(U_j)} \qquad (1)$$

where U_j is the utility value associated with alternative j

$$U_j = \beta_{0j} + \sum_{k=1}^{k} \sum \beta_k X_{kj} \qquad (2)$$

where k is the attributes of alternatives and β is the parameter to be estimated

Richardson and Habib (*4*) proposed the following MNL model from stated preference survey data on transit users of the Bedford-Halifax corridor in Halifax:

TABLE 1 MNL model Results based on the data from the stated preference survey results

Attribute	Coefficient	t-stat
Travel time	-.0554	-17.103
Travel Cost	-.3929	-23.445
Service Frequency	.0231	4.118
ASC Ferry	-.8292	-4.715
ASC Train	-.3957	-2.535
ASC Bus	-.9004	-7.318
Model Fit (Adjusted Rho-square) = 0.11		

In this study, Utility functions were derived from the above model and future modal choice was determined using the functions. To do so, travel times and frequency of existing transit options were used from the transportation model. Those of the non-existing options were taken from the proposed schedule. Transit fare was taken as travel cost for transit options, whereas running cost and parking cost were considered to calculate the travel cost of auto.

Trip matrix derived from this process was then used in the traffic assignment procedure in EMME/3 to generate the output of ridership, trip length and travel time. A calibrated transit demand forecasting model in EMME/3 was used to run the assignment model with different scenarios.

Discussion on Forecasting model results

Table 1 shows the shift of transit modal share in different traffic analysis zones using proposed SP based approach. The present transit modal share of 18.92% has a potential to be increased to 20.83% with the implementation of available options. This in an indication that with improved transit options some auto drivers are likely to switch from auto to public transit.

TABLE 1 Transit Modal share changes of the Bedford-Halifax corridor

Transit mode share (%)					
Destination Zone (TAZ)	BAU	With options	Alternate	Transit	Change
4	18.75	21.88			3.13
8	15.98	19.53			3.55
9	19.80	20.79			0.99
10	22.69	22.31			-0.38
Total	18.92	20.83			1.91

It also shows prospective modal split between auto and the alternate transit options such as BRT, commuter rail and ferry. BRT has the potential to be most popular among those options. Result shows 10.85% of prospective riders preferring BRT for the Bedford–Halifax corridor. The commuter rail is likely to have 8.23% of the commuters, whereas the ferry seems to have the least preference among the three options with 1.75%. Inter zonal modal split of auto and other transit options are shown in Figure 5.The figure demonstrates the popularity of BRT over other transit options, in most zones, while some zones are showing commuter rail as preferred options.

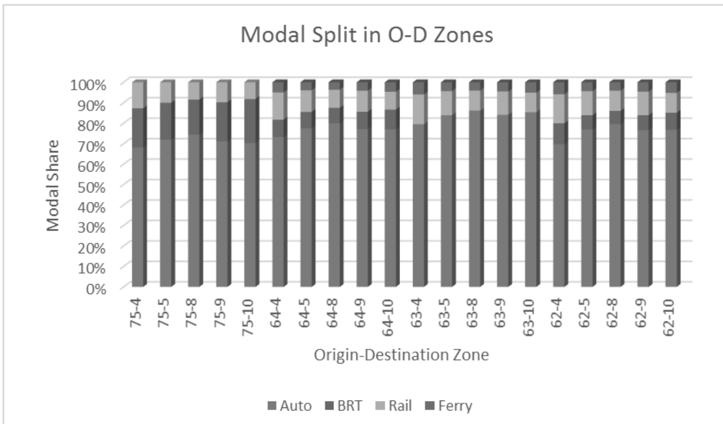

FIGURE 5 Modal split in O-D zones.

The model also evaluates the overall transit system performance of the HRM with respect to the proposed inclusion of BRT, commuter rail and ferries in the system. Table 2 shows the average trip length and the average travel time for commuting. Although this improvement is proposed for one corridor of the city, it shows some impact of overall transit performance of the city. For a business as usual scenario, the average trip length is 9.85km. Introduction of BRT decreases the value to 0.30%, whereas with the option of commuter rail it increases the distance to 1.32%. Ferry service has no significant impact on trip length, as the value remains unchanged. With all three inclusions together, the average trip length increases by 1.02%. Decreased average trip length, with the use of BRT, implies that people using the service would need to travel less than they do presently. This indicates that route chosen for BRT was effective in providing service closer to the user's home and job location. On the other hand, a commuter rail line would have to use the existing rail tract, which is not the shortest distance of travel. Therefore, average trip distance increases with the use of commuter rail. Comparing to BRT, rail stations are not at the heart of downtown (Figure 1). As a result people need to travel farther distances to reach their destinations in downtown Halifax. Overall, commuter rail trip distances increase as a result of the abovementioned limitations.

TABLE 2 Transit Network Performances Evaluation

	Total distance commute (Passenger-Km)	Total commuting time (Passenger-Hour)	Average Trip length per commuter (Km)	Average Travel time per Commuter (Minutes)
Scenario 1: Business as usual	191294.2	7815	9.85	24.14
Scenario 2: with Commuter Rail	193872.5	7870.5	9.98	24.31
Scenario 3: with BRT	190755.5	7748.7	9.82	23.94
Scenario 4: with Ferry	191284.6	7818.5	9.85	24.15
Scenario 5: with Commuter Rail , BRT & Ferry	193372.8	7805	9.95	24.11

Average travel time was determined to be 24.14 minutes in the BAU scenario. Using commuter rail increases travel time to 0.70% and for ferry it increases 0.04%. Other scenarios showed a decrease in travel time. Including BRT in the system decreased travel time to 0.83%. Implementing all three options would decrease travel time to 0.12%. In case of travel time, BRT stands out as the option creating the most improvement in the system. Commuter rail increases travel time as a result of the increased travel distance required on the existing rail line. The use of a ferry system has virtually no impact on the system performance. In contrast to the trip length, the average travel time decreases slightly with a system of BRT, rail and ferry.

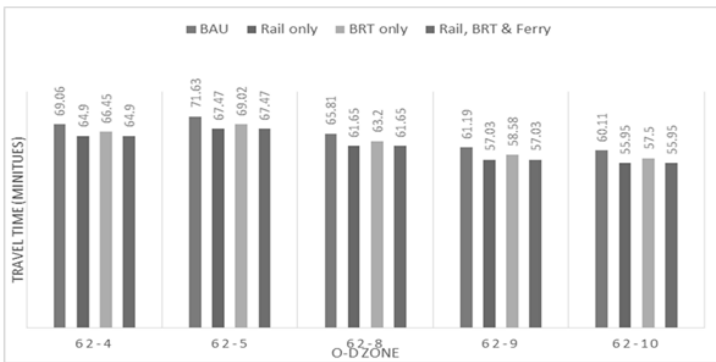

FIGURE 6 Zone to Zone travel time in different scenarios (Origin Zone 62).

The model also investigate into the change in zone-to-zone travel time with respect to different scenarios involving BRT, rail and ferry service. Some examples of those O-D zone travel time are presented in Figure 6 and 7.In case of, zone 62 different responses in travel time change has been observed. In both BRT and rail, travel time decreases, which is an indication of preference for both options. Analyzing travel time presents rail service as the most efficient option for that zone. On the contrary in zone 75, travel time decreases significantly with BRT. The proposed BRT line starts close to this zone so people commuting from that zone will be highly benefited, which is reflected in this result. Rail did not show any change in travel time to any destinations from that zone as a result of the distance of rail line from that zone.

Summary of the results can be stated as among the proposed transit alternatives of Bedford-Halifax corridor, BRT seems to be the promising option in terms of travel time, trip length, ridership and O-D zone travel time comparison.

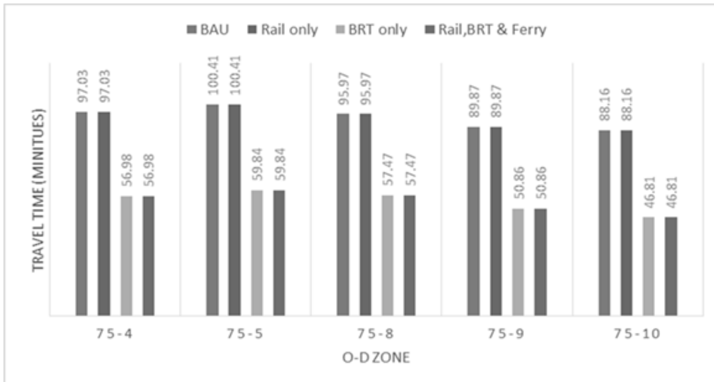

FIGURE 7 Zone to Zone travel time in different scenarios (Origin Zone 75).

Conclusion

This paper evaluated the alternate transportation options of the Bedford-Halifax corridor of the HRM. This study has taken the results of a MNL model developed from a stated preference survey to update the O-D matrix of a BAU network scenario, which was then used as the O-D matrix of the predicted future scenario. This study has unique contribution by using SP informed O-D update method for future transit alternatives. The scenarios thus reflect alternative futures, with the interaction of external conditions and as a result of choices

The study results provides an evaluation of proposed transit alternatives with respect to ridership, trip length, and travel time of the entire transit system. It can be also concluded that at the origin destination pair zone level, different options are more efficient for different zones. Zones close to the BRT line shows significant improvement in travel time efficiency in BRT. On the other hand, zones close to both BRT and rail are showing positive improvement in travel time efficiency.

The findings of this paper have important policy implications. This study sheds light on possible options to be prioritized by decision makers. It is evident from the model results that BRT has more of a positive impact on the transit system of Halifax than the other viable options. However, further studies, including feasibility studies and cost benefit analyses, are required to make the final conclusion. Results of this model can be used as a base for future research in this field. An important note regarding commuter rail is the distance of the rail station from the heart of downtown. To present rail service as a more attractive option, shuttle services connecting to important destinations can be taken into consideration. The study also reveals that a ferry service from Bedford to Halifax may not be the suitable options in terms of commuter choice and system efficiency.

This study has certain limitations. Overall, financial considerations and other associated transportation infrastructure aspects of introducing a transport alternate were outside the scope of the study. However, in future studies those can be incorporated. Along with findings of this study, the present model may be useful for choosing the best alternative transit option for Halifax.

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Reference

1. Delphi-MRC. An Operational and Life Cycle Cost Analysis of Transit Service Alternatives in the Bedford-Halifax Corridor – Final Report, 2010.

2. Kriger, D., C. Miller, M. Baker and F. Joubert.The Costs of Urban Congestion in Canada:A Model-Based Approach. In Transportation Research Record: *Journal of the Transportation Research Board, No.2269* Transportation Research Board of the National Academies, Washington, D.C, 2007

3. Rahman,M. and A.Habib. Transit Demand Forecasting Model development for HRM. Presented in CSCE 10th International Transportation Specialty Conference, 2014

4. Richardson, D. and Habib, M.A. Evaluation of Transit Alternatives for the Bedford-Halifax Corridor: A Stated Preference Study. Presented in the 58th Annual North American Meeting of the Regional Science Association International, Florida, USA, November 9-12,2011

5. Louviere, J.J., D. H. Henley, G.Woodworth, R. J.Meyer, I.P.Levin, J.W.Stoner, D.Curry, and D. A. Anderson. Laboratory simulation versus revealed preference methods for estimating travel demand models: an empirical comparison. *Transportation Research Record, 794*,1981,pp.42-51

6.Bates, J.J. Econometric issues in Stated Preference Analysis, Journal of Transport Economics and Policy, 22, pg. 56-69,1985

7.Hensher, D.A., P.O. Barnard and T. P. Truong.The Role of Stated Preference Methods in Studies of Travel Choice. *The Journal of Transport Economics and Policy. Vol 22(1).* Pg. 45-58,1988

8.Loo, B.P.Y. Role of State Preference Methods in Planning for Sustainable Urban Transportation: State of Practice and Future Prospects. *Journal of Urban Planning and Development. 128(4).* 210-224,2002

9.Train, K., and W. W. Wilson.Estimation on stated-preference experiments constructed from revealed-preference choices. *Transportation Part B, vol. 42*. 191-203, 2005

10.IBI GROUP. Five-Year Strategic Operations Plan –Taking Transit to the Next Level, Halifax Regional Municipality , Metro Transit,2009

11.Hensher, D.A. Stated preference analysis of travel choices: the state of practice. *Transportation*, *vol. 21*, 1994, pp. 107-133

12.Ben-Akiva, M., and M. Bierlaire. Discrete Choice Methods and Their Applications to short term travel decisions. Handbook of Transportation Science,1999.

13.McFadden, D., W. Tye and K. Train. An Application of Diagnostic Tests for the Independence from Irrelevant Alternatives Property of the Multinomial Logit Model. In *Transportation Research Record: Forecasting Passenger and Freight Travel, No. 637,* Transportation Research Board, 1978 pp.39-46.