SPATIAL TRANSFERABILITY OF ACTIVITY-BASED MODELS: MOVING TASHA FROM TORONTO TO MONTREAL

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ABSTRACT

Spatial transferability has been recognized as a useful validation measure for travel demand models. To date, however, transferability of activity-based models has not been frequently assessed. This paper assesses the spatial transferability of an activity-based model, TASHA (Travel Activity Scheduler for Household Agents), which has been developed by researchers at the University of Toronto, Canada. TASHA is a fully disaggregate model that estimates activity schedules and travel patterns for a 24 hour typical weekday for all individuals in a household. The model has been developed based on trip diary data from the 1996 Transportation Tomorrow Survey (TTS) for the Greater Toronto Area (GTA). Consequently, it is possible to implement this model in any city where this kind of dataset is available. Montreal undertakes large scale Origin-Destination (O-D) travel surveys every five years to collect detailed travel and socio-economic information of approximately 5% of the total Greater Montreal Area (GMA) population aged 5 years and older. This is a very similar data to that of the TTS allowing an opportunity to apply TASHA in the context of Montreal. Observed distributions of activity attributes (such as frequency, start time and duration of different types of activity) from the 1996 TTS are used as inputs in the activity generation component of TASHA. Other required data such as individual and household attributes, employment, population, activity density, and travel distance between traffic analysis zones are gathered from the 2003 O-D travel survey and the 2001 Canadian Census. TASHA generates daily schedules of activities (individual and joint) for each individual in the Island of Montreal. The modelled activity attributes from TASHA and observed attributes from the 2003 O-D travel survey are compared to evaluate the spatial transferability of the TASHA model. Time, effort, and cost are inevitable barriers to establishing models in new contexts. Model transfer can significantly decrease these barriers. The focus of transferability research, however, has been on trip generation and mode choice models. The research in this paper provides evidence of transferability of an activity-based model which could increase the application of such models in near future.

Keywords: spatial transferability, activity-based model, TASHA, Montreal.

INTRODUCTION

Spatial transferability has been recognized as a useful validation measure for travel demand models. To date, however, transferability of activity-based models has not been frequently assessed. This paper examines the spatial transferability of an activity-based model, TASHA (Travel Activity Scheduler for Household Agents), which has been developed by researchers at the University of Toronto, Canada. TASHA is a fully disaggregate model that estimates activity schedules and travel patterns for a 24 hour typical weekday for all individuals in a household. The model has been developed based on trip diary data from the 1996 Transportation Tomorrow Survey (TTS) for the Greater Toronto Area (GTA). Consequently, it is possible to implement this model in any city where this kind of dataset is available. Montreal is renowned for large scale Origin-Destination (O-D) travel surveys conducted every five years since the early 1970s. This is a very similar data to that of the TTS allowing an opportunity to apply TASHA in the context of Montreal. Therefore, the main focus of this paper is to examine to what extent the activity-based model, TASHA is transferable to the Island of Montreal, Canada.

The remainder of this paper is organized as follows. First, a brief review of the related literature is provided. Then, a brief overview of the TASHA model is presented. Next, data and research method are described. Then, a comparison between estimated results by TASHA and observed data is presented. Finally, the paper proposes a conclusion and discusses implications of the study.

BACKGROUND

Travel demand models have been employed as decision support tools for transportation planning over the last few decades. However, recent advancements of policy instruments in the field of transportation planning such as Travel Demand Management (TDM), Intelligent Transportation Systems (ITS) technology and, High Occupancy Vehicle (HOV) lanes need more precise decision support tools than the traditional four-stage travel demand model (Roorda, 2005; Shiftan et al., 2003). Consequently, activity-based approach has emerged in the literature since the 1970s to overcome the limitations observed in the traditional four-stage travel demand model. The importance of activity-based models in travel demand analysis is also well recognized in the literature (Bhat and Lawton, 2000). However, the practical application of activity-based modelling approach is still very rare; traditional travel demand models are the majority of the models used in practice (Mohammadian et al., 2009).

It is obvious that any kind of model requires extensive validity testing before reaching the application stage. Accordingly, activity-based models are also validated in several ways. The most common validity testing of activity-based travel demand model is the application of the model using the base year dataset from which the model is originally derived (Ben-Akiva and Bowman, 1998; Bowman, 1998; Kitamura and Fujii, 1998; Miller and Roorda, 2003). The models are also validated by comparing the estimated forecasts of daily travel behaviour of a future year with observed survey data of the same year (Roorda et al., 2008). Spatial transferability has been recognized as a useful validation measure for the models; however, to date, this kind of measure has not been applied extensively in case of activity-based travel demand model. Moreover, time, effort, and cost are inevitable barriers to establishing models in new contexts. Model transfer can significantly decrease these barriers.

The main concept of model transferability is the application of previously estimated model parameters into a new context (Karasmaa, 2001). Koppelman and Wilmot (1982) distinguish transfer and transferability very well. Transfer is defined as "*the application of a model, information, or theory about behaviour developed in one context to describe the corresponding behaviour in another context*", whereas transferability is defined as "*the usefulness of the transferred model, information, or theory in the new context*". To date, the model transferability research mainly includes trip generation and mode choice models. The transferability discussion was limited to the spatial and temporal contexts in previous literature; but recently it includes model specification and level of aggregation (Cotrus et al., 2005). Researchers have found mixed results in their investigations on spatial transferability of trip generation and mode choice models. A number of studies have found acceptable transferability of trip generation and mode choice models (Agyemang-Duah and Hall, 1997; Karasmaa, 2001; Rose and Koppelman, 1984), while others have reported poor transferability of the models (Daor, 1981). Wilmot (1995) has indicated that disaggregated models of trip generation tend to show better transferability than the aggregated models since the parameters used in the disaggregated models are not dependent on the zonal system. Also, the quality of the model specification of the transferred model has great impact on transferability. Wilmot and Stopher (2001) and Wilmot (1995) have proven that the partial transfers could improve the transferability of the trip generation model and transportation planning data noticeably.

As discussed earlier, to date the focus of transferability research is still on trip generation and mode choice models, very few researchers have examined the spatial transferability of activity-based model (Arentze et al., 2002). Arentze et al. (2002) have tested the spatial transferability of ALBATROSS model system at both individual and aggregate levels and have found quite satisfactory results except for transportation modes. The evidence indicated that ALBATROSS model derived from activity diary data collected in two municipalities in the Netherlands is sufficiently capable of capturing the behaviour under which individuals and households organize their daily activities in another space. Still, future research is required in this field to provide more evidence prior to application of activity-based models. This research is an effort to examine the spatial transferability of the activity-based model, TASHA with the application in the context of the Island of Montreal.

THE TASHA MODEL

The activity-based model, TASHA (Travel Activity Scheduler for Household Agents) has been developed by researchers at the University of Toronto as part of a broader development of the integrated model, ILUTE (Integrated Land Use Transportation Environment). However this model can also be used as a stand-alone travel demand model. It is a fully disaggregate microsimulation model which estimates activity schedules and travel patterns for a twenty-four hour typical weekday for all individuals in a household. The model has been developed based on trip diary data from the 1996 Transportation Tomorrow Survey (TTS) for the Greater Toronto Area (GTA). The major features of the operational model are as follows:

- *The model makes use of the concept of the project to organize activity episodes into the schedules of persons in a household;*
- *The model features interactive household agents;*
- *The model is a microsimulation of a 5% sample of households in the Greater Toronto Area;*
- *The model was designed using an object oriented programming technique;*
- *The model assumes broad project and episode types;*
- *The model assumes household decisions other than activity scheduling are made exogenously*.

The full conceptual design and methodology of this prototype activity scheduling model can be found in Miller and Roorda (2003). This modelling framework includes five components, activity generation, location choice, activity scheduling, mode choice, and trip assignment. This research limits the application to the first three components i.e. activity generation, location choice, and activity scheduling. A brief overview of these three methods is provided here. TASHA is mainly developed following a ''bottom up'' approach, i.e. activities are generated first and then scheduled. The activity generation component generates activities (individual and joint) for each individual. The activities such as work, study, return to home are first generated and then based on the duration and start time, other types of activities are generated. This stage requires person and household data and series of activity generation behaviours related to frequency distribution of different types of activities, duration and start time of activities as input. In TASHA, the activity generation is done using Monte-Carlo simulation to generate different activity patterns based on the 1996 TTS distributions of activity attributes in the GTA. The location component allocates the locations to different activity episodes generated for the individuals. Home location and usual place of work/school are direct input in the modelling framework. The activity location choices of other activities are estimated using a series of entropy models (Eberhard, 2002). Activity scheduling component is rule-based, which first organize activities into projects, and then make schedules for interacting household members. The method of activity scheduling is described here very briefly. The detail of this process will be found in other papers (Miller and Roorda, 2003; Roorda, 2005).

Step 1: Activity episodes are inserted into a project agenda with preliminary time sequence with other activity episodes to achieve a common purpose.

Step 2: Person schedules are formed by taking activity episodes from the project agenda and adding them into person schedule based on the order of precedence observed from an interactive computer survey of activity scheduling (Doherty et al., 2004).

Step 3: A "clean up" algorithm is applied to fine tune the final scheduling just before /during execution of the schedule.

TASHA has already been validated in two ways (Roorda et al., 2008). First, the model is verified by application using the base year dataset i.e. 1996 TTS from which the model is originally derived. This base year verification already tests the activity generation (frequency, start time, and duration), activity location choice, and activity scheduling model components of TASHA. Then, the model is further validated by comparing forecasts of a future year with the observed data of the same year i.e. 2001 TTS in the Greater Toronto Area. The validation results indicate that TASHA is capable of reproducing activity/travel patterns in the GTA; however it needs further improvements in the modelling framework for the Greater Toronto Area (Roorda et al., 2008).

DATA AND RESEARCH METHOD

Montreal undertakes large scale Origin-Destination (O-D) travel surveys, first collected by the Montreal transit agency and now by a consortium of transportation institutions, every five years since the early 1970s. The survey collects detailed travel and socio-economic information of approximately 5% of the total Greater Montreal Area (GMA) population aged 5 years and older. The socio-economic data of individuals and households and travel data of a specific weekday of the fall period (September to December) of all household members are collected by a telephone interview. Detailed information on the O-D travel surveys can be found in the AMT website (Agence Métropolitaine de Transport, 2010). These O-D travel surveys are very similar to the Transportation Tomorrow Survey (TTS) for the Greater Toronto Area (GTA) allowing an opportunity to apply TASHA in the context of Montreal.

This research limits the application of the TASHA model to the individuals residing on the Island of Montreal. As of March 12, 2002, the Island of Montreal is composed of an area of 499.19 square km (192.74 square miles) and a population of 1,812,723 (Statistics Canada, 2001). To fulfill the objectives, the research relies on the 2003 O-D travel survey and the 2001 Canadian census. During input data preparation for TASHA application, it is observed that some individuals make some open chains in the 2003 O-D travel survey. Here, we have followed the definition of trip chain by Primerano et al. (2008) and Srinivasan (1998) who defined trip chain as it includes all trips between leaving home and returning to it. Therefore, those trip observations of a household of which an individual's travel did not start and end at home (i.e. those who made an open chain) were excluded. After data selection, a sample of 59,624 individuals (26,960 households) is used for evaluating the spatial transferability of the TASHA model. For application, observed distributions of activity attributes (such as frequency, start time and duration of different types of activity) from the 1996 TTS are used as inputs in the activity generation component of TASHA. Other required data such as individual and household attributes, employment, population, activity density, and travel distance between traffic analysis zones are gathered from the 2003 O-D survey and the 2001 Canadian Census.

Since TASHA uses a stochastic approach for estimating activity scheduling, the model was run for ten replications. All results were recorded for comparison with the observed survey data. Both estimated TASHA outputs and the 2003 O-D travel survey are then processed to prepare activity attributes for comparison. TASHA typically estimates activity schedules for eleven types of activities, these are aggregated into five broad activity classes according to the commonly used patterns in Montreal (work, school, shopping, other, and return to home). For both TASHA output and O-D travel survey, activity start time corresponds to the travel start time. Consequently, the duration of activity includes travel time to the activity location as it was calculated using the start times of two successive trip observations. The distances (Euclidean distances) are calculated using the coordinates of the centroids of traffic analysis zones (TAZs) from an origin to destination point. Average values for activity attributes over ten replications are computed. Finally, modelled average values are compared with the 2003 O-D travel survey for different activity attributes, activity frequency, start time, duration, and travel distance. At the end Kolmogorov Smirnov test (K-S test) is performed to examine whether the modelled and observed distributions differ significantly or not.

SPATIAL TRANSFERABILITY OF THE TASHA MODEL

Activity frequency

Table 1 compares the average activity frequencies estimated by TASHA with the observed frequencies of O-D travel survey by activity type. From Table 1, it is observed that, globally, TASHA undersimulates the total number of observed activities by 10.3% (13,570 activities) which is not as good as than the results found for Toronto (Roorda et al., 2008). In Toronto, TASHA undersimulates the total number of observed activities by 0.2% in the verification test using the same year dataset (i.e.1996 TTS) on which TASHA has been developed, in addition, it also undersimulates the observed activities by 3.2% while validation using future year dataset (i.e. using the 2001 TTS).

In Montreal, the application results indicate underestimation of observed total activities for all but work activity. Only work activity is overestimated by 5.4%, whereas school, shopping, and other activities are underestimated by 6.4%, 13.9%, and 30.6%, respectively. Like Toronto, TASHA estimates work activity more closely than other types of activities (Roorda et al., 2008). This is expected as work activity is considered as highest priority activity among others, thus it is scheduled first. The largest variation is associated with other activity, which is consistent with the intrinsic variability of this type of activity. Overall, though the estimations for work, school and return to home activities are quite satisfactory, the results for shopping and other activity warrant further improvement in the modelling framework and parameters. It is noted here that activity generation was based on the observed distributions of activity attributes (such as frequency, start time and duration of different types of activity) from the 1996 TTS. It is possible that observed distributions from Toronto could not successfully capture travel pattern of the Island of Montreal.

Table 1: Estimated frequency by TASHA vs. observed frequency of Montreal O-D survey

Activity type	**Work**	**School**	**Shopping**	**Other**	**Return to home**	**Total**
Model average total activities (TASHA)*	26027	12170	9329	16862	53946	**118333**
Model Standard deviation total activities (TASHA)*	131	41	138	194	172	**382**
Observed total activities (O-D survey)	24693	13004	10829	24309	59068	**131903**
Model ± activities (#)	1334	-834	-1500	-7447	-5122	**-13570**
Model ± activities (%)	5.4	-6.4	-13.9	-30.6	-8.7	**-10.3**
Model average distance (km)*	7.94	4.43	5.11	6.91	6.12	**6.38**
Model standard deviation distance (km)*	0.03	0.02	0.05	0.03	0.02	**0.02**
Observed average distance (km)	7.94	4.21	3.63	5.01	5.61	**5.63**
Model ± distance (km)	0.00	0.22	1.48	1.90	0.51	**0.75**
Model ± distance (%)	0.01	5.26	40.87	37.87	9.10	**13.26**

* indicates the average value (standard deviation) of ten replications.

Activity start time

Modelled and observed travel/activity start time distributions by activity type are presented in Figure 1. Kolmogorov Smirnov (K-S) tests are applied to examine whether both modelled and observed distributions are similar or not. The results show a great variation for all activities with Toronto distributions. Figure 1 (a) shows that work activities are closely simulated over the day within 2% for all but 1 hour (7:00 - 7:59 AM). The K-S test result (p-value 0.893) for work activity provides strong evidence that the estimated and observed distributions are similar. We perceive, however, that the simulated distributions by TASHA are shifted in time (undersimulation of early starting activities at 7:00 AM and oversimulation of starting activities at 9:00 AM). This could indicate a difference in behaviour between the distributions observed in Montreal and Toronto. According to this comparison, it is observed that people in Montreal leave earlier for work activities than Toronto. Figure 1 (b) shows the same distributions for school activities. School activities are also simulated over the day within 2% for all but 2 morning hours of the day (7:00 and 8:00 AM). As expected, most of the observed school activities are started at these two morning hours (total 71.44%). But, we observe the same phenomenon i.e. a discrepancy between the estimated distributions by TASHA and the observed distributions of the 2003 O-D survey. There is indeed a significant underestimation of trips in start time between 7:00 - 7:59 AM and overestimation of those occurring between 8:00 - 8:59 AM. The K-S test (p value 0.441) for these distributions for school activity are inconclusive which indicates a large difference between the two distributions.

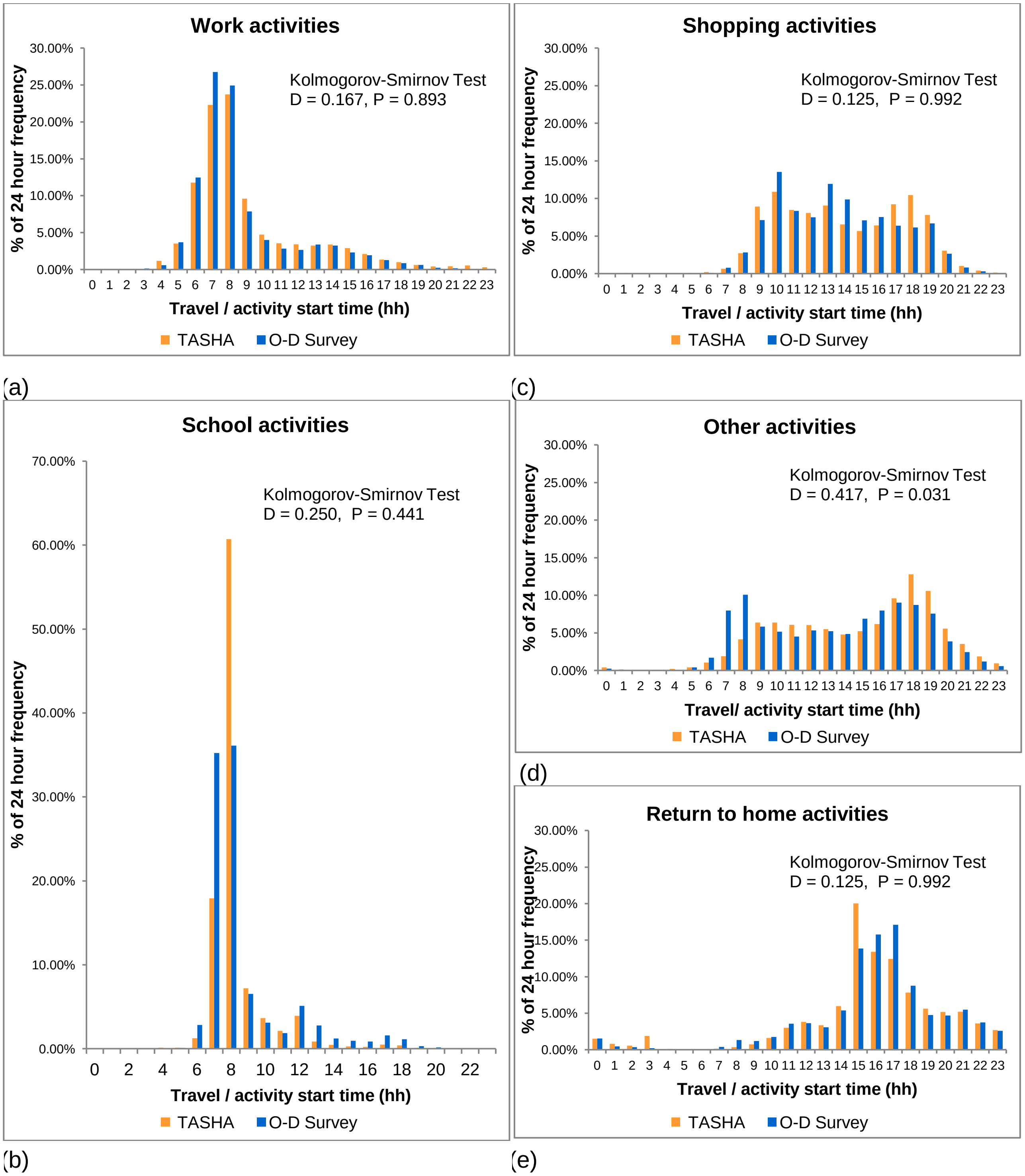

Figure 1: Travel / activity start time distributions: TASHA vs. O-D Survey (a) Work activities, (b) School activities, (c) Shopping activities, (d) Other activities, and (e) Return to home activities

Figure 1 (c) presents the estimated and observed distributions for shopping activities. Shopping activities are simulated within ranges between -3.3% and 4.3%. Typically, TASHA underestimates the proportion of shopping activities starting in early hours as well as in late afternoon. The K-S test for shopping distributions (p value 0.992) indicates a very high probability that the modelled and observed distributions are from the same distributions, whereas for other activity (p value 0.031) it rejects the null hypothesis that both distributions are from the same distributions. In case of other activities (Figure 1 (d)), there is an underestimation of activities starting before 9:00 AM and between 3:00 PM and 4:59 PM. Although the fact that these comparisons are between estimated and observed start times of activities, the differences seem to be at the behavioural level for these activities. In case of return to home activities (Figure 1 (e)), there is an oversimulation of activities starting between 12:00 PM and 3:59 PM and undersimulation of activities starting between 4:00 PM and 6:59 PM. The results show large differences in the temporal distributions of start times between modelled and observed; this may happen as TASHA simulations were parameterized with the observed distributions from Toronto.

Activity duration

Figure 2 presents average activity durations for each activity type by travel/activity start times. As expected, average activity durations for all activity types are lower for activities that started later in the day. The Kolmogorov Smirnov (K-S) tests are also applied to examine significant differences between modelled and observed distributions for all activities. In case of activity durations, the results also show a great variation for all activities with Toronto distributions. Figure 2 (a) shows estimated and observed average work activity durations by travel/activity start times. It indicates that average durations are undersimulated for all work activities starting before 5:00 PM, which includes a vast majority of departures for work. Figure 2 (b) presents the average durations of estimated and observed school activities by travel/activity start time. Here, average durations are also undersimulated for almost every hour except activities starting between 12:00 PM and 1:59 PM, and after 6:00 PM. Obviously, there is a reason for major concentration of starting school activities between 7:00 AM and 9:00 AM.

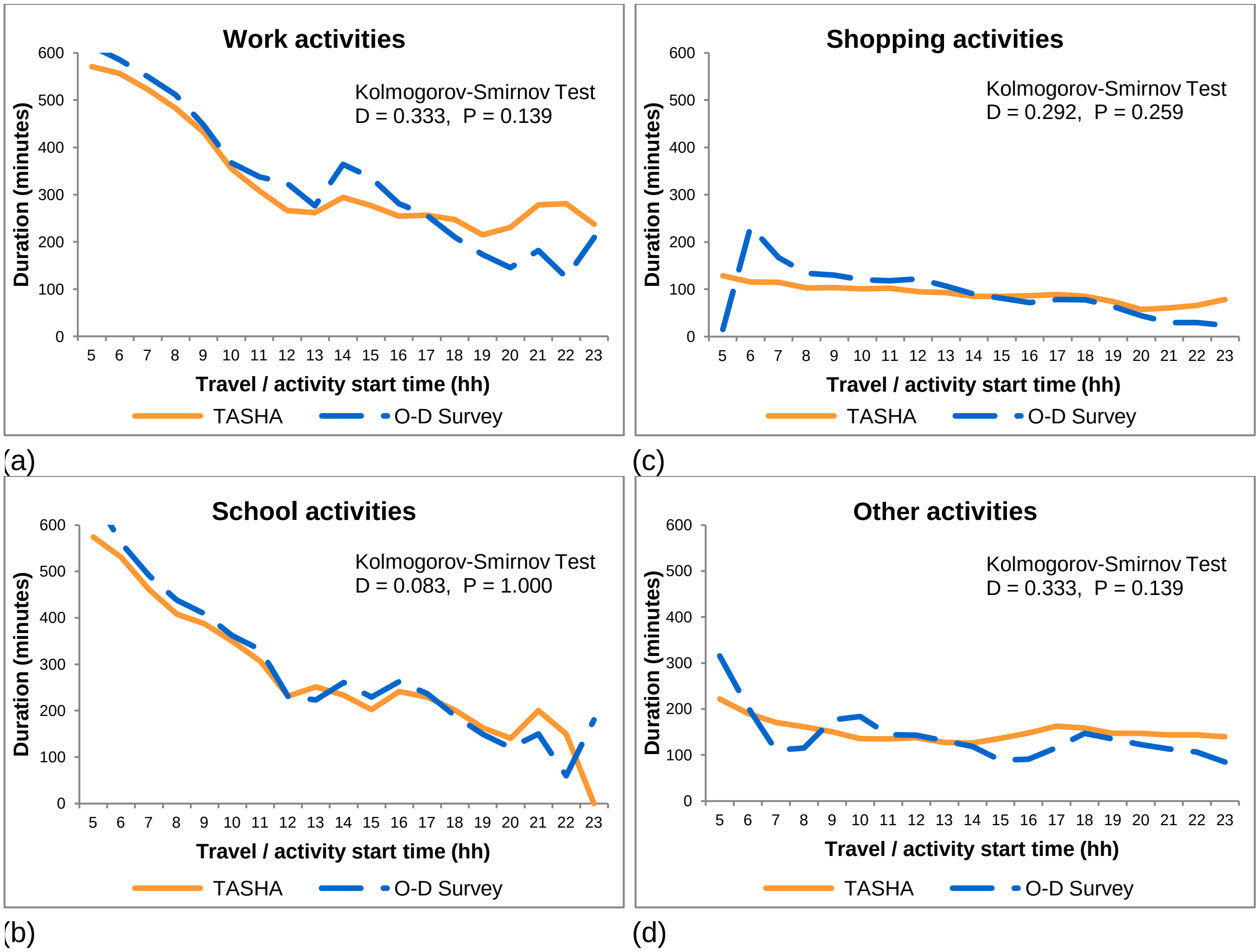

Figure 2: Activity duration distributions: TASHA vs. O-D Survey (a) Work activities, (b) School activities, (c) Shopping activities, and (d) Other activities

Figure 2 (c) shows the observed and estimated average durations for shopping activities according to travel/activity start time. Again, durations are undersimulated for activities starting before 3:00 PM, then there is overestimation of durations though the differences are smaller. Figure 2 (d) shows the observed and simulated average durations for other activities depending on the travel/activity start time. The differences are much more variable throughout the day; TASHA underestimates durations of other activities which started early in the day and overestimates the value for activities taking place in the late afternoon. From this analysis as well as frequency analysis for other activity, one can conclude that other activities differ greatly between Montreal and Toronto, both in kind and temporal distribution. For school activities, K-S test indicates a very high probability that the modelled and observed distributions are the same.

Activity location

Table 1 also compares the estimated average distances by TASHA with the observed average distances by activity type. The overall result shows that TASHA oversimulates the average observed distance by 13.26%. The average travel distance reported in the O-D survey is 5.63 km, whereas the estimated average distance is 6.38 km. TASHA overestimates the average distances for all activities, however average distance for work activity is slightly overestimated (within 0.01%). It is important to mention here that usual place of work/school are directly input in to the modelling framework which, of course, greatly reduces uncertainty. Table 1 indicates overestimation for all other activities (school, shopping, other, and return to home activity). The largest differences are observed for shopping (40.87%) and other (37.82%) activity type, which is not negligible. Except work, for all other activities, overestimations are many times higher than the standard deviations.

CONCLUSIONS

This paper discusses the spatial transferability of an activity-based model, TASHA (Travel Activity Scheduler for Household Agents), which has been developed based on trip diary data from the 1996 TTS for the Greater Toronto Area (GTA), Canada. To fulfill the objective, here, the model has been applied in the context of the Island of Montreal, Canada using the 2003 O-D travel survey and the 2001 Canadian census. TASHA estimates daily schedules of activities (individual and joint) for each individual in the Island of Montreal. A comparison between estimated activity attributes by TASHA and observed attributes from the 2003 O-D travel survey has been conducted to assess the spatial transferability of the model. Activity attributes include activity frequency, start time and average duration, and average travel distance.

Overall, TASHA underestimates the total number of observed activities by 10.3% which is worse than the results found in Toronto. The estimations for work, school and return to home activities are quite satisfactory, however the results for shopping and other activities warrant further improvements in the modelling framework on in parameters adaptation. Comparison of modelled and observed start time distributions by time of a day demonstrates that work activities are closely estimated by the model over the day within 2% for all but 1 hour (7:00 - 7:59 AM). The same comparison for school activities shows a significant variation in the two morning hours of the day (7:00 and 8:00 AM), when actually most of the observed school activities are taking place (i.e. total 71.44%). Typically, TASHA underestimates the proportion of shopping activities starting in early hours as well as in late afternoon. Like other attributes, the differences for average durations are also worse than Toronto for all activities except school activities. In addition, overall, TASHA overestimates the average observed distance by 13.26%. Average distance for work activity is slightly overestimated (within 0.01%); the largest differences are observed for shopping (40.87%) and other (37.82%) activity type, which are not negligible. From all these analyses, it is observed that all activity attributes for other activity type differ greatly between Montreal and Toronto.

The large variations found in comparative analyses for different activities could indicate the differences in behaviour between the distributions observed in Montreal and Toronto. As observed distributions of activity attributes from the 1996 TTS are used as model input in activity generation component in TASHA, maybe these distributions could not successfully capture travel patterns in Montreal. Accordingly, for successful modelling in Montreal using TASHA, activity attributes distributions for input must be prepared such that it could replicate Montreal's behaviour. Thus, we could use observed distributions from the 2003 O-D travel survey as model input; It may overall improve the model results. Subsequently, we could also validate the model both at the macroscopic (gross) and microscopic level (household/individual for instance), which seems customary in Montreal while evaluating the performance of a model. Also, observed distributions used as input are assumed to remain constant over time. However, it is quite possible that travel behaviour of individuals and households are changing over time, both in terms of activity generation and spatio-temporal structure. Yasmin et al. (2012) reveals by conducting a comparative analysis of activity attributes for work, school, shopping and other activities over a period of 10 years (1998 to 2008) that distributions of activity attributes are changing over time in the context of Montreal. Therefore, activity attributes distributions for TASHA needs to be prepared such that they reflect temporal changes in travel behaviour of this region for forecasting purposes.

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