A REVIEW OF THE TRAVEL BEHAVIOR ANALYSIS: ITS BASIS AND APPLICATION FOR DEVELOPING CITIES

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Abstract

Travel, most often viewed in theory as derived from the demand for activity participation, has almost always been modeled on the trip-based basis, i.e., the trip is treated as the unit of analysis. Attributes of a trip (e.g., its origin and destination, mode, length) have been the subjects of analysis, but not the types of activities engaged in, their durations, sequences, and timing. This paper offers a brief review of the travel behavior analysis in order to provide a better understanding and forecasting of travel behavior. The article further offers discussions on its possible applications in urban areas of developing countries where historical accumulations of transportation and communications technologies are being introduced within a short span of time, creating the environment for travel which may not be properly accounted for using the conventional trip-based models of travel demand. In addition, the dataset from Malaysia was employed as a case of study.

Keywords: *travel behavior, travel, demand, transportation planning, developing cities.*

INTRODUCTION

The traditional modeling structure for transportation demand distinguishes four decisions: how often to travel, to what destination, what mode of transportation to use, and what route to take (Small and Winston, 1999), which has come to be referred as the *four-step model* (FSM), i.e. trip generation, trip distribution, mode choice, and trip assignment. Travel, most often viewed in theory as derived from the demand for activity participation (McNally, 2000a), has almost always been modeled on the trip-based basis, i.e., the trip is treated as the unit of analysis. Attributes of a trip (e.g., its origin and destination, mode, length) have been the subjects of analysis, but not the types of activities engaged in, their durations, sequences, and timing.

McNally (2000a) said that the FSM is best seen as a particular application of transportation systems analysis (TSA), a framework due to Manheim (1979) and Florian et al. (1988). From the perspective of the state of the practice, the decision of choosing this approach is mostly because of the lack of analysis approaches available, given current institutional requirements and financial limitations (McNally, 2000a). However, although this approach was effective in facility planning that was required in the post-war expansion period in North America and Europe, its effectiveness has been questioned in the current contexts where the objectives of transportation planning have diversified and the management of demand has become the primary concern. Trip-based methods do not address the linkages between trips and activities, temporal constraints on activity scheduling, interdependencies among activities and across individuals, and other aspects of activity behavior that underlie observed travel behavior. It has failed to perform FSM in most relevant policy tests, whether on the demand or supply side (McNally, 2000a). It was clear from the beginning, however, that the derived nature of the demand for transportation was understood and accepted, yet not reflected in the FSM (McNally, 2000b).

Focusing the problem solving only based on the trip analyses makes us only deal with the top of the floating ice berg of problems without even touch the heart of the problem, which is the individual demand to travel and their behavior. Fortunately, it has been increasingly being recognized that institutions and their decisions need to be modeled more fully (Hensher and Button, 2000). Traditionally, transport planning has developed out of engineering and economics, where the concerns have been to accommodate traffic and to ensure value of money, often interpreted very narrowly (Banister, 2002). More recently, a wider range of social science perspectives has become influential in transport thinking, and new priorities have gained credence, including demand management, the allocation of priority to certain users of the system, and most recently by creating spaces for people rather than cars in cities (Banister, 2005). Emphasis in travel modeling has moved from direct prediction of traffic flows to understanding and predicting the choices that individuals and organizations are likely to make (Hensher and Button, 2000).

Increasing concern about investment, energy, and environment (and to some extent equity) prompted a new transportation-planning philosophy, where transportation planners began for the first time to consider managing the demand for travel, using what were referred to as Transportation-System Management (TSM) actions, rather than simply increasing the supply to accommodate the projected demand (Lee-Gosselin and Pas, 1997). By the mid-1970s, discrete-choice models were beginning to emerge internationally as practical alternatives to aggregate modal-split models. At the same time, travel behavior researchers began pioneering the use of psychometric-type scaling techniques to understand travelers' perceptions better and to quantify such variables as comfort, convenience, and reliability (Neveu et al., 1979). For example, Goodwin (1991) builds his research body using this method and therefore it has been widely known as the activity-based approach to travel analysis (Lee-Gosselin and Pas, 1997). As an alternative paradigm in travel behavior analysis and modeling, the activity-based approach (ABA) was founded on the idea that, since travel is generally undertaken to participate in an activity at a location that is separated from one's current location, it is crucial that the process of activity engagement be examined and understood (see Susilo and Kitamura, 2005; Susilo and Axhausen, 2007 for more discussion). Overall the activity-based approach theoretically arises as a natural evolution of research on human behavior, in general, and travel behavior, in particular (McNally, 2000b).

This paper offers a brief review of the concept of travel behavior analysis in order to provide a better understanding and forecasting of travel behavior. The article further offers discussions on its possible applications in urban areas of developing countries where historical accumulations of transportation and communications technologies are being introduced within a short span of time, creating the environment for travel which may not be properly accounted for using the conventional trip-based models of travel demand. To show the application, the dataset obtained from Malaysia was employed as a case of study.

This article consists of five sections. After this introduction section, a brief description regarding the advantages and disadvantages of travel behavior analysis is provided in section two. Section three describes an opportunity and challenge of travel behavior analysis in the context of the implementation in developing cities. Dataset regarding the household in Malaysia is employed as a case of study, while its analyses and discussions are provided in section four. The authors summarize the discussion in the last section.

TRAVEL BEHAVIOR ANALYSIS: ADVANTAGE AND DISADVANTAGE

The Trip-based Approach

Critical disadvantages of the conventional trip-based model of travel demand forecasting have been pointed out by several researchers. For example, Flyvbjerg (2005), who measures the accuracy of travel demand forecasting projects at aggregate levels to find that only 210 of 485 projects are considerably reliable with actual demands being within ±40% of projected values. Instead of being stable, the individual travel behaviors are keep changing overtime and the changes pattern are different for different type of individual. In fact, these findings are reasonable, as McNally's statement (2000b), that the FSM was developed to evaluate the impact of capital-intensive infrastructure investment projects during a period when rapid increase in transportation supply were arguably accommodating, if not directing, the growth in population and economic activity of the post-war boom. McNally (2000b) summarized the weaknesses and limitations of trip-based models as follow:

1. ignorance of travel as a demand derived from activity participation decisions;
2. focus on individual trips, ignoring the spatial and temporal interrelationship between all trips and activities comprising the individual activity pattern;
3. misrepresentation of overall behavior as an outcome of a true choice process, rather than as defined by a range of complex constraints that delimit (or even define) choice;
4. inadequate specification of the interrelationships between travel and activity participation and scheduling, including activity linkages and interpersonal constraints;
5. misspecification of individual choice sets, resulting from the inability to establish distinct choice alternatives available to the decision-maker in a constrained environment; and
6. the construction of models based strictly on the concept of utility maximization, neglecting substantial evidence relative to alternate decision strategies involving household dynamics, information levels, choice complexity, discontinuous specifications, and habit formation.

Despite its disadvantages, the FSM is still best seen within the overall framework of transportation systems analysis, which positions travel demand and network performance procedure as determining flows that tend toward equilibrium with input from and feedback to location and supply procedures (McNally, 2000a). The FSM is the primary tool for forecasting the future demand and performance of regional transportation systems. Initially developed for evaluating large-scale infrastructure projects, the FSM is a policy sensitive with regards to alternative arrangements of major capacity improvements. It has not been effectively applied for policies involving management and control of existing infrastructure, and explicitly not as the evaluation of restrictive policies involving demand management (McNally, 2000b).

Activity-based Modeling

To coup with the FSM disadvantages, in the last thirty years, a wealth of behavioral theories, conceptual framework, analytical methodologies, and empirical studies of travel behavior emerged during this same period when the policy environment was evolving. The motivation of the *activity-based approach* is that travel decisions are activity based, and that any understanding of travel behavior is secondary to a fundamental understanding of activity behavior. The activity approach explicitly recognizes and addresses the inability of trip-based models to reflect underlying behavior and, therefore, their inability to be responsive to evolving policies oriented toward management versus expansion of transportation infrastructure and services. The ABA highlights the importance of a number of interdependencies that are ignored in the traditional trip-based framework, including interdependencies between trips and travelers from the same household (Lee-Gosselin and Pas, 1997). Further, they also said that the activity-based approach explicitly recognizes the importance of scheduling in travel-behavior and the fact that travel demand is derived from need or desire of individuals to participate in out-of-home activities.

While definitions differ across researchers, Axhausen (2000) explain that the cores of the approach are:

1. Travel is derived from the need to change locations between two successive activities. It is a means not an end.
2. Movements undertaken for their own sake are an exception. These will be considered as activities, not as travel, for example: walking the dog, strolling through the park, cycling through the countryside.
3. An activity is a continuous interaction with the physical environment, a service or person, within the same socio-spatial environment, which is of importance to the person.
4. Individual activities contribute to larger personal projects, such as shopping for plants contributes to the remodeling of the garden, reflect longer-term commitments, such as work, or satisfy basic physiological or emotional demands, such as eating or sleeping.
5. Individuals operate within their budgets of time, resources (in particular money) and of social capital.
6. Individuals will schedule their activities in co-ordination with the members of their household or of their social network, so as to optimize their satisfaction balancing short and long-term considerations.
7. Scheduling encompasses the choice of time, duration, location and access mode for the activities selected.
8. Individuals are constraint in their scheduling because of the resources available to them, in particular vehicles.
9. Individuals are constraint in their scheduling due to the need to be available to others at particular times or locations, either in person or at a distance (phone, chat room, or email).
10. Individuals are constraint because of their longer-term commitments to their household members, to their residential location(s) and to their work place(s).

Early work of ABA was started by McNally (Recker et al 1986) and Clarke (Jones, 1983). While Gärling et al 1998 demonstrated the concepts of activity scheduling, Arentze and Timmermans (2000) developed the simulation system dedicated for it. Furthermore, as a micro-simulation is in the wider tradition of such models in transport (see for example Axhausen and Herz, 1985 among others), including a strong interest in the micro-simulation of flows and route choice (see for example Esser and Nagel, 2000 among others), a merger of micro-simulation with ABA is currently ongoing. The next generation of research tools will integrate models of day-by-day activity generation, of daily activity scheduling with models of activity execution, and of traffic flow and route choice, which they will also incorporate day-to-day learning to generate the paths of systems through time. Indeed, the practical tools will integrate models of activity chain execution within detailed micro-simulations of flow and route choice (Axhausen, 2000). These developments will depend on suitable data collection on the scheduling process itself and its outcomes over time, but they will also depend on work on spatial learning – an area, which has been neglected in transport, but also environmental psychology and geography, which have been interested in the learning of topologies, but not in the learning of the performance of networks.

OPPORTUNITY AND CHALLENGE IN DEVELOPING CITIES CONTEXT

One way to look at the future of this field of research is to examine the potential for different parts of the world to provide what amounts to a variety of "natural" experimental settings on a large scale (Lee-Gosselin and Pas, 1997). In fact, the conditions of the urban areas in developing countries tend to be much more dynamic than developed countries, a stability of behavior – the main requirement of FSM – is more implausible to be happened. Thus, the potential advantages can be argued as promising. As travel behavior study deals with traveler activity and perception, several substantive topics are beneficial to be studied by employing travel behavior approaches, i.e. the relationship between daily-mobility behavior based on residential-mobility process (Raux and Andan, 1997); the role of participation of women in paid work and the membership in a particular type of household (Séguin and Bussière, 1997); the transportation impacts of telecommuting (Mokhtarian, 1997); behavior changes to respond environmental policy (Gärling and Sandberg, 1997); user perception of public transport service (Ortúzar et al 1997; Joewono and Kubota, 2007); or categorization and interpretation of urban and road environments (Fleury and Dubois, 1997). In addition, to the extent that individual contexts evolve at different rates in different countries, several contexts offer valuable bases for comparison, i.e. the different combinations of states of the environment, socioeconomic/demographic, and technological (Lee-Gosselin and Pas, 1997), as well as urban forms, information technology, and instrument of public-policy.

Moreover, several efforts in applying travel behavior technique have been made in developing cities. As a way of example, a set of studies by Morikawa et al. (see Morikawa et al., 2003 and Dissayanake, 2007) overview the trends of travel behavior in four-selected cities in Asia: Bangkok, Kuala Lumpur, Manila, and Nagoya by employing several travel demand models. Using in particular Jakarta Metropolitan Area (JMA) as a study case, a similar attention was also initiated (see Senbil et al 2007; Yagi and Mohammadian, 2006). Those studies capture a tendency of changes of urban travel behavior as well as travel demand. The behavior implications of current policies of may then be valuable for decision makers.

CASE STUDY: CAR USE IN MALAYSIAN HOUSEHOLD

The study area, Klang Vally Region, covers the Federal Territory of Kuala Lumpur and its conurbation about 10 km from the boundary. Klang Vally area consists of Kuala Lumpur Metropolitan (KLMP) and Selangor state that includes four districts such as Gombak, Klang, Petaling and Ulu Langat. KLMP itself covers an area of 243 km^2. In total, the study area of Klang Vally Region is about 500 km^2. As estimated in 2000, population in the study area was about 4.1 million and average annual growth rate of population is 3.7%. The data for the study were obtained from a household travel survey that was conducted by Japan International Cooperation Agency (JICA). The study started in March 1997 and ended in February 1999. The survey was conducted as a part of a major transport project in Kuala Lumpur called "Strategies for Managing Urban Transport in Kuala Lumpur - SMURT-KL" (JICA, 1999; Morikawa et al 2003). The database provides useful information related to households, individual members and person trips.

Of these 900 households, 255 (28.3%) reside in the State of Kuala Lumpur, while the rest in Selangor. The distribution of household's district is as follows, 34.4% resides in Petaling, 11.3% in Klang, 4.2% in Hulu Langat, 19.2% in Gombak, 28.3% in Kuala Lumpur, and 2.4% in Sepang. The car ownership is illustrated by the sample that 89 (9.9%) had no vehicle available, 577 (64.1%) had one vehicle, 186 (20.7%) had two vehicles, and 48 (5.3%) had three or more vehicles available at the time of the survey. As the way of comparison, 693 (77%) out of 900 households in this survey had no motorcycle in their households, while 172 (19.1%) had one motorcycle, and 35 (3.9%) had three or more motorcycles available.

Ordinary least squares models of vehicle use are estimated as presented in Table 1. Three estimation results are provided, i.e. trips per month, per week, and per day as well. All models have very low p-*value* for *F-test* for testing the model and also chi-square test for diagnostic log-likelihood, while the R^2 and adjusted R^2 are quite low.

Table 1 Multiple Regression Model for Car Use

Variable	Trips per month		Trips per week		Trips per day	
	Coeff.	P[|Z|>z]	Coeff.	P[|Z|>z]	Coeff.	P[|Z|>z]
Constant	-6.153	-.710	-29.936	.1005	-35.084	.0520
Type of dwelling is Terrace/link [D]	23.469	.0089	22.116	.0104	21.442	.0121
Type of dwelling is flat/apartment [D]	36.793	.0000	34.043	.0001	33.145	.0001
Number of car license			-5.293	.0360	-6.126	.0143
Salary is 3k RM or less [D]			-21.203	.0142	-20.509	.0167
Salary is 3-7k RM [D]	12.794	.0209	-14.237	.1057	-15.390	.0774
Salary is 7K RM or more [D]	29.094	.0144				
Vehicle's brand is Proton [D]	9.715	.0564	8.174	.0964	8.045	.0985
Household is the vehicle's owner [D]			30.271	.0574	29.495	.0615
Company is the vehicle's owner or rented [D]			40.355	.0861	39.583	.0892
N		1386		1386		1386
R^2		.191E-01		.208E-01		.212E-01
Adjusted R^2		.155E-01		.151E-01		.155E-01
p-value for F-test		.0001		.0003		.0003
p-value for χ^2		.000		.0003		.0002

D= dummy; 1 = yes, 0 = otherwise

All variables in model for trips per month representing type of dwelling, number of car license, salary, vehicle's brand, and type of vehicle's owner are highly significant. On the other hand, variables in model for trips per week and trips per day are the same, while the variables in trips per day are better in term of *p-value*. In these two models, many variables are significant at a 10% level except the variables of type of dwelling are significant at a 5% level. As expected, households with higher income make more trips than lower income household did at any period of time. The number of trip generated has a relation with the type of ownership, where household who rent the car or used company's car seems to make more trips. Evidence can also be gathered from the model, which the variable is significant at a 10% level, that while the vehicle brand is Proton, the households tend to make more trips.

The statistical result also illustrates that number of trip has a positive relation with the salary of household. On the other words, households with higher salary tend to make more trips for any period of time. It can be also found that the households make more trips when they rent it or when it is a company car. It is also the case when the brand's car is Proton.

Table 2 illustrates the result of OLS model to study the length of travel time by the respondents as a traveler. The statistics of the model shows a good approximation of the data. All variables are significant at a 5% level of significant, while only one variable is significant at a 10% level of significant, i.e. arrival time in destination is earlier than 06.00 a.m.

Table 2 Multiple Regression Model for Travel Time

Variable	Coefficient	P[|Z|>z]
Constant	21.087	.000
Type of dwelling unit is shop-house [D]	4.863	.011
Number of car-license's holder in household	.703	.020
Number of motorcycle in household	-1.087	.035
Location of urban center is Shah Alam [D]	3.373	.007
Location of urban center is Pelabuhan Klang [D]	-4.396	.001
Location of urban center is Batu Caves [D]	-6.220	.000
Departure time from origin is earlier than 06.00 a.m [D]	16.491	.007
Departure time from origin is 06.00 – 07.00 a.m [D]	14.292	.000
Departure time from origin is 08.00 – 09.00 a.m [D]	-15.192	.000
Departure time from origin is later than 09.00 a.m [D]	-25.675	.000
Arrival time in destination is earlier than 06.00 a.m [D]	-11.707	.055
Arrival time in destination is 06.00 – 07.00 a.m [D]	-13.145	.000
Arrival time in destination is 08.00 – 09.00 a.m [D]	15.071	.000
Arrival time in destination is later than 09.00 a.m [D]	31.270	.000
Mode of transport is by walking [D]	-12.744	.000
Mode of transport is motorcycle [D]	-7.711	.000
Mode of transport is car/van [D]	-3.035	.002
Make a trip as a driver [D]	5.435	.000
N		2927
R^2		.227
Adjusted R^2		.223
p-value for F-test		.000
Durbin-watson		1.747

D= dummy; 1 = yes, 0 = otherwise

People who owned shop-house as their dwelling unit seems to travel in a longer period of time. Household with more car-license's holder has a same tendency. It can also be noticed that people with more motorcycle available in their household seem to travel shorter. The location of the urban center also has an influence to people's travel time. Urban center in Pelabuhan Klang and Batu Caves has a positive relationship with travel time, while urban center in Shah Alam has a reverse relationship. This model explains that no matter the mode the people used (i.e. walking, car/van, or motorcycle), people are more likely to travel in shorter time. In addition, it seems logical to notice that the traveler who drives has a tendency to travel longer time.

In the case of time of departure, people who depart earlier than 07.00 a.m are more likely to travel shorter period. It is also the case for people who arrive in their destination between 08.00 up to 09.00 a.m. People who depart later than 08.00 or who should arrive earlier than 07.00 seems to travel in longer period.

Trip distance is also analyzed as can be seen in Table 3. The model has a moderate statistics, while all variables are significant at a 5% level of confidence with one variable significant at a 10% level of confidence, i.e. location of urban center is Shah Alam.

Table 3 Multiple Regression Model of Trip Distance

Variable	Coefficient	P[|Z|>z]
(Constant)	10.408	.000
Number of resident in household	-.395	.033
Number of motorcycle	-1.408	.007
Location of urban center is Shah Alam [D]	5.370	.000
Location of urban center is Pelabuhan Klang [D]	2.392	.060
Departure time from origin is 06.00 – 07.00 a.m [D]	7.318	.000
Departure time from origin is 08.00 – 09.00 a.m [D]	-7.908	.000
Departure time from origin is later than 09.00 a.m [D]	-11.204	.000
Arrival time in destination is 06.00 – 07.00 a.m [D]	-6.836	.000
Arrival time in destination is 08.00 – 09.00 a.m [D]	8.162	.000
Arrival time in destination is later than 09.00 a.m [D]	18.225	.000
Mode of transport is by walking [D]	-10.256	.000
Mode of transport is motorcycle [D]	-3.620	.001
Mode of transport is Local Public Transport [D]	-6.088	.000
Make a trip as a driver [D]	3.721	.000
N		2860
R^2		.153
Adjusted R^2		.148
p-value for F-test		.000
Durbin-watson		1.791

D= dummy; 1 = yes, 0 = otherwise

People with more residents in the household or more motorcycle available in the household seem to travel shorter distance. Departure and arrival time has a similar influence to trip distance with travel time. It can be understood as travel time and trip distance has a strong relationship. The type of the mode has also a same pattern of influence between to trip distance and to travel time. People who drive their own car also tend to travel longer distance.

CONCLUSIONS

This article has illustrated a brief description regarding travel behavior analysis for the context of developing cities. Long track in the development and implementation of travel behavior analyses in developed countries have shown the advantages of this approach. Travel behavior analysis is an effective way to analyze the transport policy, as it is able to understand the human behavior, i.e. its reasons and characteristics behind their decision to respond the transport policy.

This study also provides a simple example regarding the travel behavior analysis, i.e. number of car use per period of time, travel time, and also travel distance, by employing dataset from Malaysia’s household. Several models have been build, which illustrates the benefit of the analysis to understand the traveler in a better way. The models show several things that can not be revealed by traditional approaches. The coefficient estimates also reveal the potential approach to arrange an appropriate transport policy to manage the demand, e.g. developing a policy to manage daily peak period in urban areas. It can be inferred that the Malaysian households have their specific characteristics in holding the vehicle, choosing the type or brand of vehicle, and making trip per period of time. This evidence is useful as a base to develop transport policy in managing motorization in Malaysia, as well as creating a plan of mobility management.

It can be argued that it is implausible to assume that the general public will react homogenously to respond a specific transport policy. It is imperative to understand why and who the people which like to use it, and how they will use it in their daily activities. In addition, based on previous researches in developed and small number in developing countries, it can be argued that the approaches of travel behavior might offer a better solution to the problems. It is much better if the policy maker confirms to the general public what they perceived. Before the planner or decision maker builds a policy, they should confirm the public perceptions, needs, characteristics, and activities by employing travel behavior analysis.

In addition, based on the review and case of study, the authors propose some suggestions for future transportation practice and research in developing cities. Firstly, the improvement and expansion of data collection should be done with considering the related aspects of travel behavior. Furthermore, a richer dataset such as a day-to-day travel diary survey can be introduced as a next step of collecting a travel database. The advantage of obtaining a multiple-day travel diary dataset enables transport planners to copy individual-by-individual rhythms in travels over a temporal period of time as well as to understand the mechanism of behavior response across individuals toward present transport policy. It is unfortunate that in many third-world cities, the availability of its dataset is limited and still becomes as second priority for stakeholders. Secondly, planners, researchers, and policy makers need to observe the local context and characteristics in developing transport policy in order to obtain a deeper analysis. A specific investigation should be considered due to the heterogeneity of urban transport issues which tends to vary from place to place, from individual to individual and even from time to time. Instead of a general transportation master plan, focusing on certain local-based studies such as travel behaviors of out-of-home and in-home activities; the influences of gender difference as well as household type on travels; the impacts of transport policy on individual’s choices and so on; may provide a rigorous insight of urban transportation systems. Fortunately, this motivation is definitely able to be achieved through employing activity-based approach. Lastly, it is beneficial to upgrade the learning process and content of travel behavior knowledge in transportation education in developing countries. This, together with other traditional approaches, may enrich our understanding on urban transportation phenomena in a more proper way.

ACKNOWLEDGEMENTS

The authors express their thanks and feeling of gratitude to Professor Jamilah Mohamad, Ph.D. of Malaya University, Malaysia, who has provided data and permission to do an analysis. More complete analysis regarding car holding and use in Malaysian household was under reviewing process for presentation and publication in 87th Transportation Research Board Annual Meeting.

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