Travel demand analysis with the RP/SP combining technique for developing countries

Analyse de la demande de voyage par la technique combinée RP/SP pour les pays en voie de développement

Análisis de la demanda de trayectos en los países en vías de desarrollo utilizando una combinación de las técnicas RP/SP

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ABSTRACT: Most metropolitan areas in developing countries are suffering from severe traffic congestion and resulting air pollution due to lack of public transportation and rapid motorization. Providing mass transit system is expected to be the most efficient solution for the problems. Introduction of new transportation modes, however, complicates the demand analysis because data of actual usage of such modes do not exist. Although the stated preference (SP) technique is a powerful tool in such situation, the reliability of elicited preference is unknown. Revealed preference (RP) data are also scarce in developing countries. This study is the first attempt of applying the Ben-Akiva and Morikawa's RP/SP combining technique to urban transportation in developing countries in order to alleviate the data scarcity problem. The technique is applied to the mass rapid transit project in Bangkok. The paper also proposes the framework of urban transportation demand analysis which incorporates the car-ownership model and travel mode choice model.

RÉSUMÉ: La plupart des zones métropolitaines dans les pays en voie de développement souffrent de l'encombrement grave du trafic et de la pollution atmosphérique résultante dus au manque de transport public et de motorization rapide. La disponibilite massive d'un systeme de transit pourrait être la solution la plus efficace pour juguler cette situation. L'introduction de nouveaux modes de transport, cependant, complique l'analyse de la demande parceque les données de l'utilisation réelle de tels modes n'existent pas. Bien que la technique Stated Preference (SP) soit un outil puissant dans une telle situation, la fiabilité de la préférence obtenue est inconnue. Les données Revealed Preference (RP) sont également rares dans les pays en voie de développement. Cette étude est la première tentative applicant la technique combinée RP/SP de Ben-Akiva et le Morikawa au transport urbain dans les pays en voie de développement afin de surmonter le problème d'insuffisance de données. La technique est appliquée au projet de transit rapide à Bangkok. L'etude propose aussi le cadre de l'analyse de la demande de transport urbain en integrant le car-ownership model et le model du choix du mode de transport.

RESUMEN: La mayoría de las áreas metropolitanas en los países en vías de desarrollo sufren de una severa aglomeración del tráfico con la resultante contaminación del aire debidas a la falta de un buen servicio público de transportación y al incremento rápido de la motorización. La solución más eficiente a estos problemas es posible que consista en proporcionar un sistema de tranportación en serie. La introducción de nuevas formas de transportación, sin embargo, complica el análisis de la demanda dado que, actualmente, no existen datos sobre tales formas de transportación. Aunque la técnica de preferencia especificada (SP por sus siglas en inglés) es una herramienta poderosa en tales situaciones, se desconoce la confiabilidad en el logro de la obtención de preferencias. A su vez, los datos sobre la Preferencia Revelada (RP por sus siglas en inglés) son escasos en los países en proceso de desarrollo. Este estudio es el primer intento de aplicación de la combinación de las técnicas de Ben-Akiva y Morikawa RP/SP al sistema de transportación urbana en los países en vías de desarrollo para tratar de disminuir el problema de la escasez de datos. La técnica se ha aplicado al proyecto de tráfico en forma rápida y masiva en Bangkok. El estudio propone, además, el sistema de análisis de la demanda de transportación urbana con un modelo que incluya el uso de automóvil propio y un modelo con medios alternativos de viaje.

1 INTRODUCTION

Effective travel demand policies for the developing countries should be implemented because increase in travel demand creates some adverse environmental effects such as traffic congestion, air pollution, and noise pollution. Therefore, expansion and refinement of the existing transportation system is required to fulfill the overall task. However, there exist ample approaches, which can be meaningfully solve the increase in travel demand, the introduction of new mode seems superlative regarding to the environmental concerns if the new mode is in the form of subway, LRT, MRT or even zero-emission vehicles.

Dissagregate demand modeling which describes the behaviour of transport user with discrete variables (Discrete Choice Analysis (DCA), Ben-Akiva & Lerman 1985) is very popular in transportation planning. DCA is based on the principle of utility maximization where the utilities of the alternatives are considered as random variables. Vovsha (1997) mentioned that there exists an absolute dominance of multinomial and nested logit models over other mode choice models due to the simple analytical framework. A cross-nested logit model is recently estimated to forecast the mode choices if new transit modes come into effect (Vovsha 1997). The mode choice models for commuter trips have been extensively investigated during last two decades.

Estimation of discrete choice models are basically relied on revealed preference (RP) data for actual travel behaviour. There, however, is also a substantial interest on stated preference (SP) data, which is based on hypothetical travel scenarios. Although SP techniques have several advantages over more conventional RP techniques, the reliability of the elicited preferences relating to SP techniques is questionable (Wardman 1988, Morikawa 1989). In recent years, some considerable attention was made on RP and SP combining technique, which allows to improve the accuracy of parameter estimates while exploiting the advantages of both RP and SP (Morikawa 1989, Ben-Akiva & Morikawa 1990). Abraham & Hunt (1997) estimated a nested logit model for commuter travel by using RP data and wide range of system attributes has been identified as important. There also exists some substantial interest of mode choice modeling with repeated SP observations which can be successfully used to minimize the errors in individual choice response (Fujiwara & Sugie 1995, Mehndiratta & Hansen 1997).

This study evaluates the urban travel demand in developing countries by using RP/SP combining technique (Ben-Akiva & Morikawa 1990) when the new transit mode is introduced into the system. Empirical analysis is based on the future Mass Rapid Transit (MRT) project in Bangkok, Thailand.

Since the mode choice and the car ownership are inextricably linked, development of integrated model is important for future investigations on travel demand. Discrete choice analysis is widely used for estimating car ownership among the other techniques such as general linear models (Said 1992) and non- linear analysis (Button et al. 1993). The factors influencing on car ownership under rising economic conditions are also discussed.

2 DATA DESCRIPTION

This study uses SP data on the future MRT project in Bangkok, which provides wide coverage of all the sectors in Bangkok metropolitan region. Person trip survey data in the Bangkok Metropolitan Area are also used as RP data. RP survey and SP survey were conducted in 1995/96 and 1996, respectively. The travel modes, which are currently provided in the study area, include bus, train, car, taxi/tuktuk, and motor cycle, and MRT is added in the SP survey.

2.1 *RP data*

The RP survey was carried out as a part of the Urban Transport Database and Model Development Project (UTDM).

The RP survey was conducted to collect almost all types of data relating to the travel behaviour. Additional database for home interview survey was provided by Bangkok Environmental Improvement Project (BEIP), which supports to strengthen the overall database. Survey items include characteristics of trip makers and their households, and attributes of the trips that were made on the surveyed day. Each trip is described by the characteristics of mode (unlinked) trips. Location-based information such as trip length is calculated using an Arc-View software which is helpful for easy reference and meaningful comparison whenever necessary.

2.2 *SP data*

The research group of Infrastructure and Transportation Planning laboratory at the Nagoya University conducted a SP survey to obtain information on user preference regarding the future MRT project (Anurakamonkul 1997).

SP survey was conducted by either direct interviews or mailed questionnaires. The SP questionnaire was prepared to achieve explicit coverage of requirements relating with commuter travel. More specifically, the transport users were asked to select the choices, which are best suited to solve their personal constraints, among hypothetically created travel scenarios. Also, attributes for the choices are described in the forms of travel time, travel cost, travel speed, reliability (minimum delays), safety, comfort, service frequency, accessibility of intra-model transfers, and access/egress time.

3 MODEL ESTIMATION USING SP DATA

3.1 *Modeling approach*

The new transport mode, MRT, is planned to introduce into the existing transportation system in Bangkok, which creates overall set of transportation alternatives consisting of MRT, bus, car, rail and motor cycle. Although there will be five alternatives in reality, user preference is expressed on MRT, bus, and car in the SP survey.

By considering the responses of each individual regarding the most important and the second most important factors for the mode choices, the most dominant attributes are found to be the travel time and the travel cost.

By applying discrete choice modeling, the utility functions of selecting modes: MRT, bus, and car are formulated as follows:

$$U_{mrt} = \alpha_1 + \beta_1 tt_{mrt} + \beta_2 \frac{tc_{mrt}}{inc} + \varepsilon_{mrt} \tag{1}$$

$$U_{bus} = \alpha_2 + \beta_1 tt_{bus} + \beta_2 \frac{tc_{bus}}{inc} + \varepsilon_{bus} \tag{2}$$

$$U_{car} = \beta_1 tt_{car} + \beta_2 \frac{tc_{car}}{inc} + \varepsilon_{car} \tag{3}$$

where α and β are unknown parameters; ε is the random component of utility; and *tt*, *tc*, and *inc* are the travel time, the travel cost, and the user income, respectively.

3.2 *Model estimation results*

For the model estimation, market segmentation approach is employed by categorizing transport users into smaller sub-groups. Therefore, each sub-group behaves with similar pattern of perceptions and allows to maintain the homogeneity within the sub-group.

The model is estimated for each user sub-groups, for instance, transport mode (ordinary bus, air-conditioned bus, car, and motor cycle) and income class (low income, middle income and high income).

3.2.1 *Estimation based on transport mode*

The estimation results for segments based on current modes are shown in Table 1. The parameter estimates for each user group have the expected signs and most of the estimates are significant at the 5% confidence level. In addition, goodness of fit measurements are also reasonable.

MRT constants, for instance, are significantly positive for the models of ordinary bus, air-conditioned bus, and motor cycle indicating the user intention to switch to future MRT. The negative signs on the estimated MRT and bus constants in the car user model indicate that their willingness to use car over MRT and bus if travel time and cost are the same among these modes. This inherent model preference may be an indication of belief, convenience, freedom as well as comfort of the car travel. Having a car by investing huge sums make him to use a car rather than changing the mode, even though unchosen modes are comparatively better than a car.

The coefficients for the travel time and the travel cost are readily interpretable; for instance, negative sign indicates that when the travel time and the travel cost for a particular mode increases, utility of selecting the same mode decreases by keeping all the other things constant.

Value of time (VOT) for all user groups are estimated with respect to the income class as shown in Table 1. VOT increases with increasing income for air condition bus user and car user models, which enhance the true behaviour of transport user.

Table 1. Estimation results of mode-choice model based on transport mode.
Parameter/(t- statistics)

Variables	User Category			
	Ordinary Bus	Air-cond. bus	Car	Motor cycle
MRT constant	2.11	0.56	-0.66	0.91
	(6.3)	(2.7)	(-4.0)	(2.6)
Bus constant	0.33	-0.10	-3.04	1.85
	(0.5)	(-0.2)	(-5.2)	(1.8)
Travel time (hrs)	0	-1.79	-1.41	-2.79
	(-0.1)	(-2.3)	(-2.0)	(-2.1)
Travel cost/inc/10^3	-0.65	-0.64	-0.47	0
	(-3.7)	(-3.4)	(-2.1)	(-0.8)
SP observations	221	239	374	70
$L(0)$	-242.8	-262.6	-410.9	-76.9
$L(\hat{\beta})$	-158.2	-204.9	-277.0	-62.9
ρ^2	0.348	0.220	0.326	0.182
VOT (low income)		34	47	
VOT (mid. income)		90	104	
VOT (high income)		225	377	

3.2.2 *Estimation based on income class*

Parameter estimation results for income classes: low, middle, and high are shown in table 2. Estimated coefficients are also consistent in the sense of behavioural analysis of transport users.

MRT constant is significantly positive for low-income class indicating that they have an intention to use MRT. For transport users belonging to high-income class have significantly negative coefficients for MRT and bus constants by expressing their negative tendency for those modes.

Almost all income classes have significantly negative coefficients for both the travel time and the travel cost which make sense by describing their willingness to receive maximum utility with contributing less time and cost. Therefore, some trade-off between the time and the cost is expected to select the best choice.

VOT for each income class is estimated as shown in Table 2. From the low-income class to the middle income class, VOT increases with income and it make sense as transport users in the middle income class are willing to pay more money to save units of time than the low-income class. But there is some divergence for VOT regarding to the high-income class, which possess indirect relationship with model preferences. They show smaller VOT, which may imply that they have no intention of mode change from car to transit. Most probably, vehicle availability and convenience of travel may result this divergence.

Table 2. Estimation results of mode-choice model based on income class.
Parameter/(t- statistics)

Variables	Income Class		
	Low 0-25,000 Baht	Middle 25,000-60,000 Baht	High Over 60,000 Baht
MRT constant	1.29	0.24	-0.70
	(7.5)	(1.2)	(-3.0)
Bus constant	0.16	0	-2.62
	(0.4)	(0.1)	(-4.7)
Travel time(hrs)	-0.47	-2.69	-2.09
	(-0.9)	(-2.3)	(-2.3)
Travel cost/inc/ 10^3	-0.22	-0.64	-2.75
	(-2.8)	(-2.2)	(-3.3)
SP observations	492	423	325
L(0)	-540.5	-464.7	-357.1
$L(\hat{\beta})$	-421.1	-355.3	-51.5
ρ^2	0.221	0.236	0.296
VOT(Bhat/hr)	26	139	84

4 COMBINED ESTIMATION OF CHOICE MODEL USING SP AND RP DATA

4.1 *Basic formulation*

There exist some common attributes, which are equally applied for both RP and SP choice models. But, some of the attributes have close relationship with either RP response in the sense of actual market behaviour or SP response as biased factors. For RP/SP combined analysis, Morikawa & Ben-Akiva (1990) proposed a methodology that is successfully applied in travel demand analysis.

RP model

$$\boldsymbol{U}_i = \boldsymbol{\beta' x}_i + \boldsymbol{\gamma' y}_i + \varepsilon_i \quad (4)$$

SP model

$$\boldsymbol{U}_i = \boldsymbol{\beta' x}_i + \boldsymbol{\lambda' z}_i + \xi_i \quad (5)$$

where U_i is the utility of transport mode *i;* β', γ' and λ' are vectors of unknown parameters; x_i is the vector of attributes that are commonly applied for RP as well as SP; y_i is the vector of attributes that affected the actual choice; z_i is the vector of attributes that represents biases related to SP responses; and ε_i and ξ_i are random disturbance for RP and SP data sources.

For the empirical analysis: the travel time and the travel cost are selected as common attributes for RP and SP. In addition, socio-economic variables such as car ownership is entered to the utility function of car users in RP and SP models to evaluate the relationship between car ownership with car utility. RP-mode (present mode of transportation) is incorporated into the SP model to illustrate the bias associated with present mode on SP choice.

4.2 *Model estimation results*

The choice models: RP, SP and RP/SP are estimated and the parameter estimation results are shown in Table 3.

Table 3. Estimation results of mode-choice models: RP, SP, & RP/SP.
Parameter/(t- statistics)

Variables	RP	SP	RP/SP
Travel time (hrs)	-1.43	-1.15	-1.61
	(-4.2)	(-3.4)	(-5.0)
Travel cost/inc/10^3	-0.08	-0.40	-0.32
	(-0.9)	(-5.6)	(-4.0)
Car-ownership	4.68	1.44	4.10
	(7.7)	(6.4)	(6.8)
Bus constant (RP)	2.65		1.94
	(6.2)		(4.9)
MC constant (RP)	1.06		0.44
	(2.5)		(1.1)
Rail constant (RP)	0.26		-0.62
	(0.5)		(-1.2)
Taxi constant (RP)	-0.79		-0.58
	(-1.1)		(-0.9)
Bus constant (SP)		0.91	2.89
		(2.9)	(5.4)
MRT constant (SP)		2.03	5.69
		(9.8)	(5.8)
RP mode		1.31	2.98
		(8.4)	(4.0)
μ (scale parameter)			0.44
			(5.3)
N	206	1240	1446
L(0)	-331.5	-1362.3	-1693.8
$L(\hat{\beta})$	-192.2	-967.2	-1170.5
ρ^2	0.420	0.290	0.309
VOT (low income)		35	61
VOT (mid. income)		95	168
VOT (high income)		318	550

All the estimated parameters for each model have the expected signs and most of the values are significant at 5% confidence level. High values for goodness of fit for all models dominating that the validity of RP & SP data over all the models.

The coefficient for the travel cost in the RP model, however, is insignificant, which is common in RP data analysis due to multicollinearity among attributes.

There is very high coefficient for car ownership in RP model implying that the strong relationship between car ownership and car use.

By considering mode specific constants for RP model, bus and motor cycle are significant with the expected sign. However, mode specific constant for taxi, and rail are not significant, the negative sign make sense on the user refusal relating to the expensive taxi fares and inefficient rail service in Bangkok. On the other hand, rail and taxi constants are very close to zero implying their less contribution and independence for the explanation of RP.

Mode specific constants for bus and MRT are significant for SP as well as RP/SP models and it is meaningfully interpreted by the user preferences.

The coefficients for RP mode dummy in SP and RP/SP are very significant and positive in sign, which elicits the users' hidden preference relating to their RP mode.

Significantly estimated scale parameter, μ, lies between 0 and 1, implying that the SP model contains greater random noise: approximately twice relative to the RP model.

5 FRAMEWORK OF DEMAND ANALYSIS FOR DEVELOPING COUNTRIES

5.1 *Overview on car ownership modeling*

In developing countries, car ownership and usage increase with rapid economic growth, resulting in some transportation problems. Basically, lack of public transportation facilities offers poor level of service representing traditional, unsafe, and overcrowded means of transportation (Khan & Willumsen 1989). Therefore, the transport users have to be decisive in the sense of solving their transportation needs by selecting the best mode. Car travel is found to be an attractive solution to overcome the burdens of discomfort and physical dissatisfaction of public transport although it is hard to afford.

In general, increase in car ownership not only creates the congestion, accidents and environmental problems but also it takes up additional road space as well.

Train (1980) mentioned that the factors such as the number of cars belonging to the household and number of workers using cars for commuting are very useful for the efficient analysis on transportation policies. Dargay and Gately (1999) developed a model to investigate the income effect on car ownership and found that the ownership grows twice as fast as income for the lowest and middle income levels and ownership saturation is approached for the highest income levels. There is an increasing interest on car ownership modeling for developing as well as developed countries during last two decades. The main difference of car ownership modeling for developing countries is identified as its sensitivity for country-based fiscal policies in addition to all the other factors which are equally applicable for both models (Khan & Willumsen 1989, Vasconcellos 1997). By considering the policy measures, car ownership charges, generally referred to as road-user charges consist of acquisition charges: import duties and car purchase tax; ownership charges: road tax and other car ownership taxes; and user charges: fuel tax, tax for oil, road tolls, and other road pricing measures (Khan & Willumsen 1989).

However, most previous studies on mode choice modeling assumed that car ownership is an exogenous variable, for instance, availability of cars and number of cars belonging to the household. Since mode choice and car ownership are endogenous for each other, it is important to develop some combined analysis of car ownership and mode choice modeling.

Although there has been some substantial improvement on car ownership modeling in recent years, the integrated analysis with car ownership and mode choice modeling is rarely found. Train (1980) described that modeling with one of the choices, either car ownership or mode choice, does not simultaneously accommodate the desires of the other model, and therefore, proposed a methodology to create the interaction between the models by eliminating the uncertainties associated with separate models.

The validity as well as the consent regarding the proposed policies in the previous approaches is rather low due to the limited number of explanatory variables in the models (Train 1980). Therefore, considerable attention is required to include numerous explanatory variables such as household size, the number of workers in the household, and the number of children, income, age, parking facilities, costs of alternative modes, and costs related to car use and fiscal policy measures.

5.2 *Proposal of modeling framework*

An extension of the concept on mode choice modeling is proposed to create on overall decision making process related to travel demand analysis. Therefore, consideration has placed on integrated analysis of car ownership with mode choice modeling, and the framework is proposed by observing all possible factors, which are closely related to the modeling approach (Fig. 1).

6 CONCLUSION

This study proposes a methodology to analyze travel demand, incorporating SP and RP data upon the introduction of new mode into the system.

The findings of this study provides further evidence that transport users' stated preferences can be

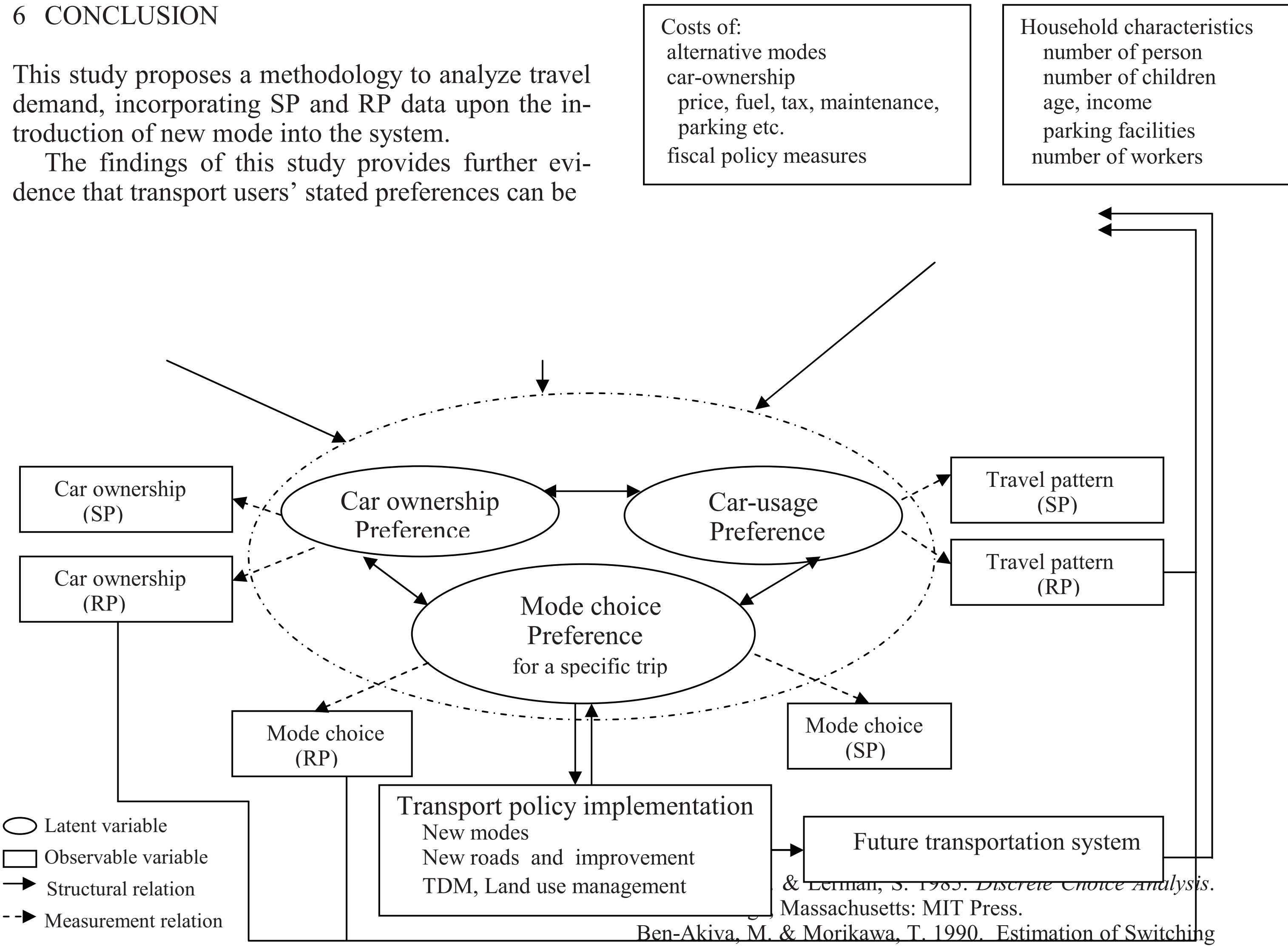

Figure 1. Proposed framework for the integrated approach

Profoundly used as an accurate guide to represent the actual underlining preferences. Market segmentation analysis, which is based on SP data, is readily interpretable for the preferences of each sub-group.

Furthermore, combined analysis of stated preferences and the revealed preferences collectively represent the true behaviour of the transport user. Therefore, the realistic results that we obtained by the combined analysis can be effectively applicable for decision-making activities related to the transportation industry.

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