A Multinomial Logit Model of Mode and Arrival Time Choices for Planned Special Events

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Abstract: A concert activity, one kind of planned special event, frequently causes congestion and unexpected delays for travelers The purpose of this study is to investigate concert participants' behaviors regarding mode and arrival time choices. A multinominal logit model is estimated to explore the most effective factors in their travel choices. A personal interview survey with 1008 respondents was conducted at Taipei Arena. The results show that significant explanatory variables of this travel choices model include total travel cost, total travel time, gender, age, household income, total number of motorcycles owned by a household, trip origin, fan seniority, expected time of arrival relative to the concert start time, single-stop trip or not, and first-time visiting or not. Our research results can assist in predicting time-dependent travel demands of each mode of concert participators in the case of planned special events.

Keywords: Stated Preference Method, A Multinominal Logit Model, Arrival Time Choice, Travel Mode Choice, Planned Special Events

1. INTRODUCTION

Planned special events (PSE) include sporting events, concerts, festivals, and conventions occurring at permanent multi-use venues as well as less frequent public events occurring at temporary venues, such as parades, fireworks displays, bicycle races, sporting games, motorcycle rallies, and seasonal festivals. Unlike emergency special events (ESE), PSEs occur at known locations and at scheduled times. PSEs create an increase in travel demands and produce significant site-specific or even regional impacts such as severe traffic congestion or transit overcrowding. Related transportation system operations are also affected, such as freeway operations, arterial and other street operations, transit operations, and pedestrian flow (FHWA, 2009). Authorities must manage the intense travel demands of PSEs to order to maintain transportation system safety, mobility, and reliability. The challenges they face include mitigating potential capacity constraints, accommodating heavy pedestrian flow, and influencing the utility associated with various travel choices.

The first task in successfully managing PSE transportation is to predict the event-generated travel demands. Accordingly, an integrated transportation management plan that can efficiently utilize the excess capacity of the roadway system, parking facilities, and transit must be developed. Kuppam *et al*. (2010) presents a travel demand modeling framework for special events participation, as shown in Figure 1. Note that event-generated travel demand modeling highlights the temporal distribution of travel demands. Event operation characteristics that influence traffic arrival and departure rates include: event time and duration (e.g., specific start time, abrupt end time, continuous operation), event time of occurrence (e.g., day/night, weekday/weekend), attendees accommodation (e.g., reserved seating, general admission), and event type (e.g., sports/concert, fair/festival, parade/race) (Tringides, 2004).

Trip generation	The daily attendance at the event is predicted, based on the capacity size at the event locale and historical data.
	The daily attendance at the event is allocated different kinds of participation trips, i.e. home-based, work-based, hotel-based, and etc.
↓	
Trip distribution	Separate destination choice logit models are estimated for each trip kind, for each day of the week, and for local attendance and regional attendance events, separately.
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Time-of-day	The demand distribution of the start times and end times will be determined and allocated based on the survey data.
↓	
Mode choice	Separate logit mode choice models will be developed for each trip kind, day of week, and time-of-day. Based on the availability of sufficient samples for each submode and a review of the estimation results, the best possible model structure in terms of nesting of the submodes will be developed.
	The auto trips and the auto person trips are converted to vehicle trips. The mode choice outputs will include transit person trip tables and drive alone and shared ride vehicle trip tables for each peak and off-peak period for weekdays and weekends.
↓↑	
Highway and transit assignment	The resultant trip tables from the mode choice procedure will be fed into the existing highway and transit assignment procedure.
	There are feedback procedures between assignment and trip distribution to recalculate travel time impedances and between assignment and mode choice to account for increased congestion on the highway or transit system due to the event.

Figure 1. A Travel Demand Modeling Framework for Special Events Participation
Source: Kuppam *et al*. (2010)

Based on these concerns, event-generated travel forecast analysis involves modal split, event traffic generation, and traffic arrival rate (FHWA, 2007). The first step is to estimate modal split. The existing modes that PSE patrons will use to access the event venue site are identified. Next, traffic generation of PSE is estimated based on advance knowledge of event attendance. According to modal split estimates and vehicle occupancy factors, the number of event-generated trips by personal automobile and the amount of event-generated traffic are estimated. Then, traffic arrival and departure rates during event ingress and egress must be estimated in order to estimate peak traffic volumes generated by the event. These factors are influenced by event operation characteristics (such as event time and duration, event time of occurrence, audience accommodation, and event type) and mode characteristics. Trip makers choose their departure times based for expected travel times on their chosen mode and their preferred start/arrival times for each activity (Day, 2008).

Arrival/departure time and mode choice decisions directly determine the temporal distribution of event-generated demands. Furthermore, these two decisions are inherently connected by the interactions between event timing constraints and expected travel times to and from event venues. Strategies and techniques of transportation demand management are expected to influence both temporal and modal decision making. In spite of this fact, there have been very few studies in the transportation literature that have jointly modeled these two travel decisions. The purpose of this study is to investigate PSE participants' behaviors regarding mode and arrival time choices and to collect data related to travel associated with these events. This will help agencies develop a stand-alone special events model to predict and analyze PSEs travel, especially for those PSEs with flexibility in arrival. Furthermore, an assessment model of TDM strategies for successfully managing PSE transportation can be developed.

2. LITERATURE REVIEW

In transport demand modeling, discrete choice models are common. Such models have been developed in coordination with econometrics. Incorporating the utility maximization assumption of neo-classical economics, multi-attribute utility analysis of travel choices was proposed to model travel demand decisions as problems in micro-economic consumer choice among discrete alternatives (Ben Akiva and Lerman 1985).

A discrete choice model is one in which decision makers choose among a set of alternatives. To fit within a discrete choice framework, the set of alternatives (the choice set) needs to exhibit three characteristics: alternatives need to be mutually exclusive; alternatives must be exhaustive; and the number of alternatives must be finite. The utility that decision maker n obtains from any alternative i is U_{ni}. The decision maker chooses the alternative with the highest utility. According to some observed attributes of the alternatives, x_{ni}, and some observed attributes of the decision maker, s_n, a function that relates these observed factors to the decision maker's utility can be specified. This function is denoted $V_{ni} = V(x_{ni}, s_n)$ and is called representative utility. For the sake of calculation, one can assume that the utility function is linear and additive. The model variables of the representative utility function commonly include attributes of alternatives (e.g., modes, routes, destinations) as well as certain situational and socio-economic characteristics of the trip-makers.

There are aspects of utility that the researcher does not or cannot observe. As a result, utility is decomposed as $U_{ni} = V_{ni} + \varepsilon_{ni}$, where ε_{ni} are the random components of a decision maker's utility. In general, the representative utility is assumed in a linear and additive function.

$$U_{ni} = \sum_k \beta_k X_{nik} + \varepsilon_{ni} \tag{1}$$

where X_{ink} is the kth observed attribute of alternative i of decision maker n. This term β_k is the coefficient of the kth observed attribute X_{ink}.

Different discrete choice models depend on what assumptions are made about the distribution about the unobserved portion of utility. A multinomial logit (MNL) model is derived under the assumption that the unobserved portion of utility is an extreme value and distributed independently from irrelevant alternatives (IIA). The nested logit has emerged as a generalization of the MNL model, in which the unrealistic, IAA property of the MNL is relaxed. Unlike the non-nested MNL, the alternatives with a certain property are grouped and represented in a nested or a hierarchical system. The composite utility of an aggregate alternative within a nest is then derived by the expected value of the maximum utility of the member of the nest and the vector of attributes common to all members of the nest, weighted by a vector of parameters. A probit model is derived under the assumption that the unobserved portion of the utility is the multivariate normal.

Most previous mode choice research has predominantly focused on weekday activity and travel. To our knowledge, travel demand models of special events participation are limited. For example, Hunt and Patterson (1996) and Steed and Bhat (2000) analyzed departure time for out-of-home recreational activity episodes, while Pozsgay and Bhat (2001) examined location choice of out-of-home urban recreational activity episodes.

Hunt and Patterson (1996) presented a stated preference experiment performed in Calgary, Canada, to examine how people are influenced in the selection of a departure time for a hypothetical trip to see a movie. A range of alternative utility functions in logit models representing this choice behavior were estimated. They found that the automobile travel time, the expected arrival time relative to the movie start time, the parking cost, the probability of being at least ten minutes late for the movie, and the movie's running time had significant effects on departure time choice. For general-purposes studies, Tringides (2004) investigated the relationship between departure time choice and mode choice for non-work trips and work trips. A recursive bivariate probit modeling framework was adopted, and worker and non-worker samples from the 1999 Southeast Florida Regional Household Travel Survey were used to estimate the travel choice model. The model estimation results showed that the causal structure of departure time choice before mode choice performed significantly better for workers. For non-workers, the reverse causal relationship (i.e. mode choice before departure time choice) was found to be a more suitable joint modeling structure. Yue *et al*. (2009) gave a detailed analysis on attendee's travel characteristics and travel modes, establishing the MNL model to forecast the demand of parking lots in the case of planned special events. Chang and Lu (2013a, b) used the MNL model and the nested logit model to investigate concert participators' behaviors regarding mode choice. Significant explanatory variables of those mode choice models include total travel cost, total travel time, gender, age, total number of motorcycles owned by a household, trip origin, expected time of arrival, and usual travel mode.

Mode choice decisions are also made in the context of one's activity schedule; the feasibility and attractiveness of each mode is determined by the level of service (e.g. wait times, travel times, costs, etc.) offered to and from the planned activities at the desired time of travel. Therefore, when scheduling trips, individuals must jointly consider activity scheduling constraints alongside mode choice decisions and their associated impacts on travel times between activities.

3. CASE STUDY

3.1 Background

Leisure activity has increased among urban residents, and weekend travel has been increasing over time. Recently, concert participation has become a popular weekend leisure activity in many countries. Taipei Arena is the main venue for popular concerts in North Taiwan. It features 15,350 seats for concerts with a central stage and 13,500 seats for concerts with remote stages.

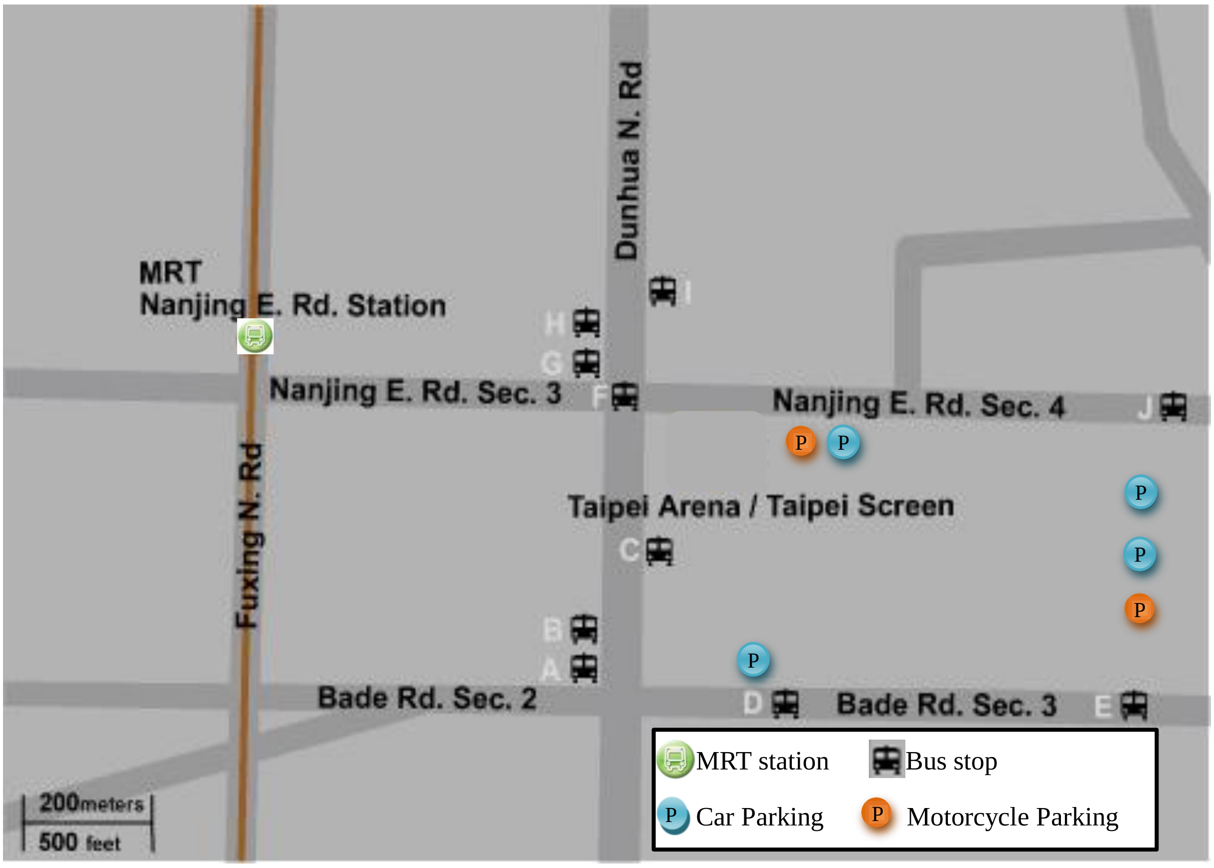


Figure 2. Transportation Map of Taipei Arena

Taipei Arena is a multipurpose arena located on the intersection of Dunhua North Road and Section 4 of Nanjing East Road in the Songshan District of Taipei City. Transportation to this arena is very convenient. It is located within 500 meters from the nearest MRT station. It is also on blocks of main streets where many buses stop. In addition, there are 415 free motorcycle parking spaces and 476 vehicle parking spaces available for NT$40 per hour. Frequently used alternative modes of inner-city travel are motorcycles, cars, mass rapid transit (MRT), and buses. The transportation map is shown in Figure 2.

A personal interview survey was conducted with 1008 respondents on April 1 and April 8, 2012. Concerts of the AmeiZING World Tour were held at Taipei Arena from March 30 to April 8, 2012. According to previous records, attendees came from the host city (Taipei City), suburban area of the host city (Xinbei City), other cities in Taiwan, and oversea. In this study, we focus on inner-city travel choice behaviors.

3.2 Survey Design

The survey items included individual and household sociodemographics, event participation attributes, and stated preference data to explore inner-city travel mode and arrival time choice behavior. Individual and household sociodemographics variables comprised gender, age, household total income, the number of cars owned by a household, and the number of motorcycles owned by a household. Event participation attributes contained the mode of inner-city travel, the travel origin, the departure time, the expected arrival time, the number of companions, the fan seniority, the single-stop or multi-stop trip, and the first-time or non-first-time visit.

A set of possible travel mode scenarios was presented, and participants were asked to indicate the order of stated preference for these scenarios. Each scenario was described by specifying the generic variables, total travel costs, and total travel times of four alternatives of inner-city travel mode. Each generic variable had three attribute levels: short-distance travel, medium-distance travel, and long-distance travel. Attribute level settings of each travel mode were pre-specified and are given in Tables 1 and 2. The L27 combinations (8 factors, 3 levels) were generated by Taguchi's Design of Experiments using the orthogonal array method for each travel type. A total of 81 travel mode scenarios were generated. This questionnaire survey forced the respondent to choose between conditions regarding attributes of 16 joint alternatives of arrival times and inner-city travel modes. That is, these 16 joint alternatives are the combination of four arrival times choices (i.e. arrive 1 hour prior to start time, arrive 1 to 3 hours prior to start time, arrive 3 to 5 hours prior to start time, and arrive 5 hour prior to start time) and four inner-city travel modes choices (i.e. motorcycles, cars, MRT, buses). Stated preference data of respondents were collected.

Table 1. Attribute Levels of Travel Costs of Various Travel Modes (NT Dollars)

Travel mode		Travel cost	Travel distance (kilometers)		
			Short 1 to 10	Medium 11 to 20	Long 21 to 30
Private mode	Motorcycles	Parking fee (0 NTD) and fuel cost	5	16	27
		Parking fee (20 NTD/day) and fuel cost	25	36	47
		Parking fee (40 NTD/day) and fuel cost	45	56	67
	Cars	Parking fee (30 NTD/hr) and fuel cost	46	78	110
		Parking fee (40 NTD/hr) and fuel cost	56	88	120
		Parking fee (60 NTD/hr) and fuel cost	76	108	140
Public mode	MRT	Ticket price decreases 40%	14	24	33
		Ticket price decreases 20%	16	32	44
		Current ticket price	20	40	55
	Buses	Ticket price decreases 40%	9	18	27
		Ticket price decreases 20%	12	24	36
		Current ticket price	15	30	45

Table 2. Attribute Levels of Travel Times of Various Travel Modes (minutes)

Travel mode		Travel time	Travel distance (kilometers)		
			Short 1 to 10	Medium 11 to 20	Long 21 to 30
Private mode	Motorcycles	Current average travel time	10	30	50
		Average travel time increases 20%	12	36	60
		Average travel time increases 40%	14	42	70
	Cars	Current average travel time	15	35	55
		Average travel time increases 20%	18	42	66
		Average travel time increases 40%	21	49	77
Public mode	MRT	Average travel time decreases 30%	14	28	42
		Current average travel time	20	40	60
		Average travel time increases 30%	26	52	78
	Buses	Average travel time decreases 30%	14	39	63
		Current average travel time	20	55	90
		Average travel time increases 30%	26	72	117

3.3 Sample Character Analysis

The proportion of female attendees is about 55.3%. The age of most attendees is 25 to 34 years old (about 61.5%). Household income of most attendees is 50 to 100 thousand NT dollars per month, and most households own one motorcycle (34.0%). Most attendees came from the host city (Taipei City) (about 43.4%). The percentage of total attendees who came from the host city and the suburban area of the host city (Xinbei City) is about 70.4%.The departure time of most attendees was about 2 to 3 hours before the concert (about 20.9%). It is interesting that about 30% of attendees needed to depart four hours before the concert. The ratio of short-distance, medium-distance and long-distance travelers is about 26:41:33. Estimated arrival times of most attendees are about one to two hours before the concert (about 27.9%). About 30% of attendees arrived three hours before the concert. In fact, attendees arrive at the concert a little earlier than expected. Attendees trend to arrive before the concert at least one hour. Early arrivals are common travel behavior for attending a concert. The major causes of early arrival are as follows. 39.5% of respondents worry about traffic jam. 23.2% of respondents have a habit of being early. 17.3% of respondents want to buy concert souvenirs. 12.4% of respondents concern about lack of parking spaces. Other reasons of early arrival are 7.6%. Over 90% of attendees were fans of the popular singer. The inner-city mode share of motorcycles, cars, MRT, and buses was 23.4%, 18.2%, 23.9%, and 13.5% respectively. Individual and household sociodemographics and event participation attributes are summarized in Figure 3.

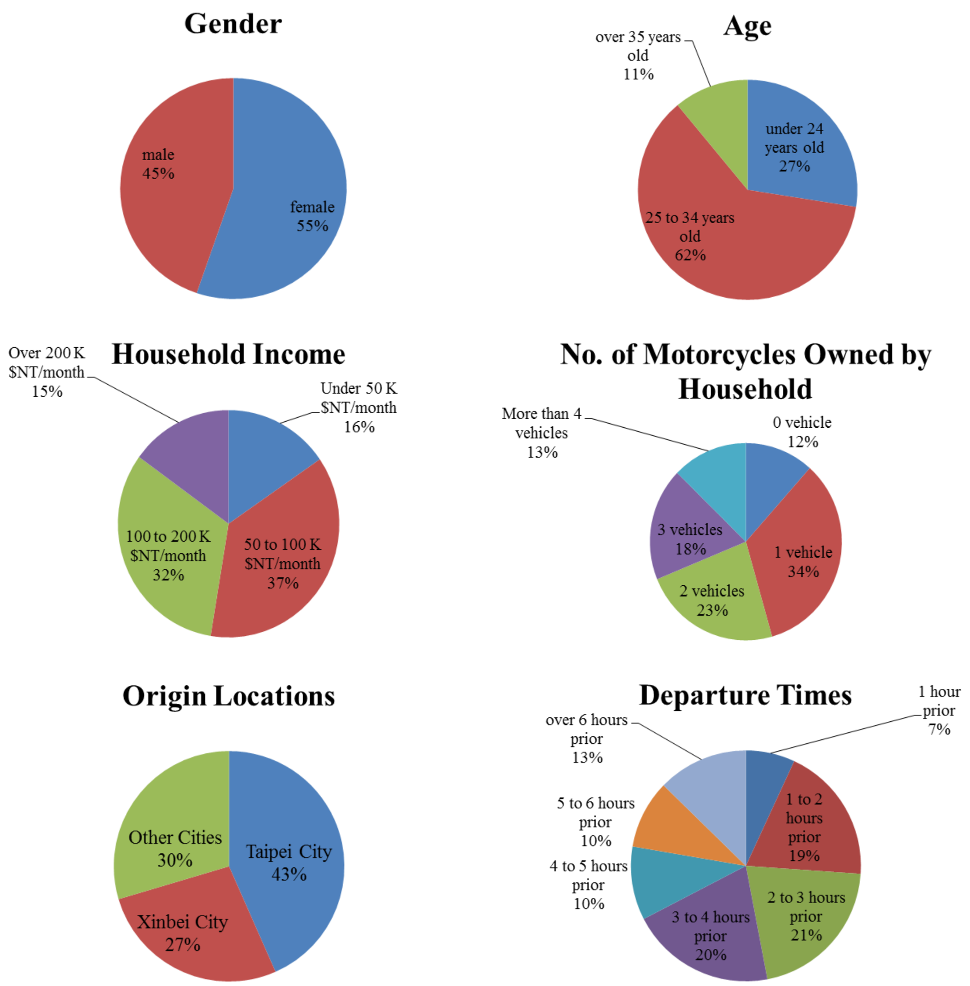


Figure 3. Sample Distribution in terms of Event Participation Attributes

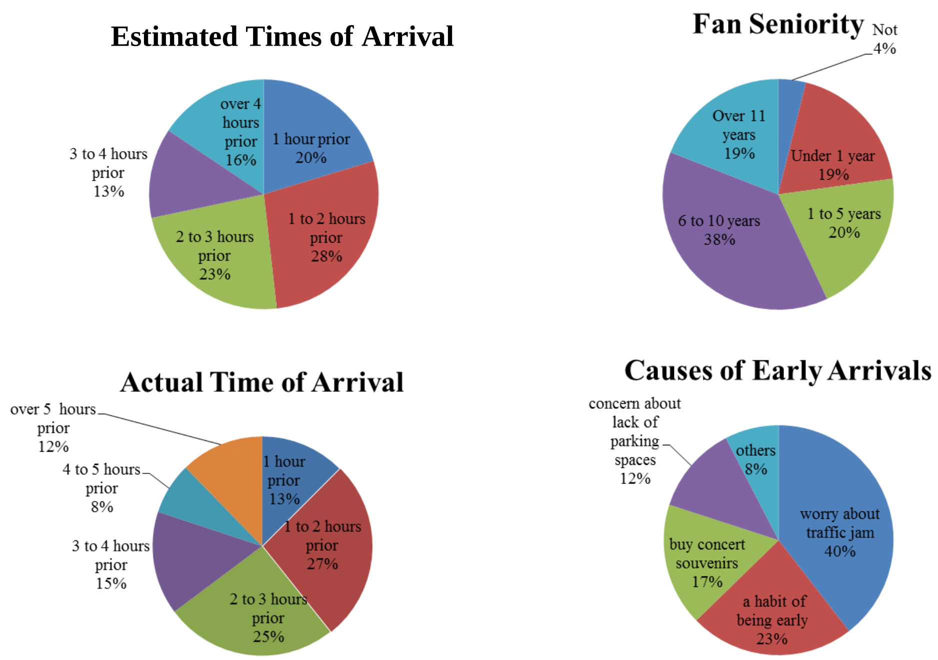


Figure 3. (continued) Sample Distribution in terms of Event Participation Attributes

3.4 Calibration Results of the MNL Model

The final model specification was developed through a systematic process of adding groups of different variables to the travel choice model and eliminating statistically insignificant variables. Also, variables were combined when their effects on the model were not statistically different. This process was guided by intuitive consideration and parsimony in the representation of variable effects.

The MNL coefficient estimates are given in Table 3. The log-likelihood value at convergence of the final MNL specification is -13119.44. The MNL coefficients for the two generic attributes (i.e. total travel costs and total travel times) and the nine alternative specific variables (i.e. gender, age, the number of motorcycles owned by a household, fan seniority, estimated time of arrival relative to the concert start time, single-stop trip, first-time visiting, he/she comes from the host city, and he/she comes from the suburban area of the host city) are significant with the expected signs. As a goodness-of-fit measure, the adjusted likelihood ratio index is 0.180. Accordingly, the explanatory power of this MNL model is fair. Influences on travel choice of PSE and their implications for this MNL model are as follows.

1. Perceived utilities decrease as total travel costs increase and as total travel times increase.
2. Men prefer not to arrive 1 to 3 hours prior to concert time by car and 3 to 5 hours prior to concert time by private transportation. Furthermore, men prefer not to arrive 5 hours prior to concert time by public transportation.
3. Middle-aged people prefer to arrive 1 to 5 hours prior to concert time by private transportation and 5 hours prior to concert time by car.
4. People who own more motorcycles prefer not to arrive 5 hours prior to concert time by bus.
5. People who plan multi-stop trips prefer not to arrive 3 to 5 hours prior to concert time by public transportation.
6. People who plan first-time trips to Taipei Arena prefer not to arrive 3 to 5 hours or 5

hours prior to concert time by MRT.

7. People who come from the host city or suburban area of this host city prefer not to arrive 3 to 5 hours prior to concert time by public transportation and 5 hours prior to concert time by bus.
8. People who are senior fans of the concert singer prefer not to arrive 1 hour prior to concert time by bus and 1 to 3 hours prior to concert time by motorcycle.
9. People who expect early arrival prefer to arrive 1 to 3 hours prior to concert time by car, not by motorcycle. People who expect early arrival prefer to arrive 3 to 5 hours prior by public transportation.

Note that the absolute values of the coefficients of alternative specific variables “he/she comes from the host city” and “he/she comes from suburban area of the host city” are greater than 0.69. This means that the trip distances between trip origins and the venue of PSE significantly influence the travel mode and the arrival time choices. Short-distance travelers of PSE prefer not to arrive 3 to 5 hours prior to concert time by public transportation or 5 hours prior to concert time by bus. Such results are more detailed than the travel mode choice models of PSE, proposed by Chang and Lu (2013a, b). Without considering the interrelationship between arrival time choice and travel mode choice, we previously found that people who come from the host city are likely to use buses.

The values of coefficients of the alternative specific variable “gender” are between -0.28 and -0.68. This means that the travel mode and the arrival time choices of men and women are rather different. Notably, fan seniority is the most particular alternative specific variable for travel estimation of PSE. In comparison, “age” and “estimated time of arrival relative to the concert start time” play minor roles in this MNL model.

3.5 Elasticity Analysis

Direct elasticity is one useful measure of the model’s sensitivity to variations in the attributes. For the MNL model, the point direct elasticity of the choice probability for alternative *i* with respect to an infinitesimal variation in the *k*th attributes X_{ik} of its own utility function is defined as

$$E_{X_{ik}}\left(P_i\right)=\beta_k X_{ik}\left(1-P_i\right) \qquad (2)$$

Direct elasticities with respect to total travel time and total travel cost are given in Table 4. For each travel mode, elasticities of the probability of arriving 1 to 3 hours prior to start time with respect to total travel time are larger than for other arrival times. This means that traffic control policy could more effectively influence the travel behaviors of attendees 1 to 3 hours prior to start time. In addition, elasticities of the probability of choosing buses are larger for arriving 1 hour, 1 to 3 hours, and 3 to 5 hours prior to start time. Moreover, elasticity of the probability of choosing MRT is larger for arriving 5 hours prior to start time. This means that bus priority is a good traffic management technique. Consequently, reducing the travel time of buses and increasing travel time of private vehicles help increase the use of public transit, especially 1 to 3 hours prior to start time. On the other hand, elasticities of the probability of choosing cars at any arrival time with respect to total travel cost are larger than others. Thus, pricing policy could be applied to influence the travel behaviors of attendees who choose to use cars. Furthermore, direct elasticities with respect to total travel time are larger than those with respect to total travel cost. Therefore, traffic control is a more effective approach than traffic pricing for shifting the traffic generated by this PSE.

Table 3. Calibration results of the MNL model of travel mode and arrival time choice

Terms	Alternative specification		Coefficients	t value
Alternative specific constants	Arrive 1 hour prior to start time by motorcycle		Base value	-
	Arrive 1 hour prior to start time by car		1.2266	13.308**
	Arrive 1 hour prior to start time by MRT		0.1309	1.349**
	Arrive 1 hour prior to start time by bus		0.3253	0.804**
	Arrive 1 to 3 hours prior to start time by motorcycle		0.0121	0.029**
	Arrive 1 to 3 hours prior to start time by car		-0.5744	-2.288**
	Arrive 1 to 3 hours prior to start time by MRT		-0.039	-0.386**
	Arrive 1 to 3 hours prior to start time by bus		-1.0934	-7.244**
	Arrive 3 to 5 hours prior to start time by motorcycle		0.131	0.609**
	Arrive 3 to 5 hours prior to start time by car		1.0293	5.914**
	Arrive 3 to 5 hours prior to start time by MRT		1.1413	8.317**
	Arrive 3 to 5 hours prior to start time by bus		0.3953	2.215**
	Arrive 5 hours prior to start time by motorcycle		-0.471	-4.181**
	Arrive 5 hours prior to start time by car		-0.2365	-0.825**
	Arrive 5 hours prior to start time by MRT		0.1714	1.002**
	Arrive 5 hours prior to start time by bus		0.1481	0.486**
Generic variables	Total travel cost		-0.084	-1.994**
	Total travel time		-0.8073	-4.554**
Alternative specific variables	Gender	Arrive 1 to 3 hours prior to start time by car	-0.423	-3.962**
		Arrive 3 to 5 hours prior to start time by motorcycle	-0.3814	-4.241**
		Arrive 3 to 5 hours prior to start time by car	-0.2986	-4.758**
		Arrive 5 hours prior to start time by MRT	-0.4342	-2.318**
		Arrive 5 hours prior to start time by bus	-0.6723	-2.376**
	Age	Arrive 1 to 3 hours prior to start time by motorcycle	0.0387	3.170**
		Arrive 1 to 3 hours prior to start time by car	0.0562	7.357**
		Arrive 3 to 5 hours prior to start time by motorcycle	0.0408	6.070**
		Arrive 3 to 5 hours prior to start time by car	0.0357	7.309**
		Arrive 5 hours prior to start time by car	0.0259	2.770**
	No. of motorcycles owned by a household	Arrive 5 hours prior to start time by bus	-0.2406	-2.106**
	Single-stop trip+	Arrive 3 to 5 hours prior to start time by MRT	-0.2716	-2.300**
		Arrive 3 to 5 hours prior to start time by bus	-0.5303	-2.268**
	First-time visiting+	Arrive 3 to 5 hours prior to start time by MRT	-0.2089	-2.442**
		Arrive 5 hours prior to start time by MRT	-0.6826	-3.733**
	He/she comes from the host city+	Arrive 3 to 5 hours prior to start time by MRT	-0.7182	-7.507**
		Arrive 3 to 5 hours prior to start time by bus	-1.8121	-9.501**
		Arrive 5 hours prior to start time by bus	-0.8091	-2.711**
	He/she comes from suburban area of the host city+	Arrive 3 to 5 hours prior to start time by MRT	-0.6957	-6.617**
		Arrive 3 to 5 hours prior to start time by bus	-0.9523	-5.968**
		Arrive 5 hours prior to start time by bus	-0.9605	-2.635**
	Fan seniority	Arrive 1 hour prior to start time by bus	-0.5559	-4.170**
		Arrive 1 to 3 hours prior to start time by motorcycle	-0.1846	-2.548**
	Estimated time of arrival relative to the concert start time	Arrive 1 to 3 hours prior to start time by motorcycle	-0.0117	-6.179**
		Arrive 1 to 3 hours prior to start time by car	0.0035	6.472**
		Arrive 3 to 5 hours prior to start time by MRT	0.0085	11.598**
		Arrive 3 to 5 hours prior to start time by bus	0.0082	6.874**
No. of samples		5793		
Log-likelihood value at zero		-16061.6		
Log-likelihood value at convergence		-13119.44		
Adjusted likelihood ratio index $\rho 2$		0.18		
Likelihood test		$5884.32 > \chi^2_{0.05}(44) = 60.481$		

Remarks: ** Significant at 5% level

+ Artificial variables

Table 4. Direct elasticity

Alternatives	Direct elasticity with respect to total travel times	Direct elasticity with respect to total travel costs
Arrive 1 hour prior to start time by motorcycle	-0.2262	-0.0122
Arrive 1 hour prior to start time by car	-0.2339	-0.0773
Arrive 1 hour prior to start time by MRT	-0.2842	-0.0229
Arrive 1 hour prior to start time by bus	-0.3455	-0.0166
Arrive 1 to 3 hours prior to start time by motorcycle	-0.3437	-0.0138
Arrive 1 to 3 hours prior to start time by car	-0.4091	-0.0831
Arrive 1 to 3 hours prior to start time by MRT	-0.4002	-0.0312
Arrive 1 to 3 hours prior to start time by bus	-0.6607	-0.0262
Arrive 3 to 5 hours prior to start time by motorcycle	-0.2595	-0.0131
Arrive 3 to 5 hours prior to start time by car	-0.2644	-0.0719
Arrive 3 to 5 hours prior to start time by MRT	-0.2866	-0.0238
Arrive 3 to 5 hours prior to start time by bus	-0.4232	-0.0197
Arrive 5 hours prior to start time by motorcycle	-0.2167	-0.0143
Arrive 5 hours prior to start time by car	-0.2370	-0.0893
Arrive 5 hours prior to start time by MRT	-0.2623	-0.0216
Arrive 5 hours prior to start time by bus	-0.2394	-0.0143

3.6 Sensitivity Analysis

As the travel time of each alternative decreases by 20%, the corresponding choice probabilities of each alternative are estimated as shown in Table 5. The percentage change of the choice probability of Alternative #10 is highest. The number of attendees who choose to use cars and to arrive 3 to 5 hours prior to start time increases most obviously since the travel time decreases. They majorly switch between Alternatives #2, #6, #9, #11, and #14. That is, the attendees who choose to use a car will change their arrival times because of the change in travel time. In addition, attendees who choose to arrive 3 to 5 hours prior to start time will change their travel mode from a motorcycle and MRT to a car due to the change in travel time. On the other hand, the percentage change of the choice probability of Alternative #4 is lowest. The number of attendees who choose to use buses and to arrive 1 hour prior to start time increase least obviously since the travel time decreases.

As the travel time of each alternative increases by 20%, the corresponding choice probabilities of each alternative are estimated as shown in Table 6. Similarly, the percentage change of the choice probability is highest for Alternative #10 and lowest for Alternative #4. That is, the number of attendees who choose to use a car and to arrive 3 to 5 hours prior to start time decreases most obviously since the travel time increases. They mainly switch between Alternatives #2, #6, #9, #11, and #14.

Tables 7 and 8 present the results of sensitivity analysis as travel costs of alternatives decrease and increase by 20%, respectively. The varying trends of choice probabilities of alternatives are similar to the results of sensitivity analysis with respect to decreasing and increasing the travel times of alternatives. Note that the percentage changes of choice probabilities with respect to travel times are larger than with respect to travel costs. This means that traffic control is a more effective approach than traffic pricing is for mitigating any possible adverse impacts that may result from this PSE.

Table 5. Percentages change of choice probabilities with respect to total travel time decrease 20%

Alternative	Original Split (%)	Alternative															
		#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	#16
#1	4.1	0.235	-0.031	-0.012	-0.002	-0.016	-0.020	-0.010	-0.003	-0.030	-0.059	-0.017	-0.005	-0.007	-0.015	-0.006	-0.003
#2	12.31	-0.037	0.749	-0.040	-0.007	-0.055	-0.070	-0.034	-0.010	-0.106	-0.206	-0.058	-0.019	-0.023	-0.051	-0.022	-0.010
#3	4.49	-0.013	-0.038	0.285	-0.003	-0.019	-0.025	-0.012	-0.004	-0.037	-0.072	-0.020	-0.007	-0.008	-0.018	-0.008	-0.003
#4	0.86	-0.003	-0.010	-0.004	0.075	-0.005	-0.006	-0.003	-0.001	-0.009	-0.018	-0.005	-0.002	-0.002	-0.004	-0.002	-0.001
#5	6.45	-0.016	-0.047	-0.018	-0.004	0.360	-0.033	-0.015	-0.004	-0.049	-0.094	-0.025	-0.008	-0.010	-0.023	-0.010	-0.004
#6	8.56	-0.024	-0.070	-0.026	-0.005	-0.039	0.543	-0.022	-0.007	-0.079	-0.150	-0.038	-0.012	-0.015	-0.035	-0.015	-0.007
#7	3.79	-0.011	-0.032	-0.012	-0.002	-0.016	-0.021	0.243	-0.003	-0.031	-0.061	-0.017	-0.006	-0.007	-0.015	-0.006	-0.003
#8	1.18	-0.004	-0.013	-0.005	-0.001	-0.007	-0.009	-0.004	0.103	-0.013	-0.025	-0.007	-0.002	-0.003	-0.006	-0.003	-0.001
#9	12.63	-0.030	-0.090	-0.033	-0.006	-0.048	-0.067	-0.028	-0.008	0.654	-0.188	-0.048	-0.016	-0.019	-0.044	-0.019	-0.009
#10	24.55	-0.069	-0.204	-0.076	-0.013	-0.109	-0.148	-0.064	-0.019	-0.218	1.271	-0.109	-0.036	-0.043	-0.100	-0.043	-0.019
#11	6.61	-0.018	-0.055	-0.020	-0.004	-0.028	-0.035	-0.017	-0.005	-0.053	-0.104	0.405	-0.012	-0.011	-0.026	-0.011	-0.006
#12	2.29	-0.008	-0.024	-0.009	-0.002	-0.013	-0.016	-0.008	-0.002	-0.024	-0.047	-0.017	0.194	-0.005	-0.012	-0.005	-0.003
#13	2.56	-0.007	-0.019	-0.007	-0.001	-0.010	-0.013	-0.006	-0.002	-0.019	-0.037	-0.010	-0.003	0.150	-0.009	-0.004	-0.002
#14	5.92	-0.017	-0.051	-0.019	-0.003	-0.027	-0.035	-0.016	-0.005	-0.052	-0.101	-0.027	-0.009	-0.011	0.390	-0.010	-0.005
#15	2.51	-0.007	-0.021	-0.008	-0.001	-0.011	-0.014	-0.006	-0.002	-0.021	-0.041	-0.011	-0.004	-0.004	-0.010	0.163	-0.002
#16	1.18	-0.004	-0.013	-0.005	-0.001	-0.006	-0.009	-0.004	-0.001	-0.013	-0.025	-0.008	-0.003	-0.003	-0.006	-0.003	0.103

Remarks:

Alternative #1: Arrive 1 hour prior to start time by motorcycle;
Alternative #2: Arrive 1 hour prior to start time by car;
Alternative #3: Arrive 1 hour prior to start time by MRT;
Alternative #4: Arrive 1 hour prior to start time by bus;
Alternative #5: Arrive 1 to 3 hours prior to start time by motorcycle;
Alternative #6: Arrive 1 to 3 hours prior to start time by car;
Alternative #7: Arrive 1 to 3 hours prior to start time by MRT;
Alternative #8: Arrive 1 to 3 hours prior to start time by bus;
Alternative #9: Arrive 3 to 5 hours prior to start time by motorcycle;
Alternative #10: Arrive 3 to 5 hours prior to start time by car;
Alternative #11: Arrive 3 to 5 hours prior to start time by MRT;
Alternative #12: Arrive 3 to 5 hours prior to start time by bus;
Alternative #13: Arrive 5 hours prior to start time by motorcycle;
Alternative #14: Arrive 5 hours prior to start time by car;
Alternative #15: Arrive 5 hours prior to start time by MRT;
Alternative #16: Arrive 5 hours prior to start time by bus.

Table 6. Percentages change of choice probabilities with respect to total travel time increase 20%

Alternative	Original Split (%)	Alternative															
		#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	#16
#1	4.1	-0.219	0.029	0.011	0.002	0.015	0.019	0.009	0.003	0.028	0.055	0.016	0.005	0.006	0.014	0.006	0.003
#2	12.31	0.034	-0.703	0.038	0.007	0.052	0.066	0.032	0.010	0.100	0.194	0.054	0.018	0.021	0.048	0.021	0.009
#3	4.49	0.012	0.035	-0.265	0.002	0.018	0.023	0.011	0.003	0.035	0.067	0.019	0.006	0.007	0.017	0.007	0.003
#4	0.86	0.003	0.009	0.003	-0.067	0.005	0.005	0.003	0.001	0.008	0.016	0.005	0.002	0.002	0.004	0.002	0.001
#5	6.45	0.015	0.044	0.016	0.003	-0.337	0.031	0.014	0.004	0.046	0.088	0.024	0.008	0.009	0.022	0.009	0.004
#6	8.56	0.022	0.066	0.024	0.004	0.036	-0.507	0.021	0.006	0.074	0.141	0.035	0.012	0.014	0.033	0.014	0.006
#7	3.79	0.010	0.030	0.011	0.002	0.015	0.019	-0.225	0.003	0.029	0.057	0.016	0.005	0.006	0.014	0.006	0.003
#8	1.18	0.004	0.012	0.004	0.001	0.006	0.008	0.004	-0.092	0.012	0.023	0.006	0.002	0.002	0.006	0.002	0.001
#9	12.63	0.028	0.085	0.032	0.006	0.046	0.063	0.027	0.008	-0.618	0.178	0.046	0.015	0.018	0.042	0.018	0.008
#10	24.55	0.066	0.196	0.073	0.013	0.105	0.142	0.061	0.018	0.210	-1.218	0.105	0.034	0.041	0.095	0.041	0.018
#11	6.61	0.017	0.051	0.019	0.004	0.026	0.033	0.016	0.005	0.050	0.097	-0.379	0.012	0.011	0.024	0.011	0.005
#12	2.29	0.007	0.022	0.008	0.002	0.011	0.014	0.007	0.002	0.022	0.042	0.015	-0.175	0.005	0.010	0.004	0.002
#13	2.56	0.006	0.018	0.007	0.001	0.009	0.012	0.006	0.002	0.018	0.034	0.010	0.003	-0.139	0.009	0.004	0.002
#14	5.92	0.016	0.048	0.018	0.003	0.025	0.033	0.015	0.004	0.049	0.094	0.025	0.008	0.010	-0.362	0.010	0.004
#15	2.51	0.007	0.019	0.007	0.001	0.010	0.013	0.006	0.002	0.020	0.038	0.011	0.003	0.004	0.009	-0.151	0.002
#16	1.18	0.004	0.011	0.004	0.001	0.006	0.008	0.004	0.001	0.012	0.023	0.007	0.002	0.002	0.005	0.002	-0.092

Remarks:
Alternative #1: Arrive 1 hour prior to start time by motorcycle;
Alternative #2: Arrive 1 hour prior to start time by car;
Alternative #3: Arrive 1 hour prior to start time by MRT;
Alternative #4: Arrive 1 hour prior to start time by bus;
Alternative #5: Arrive 1 to 3 hours prior to start time by motorcycle;
Alternative #6: Arrive 1 to 3 hours prior to start time by car;
Alternative #7: Arrive 1 to 3 hours prior to start time by MRT;
Alternative #8: Arrive 1 to 3 hours prior to start time by bus;
Alternative #9: Arrive 3 to 5 hours prior to start time by motorcycle;
Alternative #10: Arrive 3 to 5 hours prior to start time by car;
Alternative #11: Arrive 3 to 5 hours prior to start time by MRT;
Alternative #12: Arrive 3 to 5 hours prior to start time by bus;
Alternative #13: Arrive 5 hours prior to start time by motorcycle;
Alternative #14: Arrive 5 hours prior to start time by car;
Alternative #15: Arrive 5 hours prior to start time by MRT;
Alternative #16: Arrive 5 hours prior to start time by bus.

Table 7. Percentages change of choice probabilities with respect to total travel costs decrease 20%

Alternative	Original Split (%)	Alternative															
		#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	#16
#1	4.1	0.013	-0.002	-0.001	0.000	0.000	-0.001	-0.001	0.000	-0.001	-0.004	-0.001	0.000	0.000	-0.001	0.000	0.000
#2	12.31	-0.010	0.202	-0.011	-0.002	-0.015	-0.019	-0.009	-0.003	-0.028	-0.056	-0.016	-0.005	-0.006	-0.014	-0.006	-0.003
#3	4.49	-0.001	-0.003	0.022	0.000	-0.001	-0.002	-0.001	0.000	-0.002	-0.006	-0.002	-0.001	0.000	-0.002	-0.001	0.000
#4	0.86	0.000	-0.001	0.000	0.003	0.000	0.000	0.000	0.000	0.001	-0.001	0.000	0.000	0.000	0.000	0.000	0.000
#5	6.45	-0.001	-0.003	-0.001	0.000	0.020	-0.002	-0.001	0.000	-0.002	-0.006	-0.002	-0.001	0.000	-0.001	-0.001	0.000
#6	8.56	-0.006	-0.019	-0.007	-0.001	-0.010	0.144	-0.006	-0.002	-0.020	-0.040	-0.010	-0.003	-0.004	-0.009	-0.004	-0.002
#7	3.79	0.000	-0.003	-0.001	0.000	-0.001	-0.002	0.019	0.000	-0.001	-0.005	-0.002	-0.001	0.000	-0.001	-0.001	0.000
#8	1.18	0.000	-0.001	0.000	0.000	0.000	-0.001	0.000	0.005	0.000	-0.002	-0.001	0.000	0.000	0.000	0.000	0.000
#9	12.63	-0.001	-0.005	-0.002	0.000	-0.002	-0.004	-0.002	-0.001	0.037	-0.011	-0.003	-0.001	-0.001	-0.003	-0.001	-0.001
#10	24.55	-0.018	-0.055	-0.021	-0.004	-0.029	-0.040	-0.018	-0.005	-0.058	0.342	-0.029	-0.010	-0.011	-0.027	-0.011	-0.005
#11	6.61	-0.001	-0.005	-0.002	0.000	-0.002	-0.003	-0.001	0.000	-0.003	-0.009	0.032	-0.001	-0.001	-0.002	-0.001	0.000
#12	2.29	0.000	-0.001	-0.001	0.000	0.000	-0.001	0.000	0.000	0.000	-0.003	-0.001	0.009	0.000	-0.001	0.000	0.000
#13	2.56	0.000	-0.001	-0.001	0.000	0.000	-0.001	0.000	0.000	0.000	-0.003	-0.001	0.000	0.008	-0.001	0.000	0.000
#14	5.92	-0.004	-0.014	-0.005	-0.001	-0.007	-0.010	-0.004	-0.001	-0.013	-0.028	-0.007	-0.002	-0.003	0.104	-0.003	-0.001
#15	2.51	0.000	-0.002	-0.001	0.000	0.000	-0.001	-0.001	0.000	-0.001	-0.004	-0.001	0.000	0.000	-0.001	0.013	0.000
#16	1.18	0.000	-0.001	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	-0.002	-0.001	0.000	0.000	0.000	0.000	0.005

Remarks:

Alternative #1: Arrive 1 hour prior to start time by motorcycle;
Alternative #2: Arrive 1 hour prior to start time by car;
Alternative #3: Arrive 1 hour prior to start time by MRT;
Alternative #4: Arrive 1 hour prior to start time by bus;
Alternative #5: Arrive 1 to 3 hours prior to start time by motorcycle;
Alternative #6: Arrive 1 to 3 hours prior to start time by car;
Alternative #7: Arrive 1 to 3 hours prior to start time by MRT;
Alternative #8: Arrive 1 to 3 hours prior to start time by bus;
Alternative #9: Arrive 3 to 5 hours prior to start time by motorcycle;
Alternative #10: Arrive 3 to 5 hours prior to start time by car;
Alternative #11: Arrive 3 to 5 hours prior to start time by MRT;
Alternative #12: Arrive 3 to 5 hours prior to start time by bus;
Alternative #13: Arrive 5 hours prior to start time by motorcycle;
Alternative #14: Arrive 5 hours prior to start time by car;
Alternative #15: Arrive 5 hours prior to start time by MRT;
Alternative #16: Arrive 5 hours prior to start time by bus.

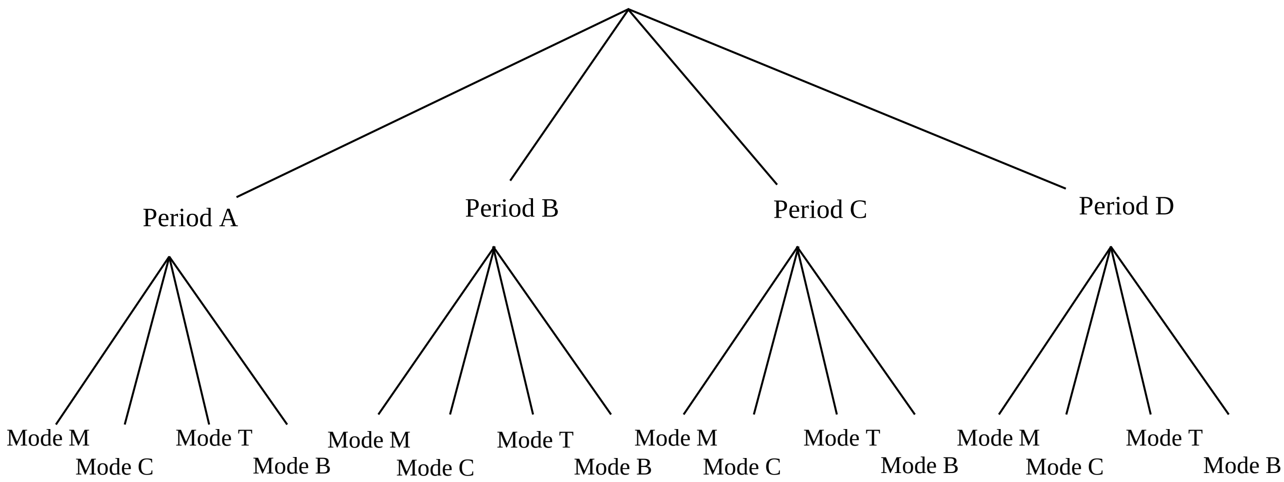
Table 8. Percentages change of choice probabilities with respect to total travel costs increase 20%

Alternative	Original Split (%)	Alternative															
		#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	#16
#1	4.1	-0.012	0.001	0.000	0.000	0.001	0.001	0.000	0.000	0.003	0.003	0.001	0.000	0.001	0.001	0.000	0.000
#2	12.31	0.010	-0.199	0.011	0.002	0.015	0.018	0.009	0.003	0.029	0.054	0.015	0.005	0.006	0.013	0.006	0.003
#3	4.49	0.001	0.003	-0.022	0.000	0.002	0.002	0.001	0.000	0.004	0.005	0.001	0.000	0.001	0.001	0.001	0.000
#4	0.86	0.000	0.000	0.000	-0.003	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
#5	6.45	0.001	0.002	0.001	0.000	-0.019	0.002	0.001	0.000	0.004	0.004	0.001	0.000	0.001	0.001	0.000	0.000
#6	8.56	0.007	0.018	0.007	0.001	0.011	-0.142	0.006	0.002	0.022	0.038	0.009	0.003	0.004	0.009	0.004	0.002
#7	3.79	0.001	0.002	0.001	0.000	0.002	0.001	-0.019	0.000	0.003	0.004	0.001	0.000	0.001	0.001	0.000	0.000
#8	1.18	0.001	0.000	0.000	0.000	0.001	0.000	0.000	-0.005	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
#9	12.63	0.002	0.005	0.002	0.000	0.003	0.003	0.001	0.000	-0.034	0.009	0.002	0.001	0.001	0.002	0.001	0.000
#10	24.55	0.019	0.054	0.020	0.004	0.030	0.039	0.017	0.005	0.059	-0.340	0.028	0.009	0.012	0.026	0.011	0.005
#11	6.61	0.002	0.004	0.001	0.000	0.003	0.003	0.001	0.000	0.005	0.007	-0.032	0.001	0.001	0.002	0.001	0.000
#12	2.29	0.001	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.002	0.001	0.001	-0.009	0.000	0.000	0.000	0.000
#13	2.56	0.001	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.002	0.001	0.000	0.000	-0.008	0.000	0.000	0.000
#14	5.92	0.005	0.013	0.005	0.001	0.008	0.009	0.004	0.001	0.015	0.026	0.007	0.002	0.003	-0.102	0.003	0.001
#15	2.51	0.001	0.001	0.000	0.000	0.001	0.001	0.000	0.000	0.003	0.003	0.001	0.000	0.001	0.001	-0.013	0.000
#16	1.18	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	-0.005

Remarks:
Alternative #1: Arrive 1 hour prior to start time by motorcycle; Alternative #2: Arrive 1 hour prior to start time by car;
Alternative #3: Arrive 1 hour prior to start time by MRT; Alternative #4: Arrive 1 hour prior to start time by bus;
Alternative #5: Arrive 1 to 3 hours prior to start time by motorcycle; Alternative #6: Arrive 1 to 3 hours prior to start time by car;
Alternative #7: Arrive 1 to 3 hours prior to start time by MRT; Alternative #8: Arrive 1 to 3 hours prior to start time by bus;
Alternative #9: Arrive 3 to 5 hours prior to start time by motorcycle; Alternative #10: Arrive 3 to 5 hours prior to start time by car;
Alternative #11: Arrive 3 to 5 hours prior to start time by MRT; Alternative #12: Arrive 3 to 5 hours prior to start time by bus;
Alternative #13: Arrive 5 hours prior to start time by motorcycle; Alternative #14: Arrive 5 hours prior to start time by car;
Alternative #15: Arrive 5 hours prior to start time by MRT; Alternative #16: Arrive 5 hours prior to start time by bus.

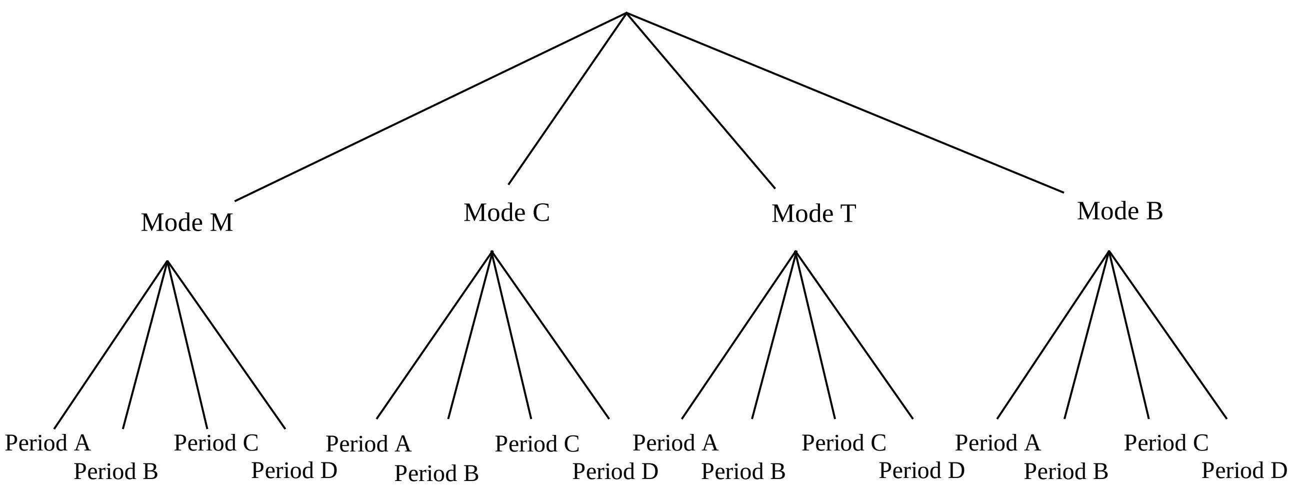
3.7 Discussions of Nested Logit Models

Nested logit (NL) models are the most widely known relaxation of the MNL model. The NL model allows the error terms of groups of alternatives to be correlated. Two chosen nesting structure of NL models are developed, as depicted in Figures 4 and 5. The NL coefficient estimates are given in Table 9. The log-likelihood value at convergence of the NL Model 1 is -12900.61. It is greater than for the MNL model (-13119.44). One of the inclusive values of NL Model 1 are not in the (0, 1) range. Others of the inclusive values of NL Model 1 are not significantly different from zero and one. The log-likelihood value at convergence of the NL Model 2 is -12635.92. It is also greater than for the MNL model (-13119.44). All the inclusive values of NL Model 2 are greater than 1. Giving above results, we conclude that these two nested logit structures are not reasonable.



Period A: Arrive 1 hour prior to start time; Period B: Arrive 1 to 3 hours prior to start time; Period C: Arrive 3 to 5 hours prior to start time; Period D: Arrive 5 hours prior to start time
Mode M: Motorcycles; Mode C: Cars; Mode T: MRT; Mode B: Buses

Figure 4. Nesting Structure for NL Model 1



Period A: Arrive 1 hour prior to start time; Period B: Arrive 1 to 3 hours prior to start time; Period C: Arrive 3 to 5 hours prior to start time; Period D: Arrive 5 hours prior to start time
Mode M: Motorcycles; Mode C: Cars; Mode T: MRT; Mode B: Buses

Figure 5. Nesting Structure for NL Model 2

Table 9. Calibration results of NL Models of Travel Mode and Arrival Time Choice

Travel Choice Model	Log-likelihood Value at Convergence	Nest	Inclusive Value	*t* Value
NL model 1	-12900.61	Arrive 1 hour prior to start time	0.1212	1.047
		Arrive 1 to 3 hours prior to start time	0.1037	1.651
		Arrive 3 to 5 hours prior to start time	0.0803	3.499
		Arrive 5 hours prior to start time	7.0665	2.682
NL model 2	-12635.92	Motorcycles	20.2906	2.850
		Cars	17.3973	1.892
		MRT	18.4254	2.560
		Buses	22.0679	1.917

Remarks: ** Significant at 5% level

4. CONCLUSIONS

In this paper, we present a detailed analysis on attendees' travel characteristics and travel choices and establish the MNL model to forecast the time-dependent demands of inner-city travel modes in the case of planned special events. The explanatory power of the MNL model regarding inner-city travel modes and arrival time choices is fair. A pre-test/ post-test type of study, where participants answered the SP survey before attending the event, and then prior to help scale the responses after experiencing the event from what is perceived prior to the event, can help researchers collect more information to calibrate a better travel choice model. In addition, including non-motorized modes in the mode choice would make this model more practical.

According to the results of elasticity analysis and sensitivity analysis, total travel time has a larger influence on shifting the traffic generated by this PSE than total travel cost. Thus, traffic control is more effective than traffic pricing for mitigating adverse impacts that may result from this event. According to our research results, we can assist public agencies to develop transportation management plans. According to the data of the questionnaire survey, the percentage of private mode usage is around 42%. Peak traffic volumes generated by the event is about 2 to 3 hours prior to the event start time. We suggest that public agencies may take some traffic control measures to reduce the travel time of buses and increase travel time of private vehicles; they help increase the use of public transit. Especially for 2 to 3 hours prior to the event start time, such traffic control and management for private vehicles is workable.

As a case study, our research focuses on modeling travel demands of concert participation at Taipei Arena. According to the calibrated logit model, the trip distances between trip origins and the venue of PSE significantly influence the travel modes and the arrival time choices. Attendees who come from the host city or the suburban area of the host city and choose to arrive 3 to 5 hours or 5 hours prior to start time prefer not to use buses. Such results are more detailed than the travel mode choice models of PSE proposed by Chang and Lu (2013a, b). Without considering the interrelationship between arrival time choice and travel mode choice, we previously found that attendees who come from the host city are likely to use buses. In addition, we also found that there is a fair amount of trip-chaining that occurs. A four-step model which is trip based may not be very adequate for analyzing travel demand of PSE. Future research may benefit from attempts to introduce activity based analysis.

Travel demands of special events vary due to the nature of individual events. More research is recommended to explore travel demands of other types of special events participation. Especially for the PSE without tickets, the travel associated with such special events can produce significant site-specific or even regional impacts such as severe traffic congestion or transit overcrowding.

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