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Time of Day Model, a Different Approach to Identify Effective Factors in Mode Choice, Evidence from Mashhad

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ABSTRACT: An increase in population and car ownership has caused significant changes in traffic flow patterns at different periods of the day. Considering the importance of analyzing different periods, the time of day (TOD) model is crucial and needs to be accounted for more explicitly. However, few studies have been conducted in this field, which prompted the authors to investigate TOD models and their calibration for mode choice of Mashhad using multinomial logit (MNL) quantifying its impact in demand analysis. In this study, household data and origin-destination matrix of 253 traffic analysis zones of Mashhad (including socio-economic, transportation network, land use, and trip characteristics) were used. Model results showed that not only the effective factors in mode choice and their impacts are different in various periods and trip purposes but also for the same purpose and mode, these factors are different for various periods. More specifically, an increase in car ownership will increase the probability of choosing both private cars and taxis for all trip purposes, but to a different extent for different periods. Tendency to use taxis for work trips reduces as trip distance increases five kilometers due to its high cost, and for educational trips reduces at noon peak due to availability of school buses and lower cost of buses. Moreover, the likelihood of choosing a bus for educational trips had a direct relationship with the ratio of students to the population of each zone.

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1- Introduction

Time of day models are not part of the conventional four-step travel demand models, but in many different modeling approaches, an external model with an internal subset of time has been used as input. Previous studies show the importance of time in travel generation and route traffic volume. Also, regarding the different levels of service in the network at different periods and the importance of different factors in different time intervals, the prediction of the time of trip seems vital in the planning process.

This paper aims to investigate the effective factors in the management of travel demand, analysis and evaluation of time of day model in modal split using multinomial logit (MNL) model to analyze the effect of time of day model in mode choice at different time interval including 24 hours, morning peak, noon peak and evening peak.

Among the innovations of this research, we can mention the identification of the effective factors in mode choice at different times of day in Mashhad, regarding the lack of studies in this field. Also, the analysis of people's behavior in Mashhad as a tourist and pilgrimage city in Iran as a developing country will lead to valuable insights.

2- Methodology

The MNL model is the simplest and the most popular discrete choice model (DCM) [1]. The basic assumption of DCMs is that each individual is faced with a set of choices, and his/her individual preference for each option can be expressed by a utility function (Eq. (1)) [2, 3].

$$U_{jq} = V_{jq} + \varepsilon_{jq} \tag{1}$$

Assuming an independent and identically distributed (IID) and Gamble distribution for the random component of the utility function, the probability of choosing each option (Eq. (2)) will be calculated based on MNL closed form [4].

$$P_{iq} = \frac{\exp\left(V_{iq}\right)}{\sum_{A_j} \exp\left(V_{jp}\right)} \tag{2}$$

Also, the model's goodness of fit has been evaluated using Eqs. (3) & (4) [5].

$$\rho_0^2 = \frac{LL(\beta) - LL(0)}{LL(*) - LL(0)} = \frac{LL(\beta) - LL(0)}{0 - LL(0)} = 1 - \frac{LL(\beta)}{LL(0)} \tag{3}$$

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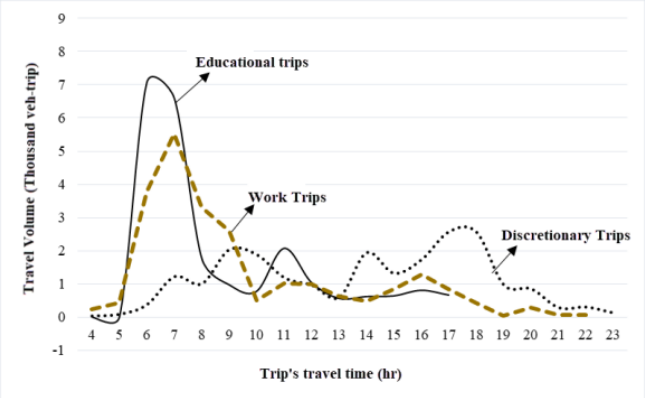

Fig. 1. Frequency distribution of trips with different purposes [6].

$$\rho_c^2 = \frac{LL(\beta) - LL(C)}{LL(*) - LL(C)} = \frac{LL(\beta) - LL(C)}{0 - LL(C)} = 1 - \frac{LL(\beta)}{LL(C)} \quad (4)$$

2- 1- Data

To determine the peak times, the travel volume diagram (Fig. 1) at different periods by different travel purposes was studied using the comprehensive transportation study of Mashhad in 2010 and mode choice models calibrated for these periods and purposes. Variable definition and descriptive analysis are presented in Table 1 [6].

3- Results and Discussion

According to the model results, it can be seen that in different periods, different factors affect the choice of people.

For all trip purposes, private car ownership, the distance of more than five kilometers between origin and destination, origin or destination within the CBD, in-bus travel time or travel time by taxi are effective in people's mode choice at different periods, but their effectiveness in different periods are different.

On work and educational trips, more variables were significant than discretionary trips in different periods which the effectiveness of variables varies in each period, but according to the proposed models, an increase in car ownership will increase the probability of choosing a car for all the trip purposes.

Finally, to determine how different factors affect the mode choice at different periods, a comparison is presented in Table 2, which shows that not only the effective factors in mode choice and their impacts are different in various periods and trip purposes; but also for the same purpose and mode, these factors can be different for various periods.

4- Conclusion

Results show that not only the effective factors in mode choice and their impacts are different at various periods and trip purposes, but also for the same purpose and mode, these factors can be different for various periods.

Table 1. Definition and Frequency analysis of variables.

Variable	Definition	Average (SD)
Tin	In-vehicle travel time (Bus)	13.71 (9.38)
Tout	Out of vehicle travel time (Bus)	21.75 (7.02)
Tr	$\frac{Tin}{Tout}$	0.65 (0.47)
Tc	Travel time of non-bus vehicles in the network	19.53 (8.62)
To	Travel time of non-bus vehicles at free-flow speed in the network	15.24(4.90)
Tt	$\frac{Tc}{To}$	35.46 (12.79)
Ndst	Shortest distance between origin and destination	7.25 (4.64)
Ddst	The aerial distance between the origin and destination	5.38 (3.85)
D_5	If $0 \leq Ndst \leq 5$, D_5=1, otherwise D_5=0	0.39 (0.48)
llNdst	If Ndst>5, llNdst=(1-D_5)*lnNdst, otherwise equals 0	1.75 (0.73)
Nbrd	The number of boarding a bus	1.81 (0.68)
Amo	average per capita motorcycle ownership in the origin	0.05 (0.03)
Aco	average per capita car ownership in the origin	0.18 (0.06)
PCBD	If origin locates at CBD equals 1, otherwise zero	0.21 (0.41)
ACBD	If destination locates at CBD equals 1, otherwise zero	0.48 (0.50)
PACBD	If origin and destination locate at CBD equals 1, otherwise zero	0.13 (0.34)
STP/Pop	The ratio of the number of students residing in the to the population	0.31 (0.36)

Table 2. Comparison of effective variables in different periods and trip purposes.

		Discretionary Trips				Educational Trips				Work Trips			
	Periods	E* Peak	N Peak	M Peak	24 hrs.	E Peak	N Peak	M Peak	24 hrs.	E Peak	N Peak	M Peak	24 hrs.
Private car	Aco	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑**
	PCBD	-	-	-	-	-	-	-	-	-	-	-	↑
	ACBD	-	-	↓	-	-	-	-	-	-	-	-	-
	LnTc	↓	↓	-	↓	-	↓	↓	↓	-	-	-	↓
	Tt	-	-	-	-	↓	-	-	-	-	↓	-	-
	LnNdst	↑	↑	-	-	-	-	-	-	-	-	-	-
Taxi	Aco	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
	llNdst	-	-	-	↓	↑	↑	↑	↑	↓	↓	↓	↓
	D5*lnNdst	-	-	-	↓	-	-	-	-	-	-	↓	↓
	PACBD	↑	-	-	-	-	-	-	↓	-	-	-	-
	ACBD	-	↑	↓	-	-	-	-	-	-	-	-	-
Bus	Tr	-	-	-	↑	-	-	-	↑	↑	-	↑	↑
	Tin	-	↑	↑	-	↑	-	↑	-	-	-	-	-
	STP/Pop	-	-	-	-	-	-	↑	↑	-	-	-	-
	Tout	↑	-	-	-	-	-	-	-	-	↓	↓	↓
	lnNbrd	-	↓	↓	↓	-	↓	↓	-	-	-	-	↓
	PCBD	-	-	-	↓	↓	-	-	↓	-	-	-	↓
	ACBD	↑	-	-	-	↑	-	-	-	-	-	↑	-
	PACBD	-	-	↓	-	-	-	↑	-	↓	↓	-	-
Motor	Amo	-	-	-	-	-	-	-	-	↑	↑	↑	↑
	lnNdst	-	-	-	-	-	-	-	-	↓	↓	↓	↓

* E: Evening, N: Noon, M: Morning.
** ↑: Increase, ↓: Decrease, -: no significance.

An increase in car ownership will increase the probability of choosing both private cars and taxis for all trip purposes, but to a different extent for different periods. Tendency to use taxis for work trips reduces as trip distance increases five kilometers due to its high cost, and for educational trips reduces at noon peak due to availability of school buses and lower cost of buses.

Moreover, the likelihood of choosing a bus for educational trips has a direct relation with the ratio of students to the population of each zone.

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