Tour complexity and transportation demand management: A focus on CBD work tours

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Paper Submitted to the 96th Annual Meeting of the Transportation Research Board and Transportation Research Record

1 August 2016

Words: 5604 +5(Table)+2*(Figures)= 7354*

ABSTRACT

Since life is growing complex and time is a finite resource, propensity of people to link several trips with different purposes increases. The sequence of these linked trips that starts and ends at home including a work stop is defined as a work tour. The number of stops in a tour introduces an index which is called tour complexity. The analysis of tour complexity may lead to a better understanding of travel behavior and provide a more appropriate framework for examining various transportation policy issues. This study aims to assess the interaction between tour complexity and Transportation Demand Management (TDM) policies through analyzing the mode choice behavior of car commuters who regularly commute to their workplace in the center of the city of Tehran, Iran. The policies include cordon pricing, increasing parking cost, increasing fuel cost, transit time reduction, and transit access improvement. In this study, two different nested logit models which reflect the impacts of TDM policies on car commuters' consideration of six modes of transportation are developed for 177 commuters with simple work tours and for 189 commuters with complex work tours. Results indicate that, cordon pricing followed by increasing parking cost in simple work tours as well as cordon pricing in complex work tours have the most impact on decreasing the probability of car usage. Furthermore, in response to single and multiple TDM policies, car commuters with simple tours choose alternative modes completely different to those alternatives car commuters with complex tours choose.

Keywords: Travel behavior, Trip chain, Nested logit, Tour complexity, Work tour, Transportation demand management (TDM) policies, Tehran

1 INTRODUCTION

Like other big cities of the world, city of Tehran is affected by environmental and social costs of congestion, such as air and noise pollution, depletion of energy, road casualties, and daily delays caused by growing car usage. In recent years, much attention has been drawn toward congestion management strategies that can be used to alleviate traffic problems in metropolitan areas. As the proposed policies try to maximize the efficiency of the urban transportation system especially by changing or reducing demand for car usage, they are generally referred to as transportation demand management (TDM) policies *(1, 2)*.

Probably the most important consideration in implementing TDM policies is related to the fact that they focus on changing individuals' travel behavior *(3)*. Since each city consists of citizens with different considerations and limitations, their mode choice behavior in response to various TDM policies could be different. Therefore, selecting the appropriate TDM policies aiming to reduce the congestion problems associated with private car usage needs a thorough understanding of the behavioral consequences of different policies *(4)*. In this regard, the analysis of tour of individuals may lead to a better understanding of travel behavior and provide a more appropriate framework for examining various transportation policy issues *(5)*. A sequence of linked trips that begins at home, involves one or more stops at other places, and ends at home forms a tour *(6)*. Depending on the number of stops within the tour, the tour may be classified into two categories: simple and complex. A tour with a single stop outside the home location is defined as a ‘‘simple’’ tour, whereas a tour with more than one stop outside the home location is defined as a ‘‘complex’’ tour. Furthermore, any tour that includes a work stop (regardless of the presence of other types of stops) is classified as a work tour while any tour that includes only non-work stops is classified as a non-work tour *(6)*.

Owning to the rapid suburbanization and dispersion of job and residential locations, commuters tend to insert more non-work stops on their work tours to get a more efficient time table *(7)* and this also requires the travel modes to be spatial and temporal flexible, convenient to access and multi-objective travel friendly *(8)*. Undoubtedly, for individuals who choose complex tours, the automobile is considered to provide greater flexibility and convenience for making more stops compared with public transit modes that are generally constrained with respect to schedules and routes/destinations *(6)*. Strathman and Dueker *(5)*, in an analysis of the 1990 NPTS, found that complex tours may tend to be more auto-oriented than simple tours which is consistent with the findings by Toint and Cirillo *(9)* who found, based on a large scale mobility survey and frequency tables, that complex trip patterns are preferably executed by car. Therefore, a particularly important policy implication of complex tours is the potential barrier it creates in attracting car users to switch to public transit *(10)*.

Accordingly, individuals' responses to TDM policies attempting to make car usage less beneficial (i.e., push policies) and TDM policies aiming to improve alternative travel options especially public transit (i.e., pull policies) are influenced by tour complexity of individuals. Since commuters with complex work tours need to conduct more stops in their tours, they are claimed to be more dependent on their cars in comparison with commuters with simple work tours and consequently, it seems that by implementing TDM policies, car commuters with complex work tours might show less tendency to shift their mode from private car to alternative options as compared to the commuters with simple work tours. Therefore, mode choice behavior of commuters with simple work tours in response to various TDM policies might be totally different from that of commuters with complex work tours.

While a great deal has been learned about the travel patterns and other aspects of travel behavior in developed urban societies, little is known about the travel patterns and their interactions with TDM policies in nations of the developing world including the city of Tehran which does not have a long history in the field of transportation demand management. This dearth of knowledge may impair the effective design and successful implementation of TDM policies in the cities of developing countries and specifically in Tehran.

Through analyzing the mode choice behavior of car commuters who regularly commute to their workplace in the center of the city of Tehran, this paper aims to answer the question whether the complexity of tours that individuals make including simple or complex work tours could affect their responses to five TDM policies including cordon pricing, increasing parking cost, increasing fuel cost, transit time reduction, and transit access improvement.

The remainder of this paper is organized as follows. The next section provides a brief review of related literature. Then, the survey and the related data are described, followed by the model development, specification, calibration, and results explanation. Finally, conclusions are drawn, and directions for further research are discussed in the last section.

2 LITERATURE REVIEW

There are many studies that look at the main impact of single TDM policies on mode choice behavior of car commuters without considering their travel pattern. Su and Zhou *(11)* developed a nested logit model to examine the impact of parking management policies on people's commute mode choice in Seattle. The major findings of this paper suggest that as a response to higher SOV parking charges, higher HOV parking discount, and lower onsite parking space ratio, the rate of commuters' drive alone to work decreases. He et al. *(12)* investigated the effectiveness of six TDM policies implemented from 2006 to 2009 in Beijing according to the variation of traffic status data before-and-after policies implementation. In this regard, while the most effective combination is the implementing all of the six study policies simultaneously, it is followed by simultaneous implementation of staggered work hours and odd-even day vehicles prohibition policies.

Some other studies incorporate a group of TDM policies in the mode choice model of individuals with regard to their travel patterns. A research by Lu et al. *(13)* proposes a nested logit model to describe the travel behavior among three modes: subway-only, park and ride (P&R) and auto-only under the background of “home-work-home” pattern (i.e., simple work tour) in response to parking management policies and public transportation fares. They found that the effects of the change in subway fare and parking fee can effectively rule out the parking behavior of commuters with simple work tours without transferring and encourage the use of P&R mode. Furthermore, higher parking fee at the workplace reduces the total travel demand and auto commuters, increases the P&R commuting, but brings the uncertain change in the number of simple work commuters only by subway.

To solve urban transportation problems, the integration of transportation policies is promoted as a more realistic and effective approach than the use of single policies, but the role of the interactions among different policies is said to be the difficulty of this approach from a research perspective. In a research by Habibian and Kermanshah *(14)*, to explore the impact of TDM policies on mode choice behavior of citizens in the city of Tehran, single and simultaneous TDM policies as well as travel patterns are investigated as explanatory variables in the commuters’ mode choice. They concluded that complex tour pattern for commuters who have one or two workplaces negatively affect the usage of motorcycle and shared-taxi modes, respectively.

3 SURVEY & DATA

The survey was conducted in the city of Tehran in 2009. At the time of survey, two push policies were being applied in the city of Tehran which are still being implemented. The first policy is car-free zone in the CBD area of the city (about 30 km^2), and the second one is an odd-even scheme based on the last digit of car plates that attempt to enter extended-CBD area, which is about three times larger than, and includes, the CBD area. A few people can drive to the CBD area with a license called permission.

To assess the role of tour complexity in the response of car commuters to TDM policies, five TDM policies were chosen consisting of three push policies including cordon pricing, increasing parking cost, increasing fuel cost, and two pull policies including transit time reduction, and transit access improvement. Each policy consists of two or three levels of cost or time. Table 1, shows the policies and their levels.

TABLE 1 Policies and Levels of Policies

Policy	Type	Number of levels	Description of levels
Increasing parking cost	Push	3	No change, 0.4, 0.7 Dollars/h
Cordon pricing	Push	2	2.5, 5 Dollars /day
Increasing fuel cost	Push	3	No change, 0.3, 0.5 Dollars/liter
Transit time reduction	Pull	3	No change, 15, 30 percent reduction
Transit access improvement	Pull	2	No change, 25 percent reduction

A stated preferences (SP) survey was designed for the morning car commuters to the extended-CBD area. The extended-CBD area is selected as study area (see *(15)* for more detail).

It was necessary that the respondents drive his/her car in the day studied. In the trip diary portion of the questionnaire, all the respondents were asked to report their trips and the purpose of each trip in their work tours. A tour is defined in this paper as a complete home-to-home journey where the origin of the first trip is home and the destination of the last trip is home. Since the work tours are to be studied in this paper, at least one of the intermediate trips in the home-to-home journey reported by respondents in the trip diary portion must be a work trip. According to the reported trips in the trip diary portion of each questionnaire, commuters are divided into two groups of commuters with simple work tours and commuters with complex work tours.

The scenarios formed the remainder portion of the questionnaire. In each scenario, every respondent was asked the question "What will be your preferred travel mode for all of the reported trips (work tour) if all of these changes were in place on the day studied?" For example, one who currently drives his/her car in whole work tour, may state an alternative mode as his/her preference for the whole tour while encountering these changes: 0.7 Dollars/h for parking, 2.5 Dollars per entrance to the cordon, no change in transit access time and fuel cost, and a 30% decrease in transit time simultaneously. In preparing a questionnaire for the stated preferences part, the Efficient Design approach was adopted which considers all two-way interactions in addition to the main effect of policy variables (see (*16*) or (*17*), for more details on efficient design).

Depending on individual responses, six main options were distinguished. These choices were to still drive a car (Car), public transit (including rail and bus) accessed by walking (W&R), public transit accessed by driving (D&R), shared-taxi (Taxi), ride a motorcycle (MC), and take a taxi by phone (Tel-taxi). Only one of the mentioned travel modes was selected by the respondents as the preferred mode for the whole tour.

For this study, 2196 choice situations from 366 individuals were achieved including commuters with simple work tours and commuters with complex work tours. Since all of the respondents were commuters, they all had a work stop in their tours. Accordingly, if the number of non-work stops in the home-to-home journey reported in the trip diary of an individual was zero, he/she had a simple work tour; otherwise, he/she had a complex work tour. Accordingly, the sample was divided into two sub-samples. The first sub-sample included 177 commuters (48% of all commuters) who had simple work tours with 1062 observations while the remainder sub-sample included 189 commuters (52% of all commuters) who had complex work tours with 1134 observations.

After the data was collected, the variables obtained from the survey were grouped under the following three categories: first, TDM policy variables which present the value of policies according to the levels presented in Table 1, second, commuting trip characteristics which address the specifications of individuals' tours, and third, household socio-economic characteristics which also consists of individuals' characteristics. It is worth noting that all of the variables are treated as alternative-specific variables. The variables that are statistically significant in the final models of this study are presented in Table 2.

TABLE 2 Definitions of Significant Variables in the Final Model

Variables	Abbreviation
Transportation demand management policies	
Cordon price, Dollars per entrance	Cordon
Parking cost increase, Dollars per hour	Parking
Public transit access time reduction, percent	Access
Fuel cost, Dollars per liter	Fuel
Cordon pricing and parking cost increase simultaneous effect	Cordon&Parking
Cordon pricing and public transit time reduction simultaneous effect	Cordon&Pub.time
Cordon pricing and public transit access time reduction simultaneous effect	Cordon&Access
Public transit access time reduction and public transit time reduction simultaneous effect	Access&Pub.time
Cordon pricing and fuel cost simultaneous effect	Cordon&Fuel
Trip characteristics	
Likelihood of unsubsidized fuel use [a] (self-reported on a Likert scale)	Pff
Number of passengers in first trip	T1_ocp
Start time of first trip	T1_t
Permission to enter to the study area (yes=1)	Permit
I use my car because transit has transfer (yes=1)	Transfer
I use my car because I need it at the work time (yes=1)	Carnd
Travel time from home to workplace	Go_t
Likelihood of going to work, in absence of that car (self-reported)	P_go
Non-walk access to transit (yes=1)	Paccnw
Any passenger on that day? (yes=1)	Accmp
Parking payment in last week, Dollars	Pk_pay
I use my car because transit is not good (yes=1)	Poort
HH socio-economic characteristics	
Car accessibility in household (number of cars to number of HH driving licenses ratio)	Caracc
Number of motorcycles owned by HH	Mown
Home location is in study area (yes=1)	H_cbd
Gender (Female=1)	Female
Number of years that individual has been at his/her job	Job_d
Household size per number of household employed members	HH_resp
Age younger than 30 (yes=1)	Age_30
Child younger than 18 in HH (yes=1)	Child
Degree of education is B.Sc. (yes=1)	Edu1
Degree of education is higher than B.Sc. (yes=1)	Edu2

[a] According to a government policy, cars manufactured in Iran can use 100 liter of subsidized fuel per month.

4 RESULTS

This section includes the important findings by multinomial logit (MNL) and nested logit (NL) models developed for simple and complex tours. Since MNL and NL models as well as their specification tests are broadly used in the discrete choice area, it suffices to point the reader to the econometric literature to get the explanation.

4.1 Multinomial Logit (MNL) Models

In order to detect the policies that affect individuals' mode choice behavior, two MNL models are estimated for the first step using NLOGIT 5.0 by 1062 and 1134 observations, respectively, for commuters with simple tours and commuters with complex tours.

Adopting the Small & Hsiao (SH) test showed that independence of irrelevant alternatives (IIA) assumption has been violated in both of the MNL models (see (18) and (19) for more detail on SH test). This suggests that the MNL models are not valid and more advanced models (e.g., Nested Logit models) which relax the IIA assumption should be considered.

The nested logit (NL) model represents a partial relaxation of the IIA assumptions of the MNL model (*20*). The development of the NL formulation using random utility theory is well known and has been thoroughly described elsewhere (see (*18*), (*19*), and (*21*) for more detail). Therefore, it is sufficient to present the resulting formulation for the structure shown in Figure 1, for commuters with simple tours (left structure) and commuters with complex tours (right structure). It should be noted that only two-level logit models have been examined in this study.

According to the nested structure validity tests, Figure 1 shows the best structures after calibrating all possible hierarchies for modeling mode choice behavior of commuters with simple and complex tours.

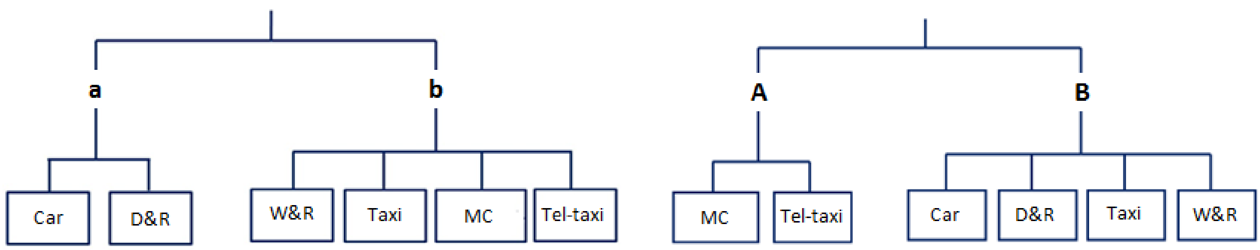

FIGURE 1 Final Nested Logit (NL) Structure for Commuters with Simple Tours (left structure) and Complex Tours (right structure)

Regression results from the nested logit models are reported in Table 4 and Table 5.

The two-level nested logit (NL) models are estimated using NLOGIT 5.0. According to Table 3, the NL model of commuters with simple tours results in goodness of fit value of 0.347 showing a better fit compared with the previous MNL model with a goodness of fit value of 0.307. In addition, as presented in Table 4, the NL model of commuters with complex tours results in a goodness of fit value of 0.391 which indicates a considerable improvement compared with the previous MNL model with a goodness of fit value of 0.300.

TABLE 3 NL Regression Results for Commuters with Simple Tours

Variables	Mode					
	Car	W&R	Taxi	D&R	MC	Tel-taxi
Constant	5.48071***	4.68653***			1.70671***	
TDM Policies						
Cordon	-0.00063***					0.00019*
Parking	-0.00170***		0.00065**			
Cordon&Fuel					-0.32619D-06*	
Cordon&Access		-0.15706D-04***				
Trip Characteristics						
Pff	1.23324***		-1.02378**		-4.39323***	-10.5894***
T1_t		-0.00467***				
Transfer				6.22953***		
Go_t						-0.09421***
P_go	-0.02810***					
Paccnw		-0.61131***		2.20223***		
Accmp		-0.76547***		-2.64152***		
Pk_pay	0.00043**		-0.00067**			
Carnd				1.31573***		
Poort			-0.48802**			
HH socio-economic Characteristics						
Caracc					-2.21058***	
Mown					1.37916***	
H_cbd				-1.91736***		
HH_resp			0.20180***	-0.35086***		
Female						1.53242***
Job_d	0.03889**	0.03800***				-0.10117**
Age_30					0.95220***	
Child						0.84412***
Edu1					-2.34702***	
Edu2	2.08900***		1.10097***			1.06594**
IV(A)	0.64433***					
IV(B)	1.0					
L(β)	-1293.84					
ρ^2	0.347					

*2-tail significance at α=0.10. **2-tail significance at α=0.05. ***2-tail significance at α=0.01.

TABLE 4 NL Regression Results for Commuters with Complex Tours

Variables	Mode					
	Car	W&R	Taxi	D&R	MC	Tel-taxi
constant	3.18816***	2.20577***	1.71797***			-4.64532*
TDM Policies						
Cordon	-0.00033***					
Fuel	-0.00146***					
Access		-0.01648*		0.03062***		
Cordon&Pub.time				0.13855D-05*		
Cordon&Parking	-0.41186D-06***					
Trip Characteristics						
Pff		-2.29397***	-3.13168***	-3.26472***		
T1_ocp					-11.8307**	
Permit	0.85604***					
Go_t			-0.01397***			
P_go					-0.21331**	
Paccnw			0.49385***	0.64165**		-4.44486*
Accmp			0.61466***			
Pk_pay		-0.00016**				
Poort			0.36377*			3.89452*
HH socio-economic Characteristics						
Caracc						3.70637*
Mown					10.8318**	
H_cbd				-1.63664***		-3.42108**
Female						2.10866*
Job_d	0.02063*				0.68075***	
Age_30	0.34817**				29.0040**	3.42640*
Child		-0.48212***				
Edu2		-0.84599***				
IV(A)	0.421**					
IV(B)	1.000					
L(β)	-1388.032					
ρ^2	0.391					

*2-tail significance at α=0.10. **2-tail significance at α=0.05. ***2-tail significance at α=0.01.

5 DISCUSSION

In this section, the results of the final NL model presented in Table 3 related to the commuters with simple work tours are compared to the results of the final NL model presented in Table 4 related to the commuters with complex work tours.

5.1 Analysis of NL Models

In this part the policy variables which appeared in the final NL models are compared together. It is worth noting that only the policy variables with the p-value less than the significance level of 0.05 ($p < 0.05$) are included.
According to Table 3-4, cordon pricing policy has been effective in both the simple and complex work tours as a single policy. On the other hand, increase in parking cost as a single policy has an impact on simple work tours while to be effective in complex work tours it has to be implemented simultaneously with another push policy of cordon pricing. In addition, increase in fuel cost as a single policy has been effective in complex tours that seems to be related to the possible longer distances they have to drive due to more stops in their tours. In fact, in complex tours all of the three studied push policies are involved in the utility function of car mode in the form of two single policies and one interactive policy. This may be related to the fact that individuals with complex work tours are more reliant on their cars due to more stops in their tours so that it is required to adopt more push policies to discourage car usage.

Considering the commuters with simple tours, simultaneous implementation of cordon pricing and transit access improvement has an impact on the utility function of the mode defined as public transit accessed by walking (W&R). This result indicates that in simple work tours, implementing the single pull policy of transit access improvement is not effective unless it is implemented simultaneously with a push policy like cordon pricing.

Although in complex tours no policy has been found effective in the utility function of shared-taxi (Taxi) directly, increase in parking cost as a single policy has led to an increase in the attractiveness of shared-taxi in simple tours. This may be because shared-taxi has a close level of service to the car mode and unlike using car if one uses shared-taxi he/she does not need to pay for parking fee. Furthermore, shared-taxi can be an alternative for car due to its lower cost in simple tours.

In simple tours, no policy has been effective in the utility function associated with the mode of public transit accessed by driving (D&R) while in complex tours, transit access improvement policy has led to a decrease in the utility of this mode. It is worth noting that transit access improvement policy had a positive impact on commuters with complex work tours' consideration of public transit accessed by walking (W&R) at 10% level of significance.

5.2 Sensitivity analysis

This section aims to examine how the mode choice behavior of commuters with simple tours and the commuters with complex tours would be affected if the TDM policies were implemented. Therefore, Table 5 display the elasticity values of simple and complex tours. These values are the percent of change in choice shares for each of the alternatives with regard to the base shares for the base model in response to 1% increase in each studied policy.

The estimates are not evaluated at the sample means but calculated using probability-weighted sample enumeration which calculates the elasticity for each individual decision maker and weight each individual elasticity by the decision maker's associated choice probability.

TABLE 5 Elasticities (%) for Commuters with Simple and Complex Tours

TDM Policy Variable	Mode											
	Car		W&R		Taxi		D&R		MC		Tel-taxi	
	S*	C**	S	C	S	C	S	C	S	C	S	C
Cordon	-0.23	-0.20	0.08	0.06	0.07	0.09	0.05	0.02	0.02	0.01	0.01	0.02
Parking	-0.07	<0.001	<0.001	<0.001	0.06	<0.001	0.01	<0.001	<0.001	<0.001	<0.001	<0.001
Fuel	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Access	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Pub.time	-	<0.001	-	<0.001	-	<0.001	-	<0.001	-	<0.001	-	<0.001

*Simple tours. **Complex tours.

Evaluation of elasticities indicates that commuters with simple tours have been mainly affected by any increase in cordon price and any increase in parking cost while commuters with complex tours have been mainly affected by increase in cordon price. It might be because the need to make more stops to attend the activities and more dependency on private car have induced commuters with complex tours to accept any increase in parking cost so that they have shown no significant sensitivity to the increase in parking cost. On the other hand, it can be seen that car commuters with simple tours are more likely to use shared-taxi as the alternative mode as cost of parking increases. Since shared-taxi has a closer level of service to the car mode, this mode change might be because using shared-taxi exempts commuters with simple tours from paying parking fee compared to using car. It is worth noting that sensitivities of car commuters with simple and complex tours to other studied policies are negligible.

The only policy with a significant effect which is common between simple tours and complex tours is cordon pricing policy which has appeared in the utility functions of car mode. According to the values presented in Table 5, a graph is displayed in Figure 2 to compare the elasticity values of mode choice probabilities with respect to the cordon pricing policy.

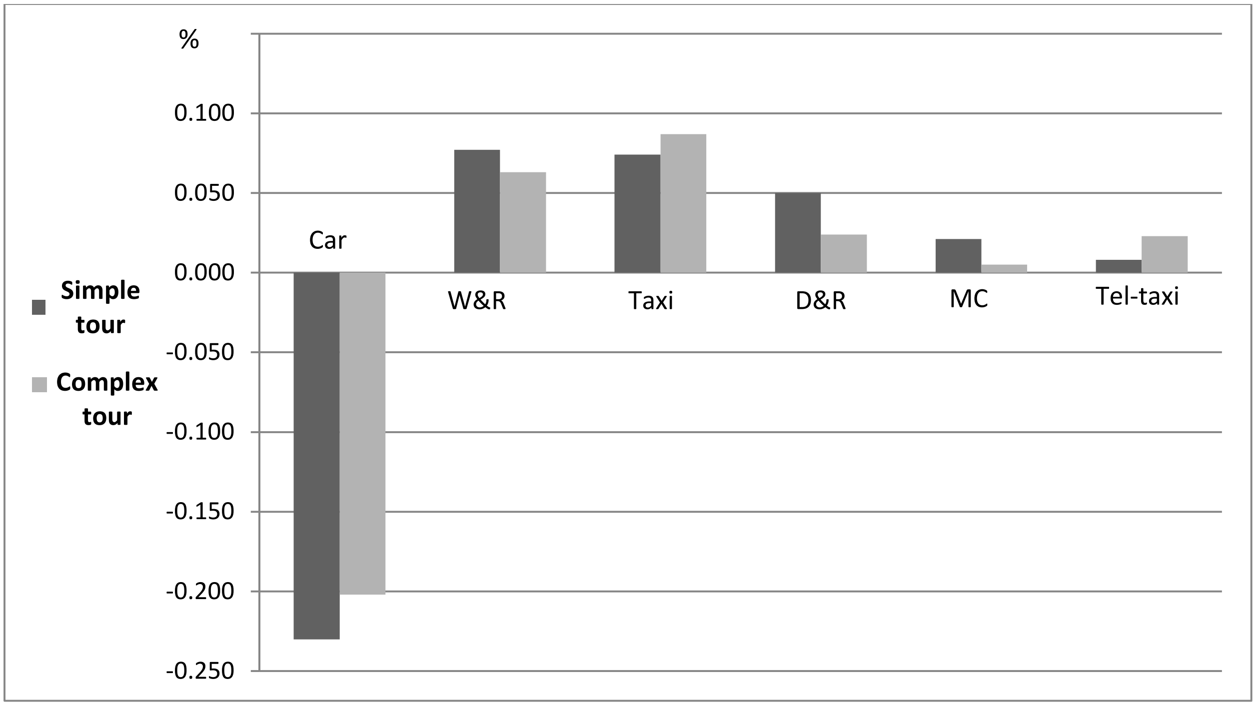

FIGURE 2 Elasticity of Choice Probabilities with Respect to the Cordon Pricing Policy

According to Figure 2, the sensitivity of car commuters with simple tours to cordon pricing policy is higher in comparison with the car commuters with complex tours. It could be concluded that with an increase in cordon price, car commuters with complex tours show less inclination to shift their mode from private car to alternative options in comparison with commuters with simple tours. This may be related to the fact that due to more stops in complex tours, individuals with complex tours are more dependent on their cars in order to provide the desired flexibility to carry out the activities.

Figure 2 also indicates that any increase in cordon price would incline car commuters with simple tours to shift to transit mode as main part of their "walk and ride (W&R)" mode followed by shared-taxi mode which may be related to the fact that commuters with simple tours have the minimum possible stops in a tour so that they are less dependent on flexible and occasionally expensive travel modes. On the other hand, car commuters with complex tours are more likely to use shared-taxi mode to go to work as the cordon price increases. Since shared-taxi has a closer level of service to car mode, this mode change from car to taxi might be because the commuters with complex tours need flexible travel modes as car mode due to their multi-stop travel patterns.

6 SUMMARY & CONCLUSION

Selecting the appropriate TDM policies aiming to reduce the congestion problems associated with private car usage, needs a thorough understanding of the behavioral consequences of different policies. The analysis of tour complexity may lead to a better understanding of travel behavior and provide a more appropriate framework for examining various transportation policy issues. This study examines the role of tour complexity in the response of car commuters to single and interactive TDM policies through analyzing the mode choice behavior of car commuters who regularly commute to their workplace in the center of the city of Tehran. The policies include increasing parking cost, increasing fuel cost, cordon pricing, transit time reduction, and transit access improvement as well as their interactions. In this regard, nested logit models which reflect the impacts of TDM policies on car commuters' consideration of six modes of transportation including still drive a car (Car), public transit (including rail and bus) accessed by walking (W&R), public transit accessed by driving (D&R), shared-taxi (Taxi), ride a motorcycle (MC), and take a taxi by phone (Tel-taxi) are developed for commuters with simple work tours and for commuters with complex work tours. Then the responses of 177 car commuters with simple work tours to TDM policies are compared with the responses of 189 car commuters with complex work tours to explore the role of tour complexity in the responses of car commuters to TDM policies.

The design of experiments approach is used to design the questionnaire that would capture the stated preferences of car commuters. All two-way interactions through efficient design approach have been included. Using data gathered from a survey implemented in the year 2009 in Tehran, car commuters with simple work tours are separated from car commuters with complex work tours. In the first step, an attempt is made to develop MNL choice models for six alternative modes to work. Small-Hsiao test results show that IIA assumption is violated for both of MNL models. Finally, nested logit (NL) structures are introduced to accommodate violations of the IIA assumption. The models incorporate different descriptive variables including TDM policy variables and their interaction effects as well as socio-economic and trip characteristics of individuals. The estimation results show a rather significant goodness of fit.

Evaluation of elasticities indicates that commuters with simple tours have been mainly affected by any increase in cordon price as well as any increase in parking cost while commuters with complex tours have been mainly affected by increase in cordon price. It might be because the need to make more stops to attend the activities and more dependency on private car have induced commuters with complex tours to accept any increase in parking cost so that they have shown no significant sensitivity to the increase in parking cost. It can be seen that car commuters with simple tours are more likely to use shared-taxi as the alternative mode as cost of parking increases. However, both of commuters with simple tours and commuters with complex tours are most affected by increase in cordon price. According to the table of elasticities, car commuters with simple tours show more tendency to shift their mode from car to other modes in response to increase in cordon price while car commuters with complex tours show less willingness to shift their mode from car to other modes in response to increase in cordon price that might be related to their multi-stop travel patterns which induce them to use their cars due to desirable flexibility of car mode. Furthermore, any increase in cordon price would incline car commuters with simple tours to shift to transit mode as main part of their "walk and ride" mode followed by shared-taxi mode which may be related to the fact that commuters with simple tours have the minimum possible stops in a tour so that they are less dependent on flexible travel modes. On the other hand, car commuters with complex tours are more likely to use shared-taxi mode as an alternative to car mode as the cordon price increases. This might be because shared-taxi has a closer level of service to the car mode and provides the desired flexibility for commuters to have multi-stop travel patterns.

Analyzing the mode choice behavior of car commuters with complex tours reveals that they are especially affected by push policies like increase in fuel price which might be due to the possible longer distances they drive to make more stops to attend the activities. Other push policies like increase in parking cost as a single policy has an impact on simple work tours and evaluation of elasticities indicates that any increase in parking cost would incline them to shift from car to taxi mode while to be effective in complex work tours increase in parking cost policy has to be implemented simultaneously with cordon pricing policy. These findings indicate that in complex tours, all of the three studied push policies are involved in the utility function of car mode in the form of two single policies and one interactive policy. Altogether, it could be concluded that individuals with complex work tours are more reliant on their cars due to more stops in their tours so that it is required to adopt more push policies to discourage car usage among commuters with complex work tours.

In terms of public transit usage, this study finds that commuters with simple tours and commuters with complex tours are affected by TDM policies differently. Results show that in commuters with simple tours the policy of transit access improvement as a single pull policy is not effective to persuade individuals to choose public transit while the simultaneous implementation of this pull policy with the cordon pricing policy as a push policy could be effective.

As it is expected, individuals' commuting trip behavior and socio-demographic characteristics have significant impact on mode choice decisions. The very different number of relevant variables across the studied modes is notable. The results of mode choice models based on the stated preference (SP) data developed in this study are promising. A nested logit structure developed in this paper incorporates TDM policy variables and their two-way interactions appropriately.

The study can be extended and improved in future. According to the limited sample size of current study including 366 commuters, increasing the sample size would improve the reliability of results. Also, by expanding the study area to the whole city, the practical usefulness of the findings is ensured. It is also desired that the generality of the empirical results of this study be verified by additional analyses with large scale data sets that are accomplished in other cities of the world. According to the quantitative form of the studied policies, it is also recommended that behavior change policies could be also studied to explore the more qualitative aspects of such policies. It is also desired to model tour making of individuals as well as mode choice modeling in response to TDM policies. Furthermore, use of other models to release restrictive assumptions associated with the nested logit models is also desired.

Acknowledgments

The authors would like to acknowledge Professor Mohammad Kermanshah for his contribution in the design step of this study.

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