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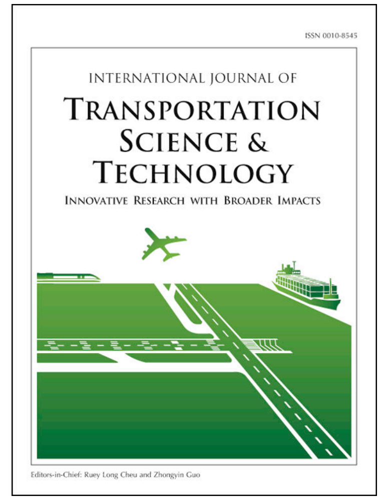

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Survival Analysis for Motorcycle Usage Time in Work Tours

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ABSTRACT
The aim of this paper is to identify effective factors on motorcycle usage time in work-tours. To do so, a survey on motorcyclists whose workplaces are in the Central Business District (CBD) of Tehran is conducted. Due to the connected nature of daily activities, travel pattern usually has tour shape, so tour-based approach is employed in this study. For identifying and comparison of variables reflecting motorcycle usage time in simple and complex work-tours, two Accelerated Failure Time (AFT) models are developed. The results indicate that in simple tours model "home location" and "tour start time" are significant while in complex tours model "trip number", "motorcycle age" and "driving experience" are the most significant factors. Moreover, it has been shown that trip distance and monthly fuel cost are two effective factors on motorcycle usage time in both simple and complex tours. However, trip distance has greater effect in complex tours.

Keywords: Motorcycle usage time, Work-tour, Accelerated failure time model, Simple tour, Complex tour

INTRODUCTION

Nowadays, motorcycle usage is increasing in many megacities, especially in developing countries due to unique characteristics of motorcycles and congested traffic situation in these cities. Tehran, the capital city of Iran, is not an exception. The growing number of motorcycles have caused a plethora of fatal accidents in addition to environmental implications such as air and noise pollution, which have several irreparable effects on citizens' physical and psychological health. As an example of this case, motorcycles are responsible for 29% of fatal accidents in Tehran *(1)*. In addition, it has been shown that each motorcycle averagely emits six times more pollutant than a standard euro 2 vehicle in this city *(2)* and 49% of Tehran's noise pollution is caused by motorcycles *(2)*.

Despite the undeniable role of motorcycles on people's travel pattern and their contribution in several transportation problems, it should be accentuated that the focus of recent studies has in Tehran been mostly on private cars *(3-5)*, and to the best of authors knowledge, motorcycle has been remained deeply unknown. Furthermore, among the few studies which have considered motorcycles, there is almost no literature on motorcycles usage time despite the fact that motorcycle usage time has a direct relation with the environmental impacts such as air and noise pollution, and increasing possibility of accidents.

Nowadays, since people's travel patterns usually include interplays with other household members and time is a limited resource, inclination of people to chain several trips with different purposes is growing *(6, 7)*. Therefore, linking various daily activities in a tour can have more efficiency and convenience for individuals. In addition, chaining trips would provide a more proper framework for evaluating a variety of transportation policy issues *(6, 8)*. The complexity of a tour is defined based on the intermediate stops *(9)*. A tour or chain with a single stop or activity outside the home location is defined as a simple tour, whilst a tour or chain with more than one stop outside the home location is defined as a complex tour *(10, 11)*. In addition, a tour that includes at least a work-stop is known as work-tour, while any tour that includes only non-work stops is classified as none-work-tour *(6, 11)*.

In the complex tours, dislike public transit and private cars, motorcycle is not restricted by schedules, routes, destinations, traffic congestion, and parking availability. Thus, using motorcycle provides more convenience and flexibility for those with greater number of stops in their tours. As a result, since motorcyclists with complex work-tours need to have more stops in their tours, they may rely more on their motorcycles in comparison to motorcyclists with simple work-tours. Therefore, it seems that the travel pattern of those motorcyclists with complex tours be completely different from those with simple tours.

Using sample data of those motorcyclists whose workplaces are in the CBD of Tehran, this paper aims to distinguish between effective factors on motorcycle usage time in simple and complex work-tours. As motorcyclists with different tour types may differently rely on their motorcycles, and consequently their usage be also different, the results of this study may help policymakers to design appropriate transportation policy issues.

The remainder of this paper is organized as follows. First, research background is briefly described. Afterward, the case study is introduced. Then, the data collection procedure, and the descriptive analysis is presented. This is followed by a description of the methodology, as well as the modeling results. Finally, the discussion and key conclusions of the study and recommendations for future studies are provided.

LITERATURE REVIEW

Despite the developed countries in which motorcycle is usually used for recreational activities and leisure, motorcycle usage is increasing as the primary and dominant means of urban transportation in several developing countries such as some parts of Republic of China (e.g., Taiwan), Indonesia, and Thailand *(12-15)*. Population density, narrow streets, and traffic congestion situation have made the motorcycle a desirable and convenient choice in the megacities of mentioned countries *(16)*. In addition, since people who are in the middle or low income categories mostly ride motorcycles in developing countries *(17)*, motorcycles' low out-off-pocket costs have been effective in its dominance.

The growing number of motorcycles has motivated researchers to address the factors, which are influential on motorcycle ownership. Leong and Sadullah conducted a research in 2007 to develop a motorcycle ownership model in Malaysia *(18)*. They found age, income, car ownership and gender as effective factors. They also showed that the more the number of car ownership, the less the number of motorcycle ownership. Asri in 2007 indicated that house type, car ownership, household size, household income, and number of households' employee are effective in motorcycle ownership in Indonesian households *(14)*. In another study, Sanko et al. showed that accessibility measures and motorcycle ownership behavior are correlated *(19)*.

Over the past few decades, trip-based approach has been taken into consideration in many studies *(20-24)* whereas tour-based approach is recently suggested increasingly to be used *(25)* due to its capability in capturing the impact of interaction between a trip with its previous and next trips. The term, tour, is used to refer to a sequence of trips in such a way that the beginning and ending of the tour being at the same location *(9)*. Ben-Akiva et al. emphasized the importance of tour-based approach and criticized the trip-based approach due to the lack of behavioral realism and tour information *(26)*. In addition, some studies claim that considering people's activity pattern as a tour can have considerable effects on changing people travel pattern and reducing the total mileage and costs *(27, 28)*.

It is important to be accentuated that for a transportation planner, examining the extent of using motorcycles is more important and more effective than its ownership, as some may own more motorcycles, but their usage be negligible. Hence, some studies, were conducted with special attention given to motorcycle usage (29); however, the number of studies that surveyed the use of motorcycles is less than those surveyed for its ownership. In these studies, motorcycles usage is considered as a discrete variable. Lai and Lu in 2007 indicated that motorcyclists' age, household income, fuel cost, the number of children in a household, daily usage of motorcycles, and the mileage of private cars affect motorcycle usage in Taiwan *(30)*. Chang and Lai conducted a research in 2015 in order to examine effective factors on motorcycle usage in Taiwanese households *(13)*. In their study, the influence of parents' role on choosing and usage of motorcycle as a mode of transportation has been highlighted. Parsa and Habibian in 2017 found that coping with congestion and other modes disutility are the main reasons for motorcycle usage in the city of Tehran *(31)*. Considering the fact that increasing in motorcycle usage could have irreparable environmental and safety outcomes, some studies have suggested different policies to reduces these effects. For example, Jou et al. investigated the effective factors on motorcycle commuters' behavior under three road pricing schemes: including fixed pricing, credit-based pricing, and differential pricing (peak and off peak) *(32)*.

Reviewing the literature shows that in most of the studies conducted to examine the effective factors on motorcycle usage and ownership, conventional discrete choice models including multinomial logistic regression *(18)*, binomial logistic regression *(19)*, and ordered models *(33)* have been used, and minimal research exists with regard to the motorcycle usage time using duration models, especially for motorcycles. Therefore, this study tries to investigate the effects of socio-demographic, trip-related and motorcycle characteristics of motorcyclists on their motorcycle usage time using fully parametric' hazard-based model namely Accelerated Failure Time (AFT) for the simple and complex work-tours distinctively.

Although, to the best of authors knowledge, Accelerated Failure Time (AFT) technique was not utilized to model motorcycle usage time in the literature, it has been used widely to model duration in transportation behavior studies. In traffic safety, AFT model used to estimate incident duration in which log-logistic distribution was selected as the best distribution for modeling duration of the Chinese incident record *(34)*. Hojati et. al., on the other hand, showed that AFT models with random parameters could accurately model incident duration while Weibull model with gamma heterogeneity is appropriate to model incident duration of stationary vehicles *(35)*. Yang et.al., developed four AFT models with respect to four distributions of exponential, Weibull, lognormal and log-logistic to model duration times for pedestrians' waiting behavior. Their results showed that Weibull AFT model with shared frailty is appropriate for modelling pedestrian waiting durations *(36)*. Drivers' reaction times to a pedestrian in the zebra crossing were also modelled due its nature using a Weibull AFT technique and it was shown that the Weibull AFT model with gamma heterogeneity is the most appropriate fitted model *(37)*. Regarding travel time, In New York 397 commuters' data including transportation-related disruptions and socio-demographic characteristics along with an AFT model were used to model home to work commute travel changes after Hurricane Sandy in 2012 *(38)*. They showed income and education are two important factors affecting time to return to normal working schedules and telecommuting duration. It is important to know that in all these studies the Akaike information criterion (AIC) and Bayesian information criterion (BIC) are two popular measures which are used to select best model with the most appropriate distribution.

CASE STUDY

Tehran, the capital city of Iran, with a population of more than 8.9 million *(1)* is one of the largest cities in the Middle East. This population live in an area of more than 270 square miles resulting in 119 persons per hectare population density and complicated traffic situations *(1)*. The average household size of the city is 3.1 *(39)* and average daily trip for each person is 2.05 *(1)*. The city of Tehran has developing infrastructure of public transit system including subway, local bus, Bus Rapid Transit (BRT) in addition to a para-transit system including shared-taxis. The contribution of these modes of transportation in Tehran's daily trips is 58.2% of all trips *(1).* In addition, the highest share of trips in Tehran city, 37 percent, are work trips *(1)*, so work trips are considered in this study which are also widely considered in the previous studies *(20-22)*.

According to the population growth, increasing transportation demand, traffic congestion problem and its undesirable consequences such as air pollution, noise pollution, low parking space and daily delays two Transportation Demand Management (TDM) policies have been formed for private cars in the city of Tehran, while no limitation is placed on motorcycle usage in this city. The first policy is car-free planning in the CBD of the city with an area of more than 12.3 square mile (4.2% of the city area). The second policy is an odd-even scheme which restricts car access to the extended-CBD area (this area is about three times larger than CBD and includes the CBD) based on the last digit of car plates (For more information on these policies see *(3, 4)*). In fact, controlling and reducing the traffic congestion as well as air pollution through limiting private cars' entrance to the CBD of Tehran, were the main goals of these policies. However, while it was expected that people's tendency to use public transit increases through these policies, more shift to motorcycle usage was observed instead. Actually, citizens who have prevented to access the CBD of the city by their private cars, were encouraged to use motorcycle instead. This is possibly because of the unique features of motorcycles such as its affordability, maneuverability, in addition to the low level of service of public transit in this city.

Based on reports, the total cumulative number of registered motorcycles in 2013 in Tehran province is nearly 6 times higher than that of 2003 *(1)*. In addition, by 2022, the number of motorcycles only in the city of Tehran is estimated to be more than two million *(2)*. The dominant type of motorcycles in Tehran is not so powerful. The engine volume of more than 70% of motorcycles in the city of Tehran is 125 cc *(40)*. According to a government law, females are not allowed to ride motorcycle in any city of Iran.

Figure 1 shows the distribution of motorcycle ownership in different regions of the city of Tehran and its CBD. As shown in this figure, the major proportion of motorcycle ownership is in the CBD and its adjacent regions. Todays, motorcycles are used as the third most commonly transportation vehicle in this city *(1)* in such a way that more than one million active motorcycles are moving on its roads *(1)*.

SURVEY

In this study, a paper-based questionnaire was used for data collection. The final version of questionnaire included five sections and 71 questions prepared in four pages. Respondents were interviewed face-to-face in their workplaces. The survey was conducted in December 2015, and a group of Bachelor and Master students of Amirkabir University of Technology contributed as a survey team to carry out interviews with motorcyclists who commute to the CBD of the city based on a systematic random sample plan in which the interviewers were supposed to carry out the interviews with a random start and then proceed with the selection of every 10th workplaces once from then onwards. In the case that the selected workplace for interview did not have a motorcycle, the next workplace was chosen. In addition, it was necessary that respondents rode their motorcycles one day before the survey day because they were asked about the tours' detail they had done one day before the survey day. For more information on survey details, see *(31)*. Eventually, after applying data cleaning techniques and removing erroneous data, the final sample includes 503 records which is in the similar sample size range of other studies *(15, 18)*.

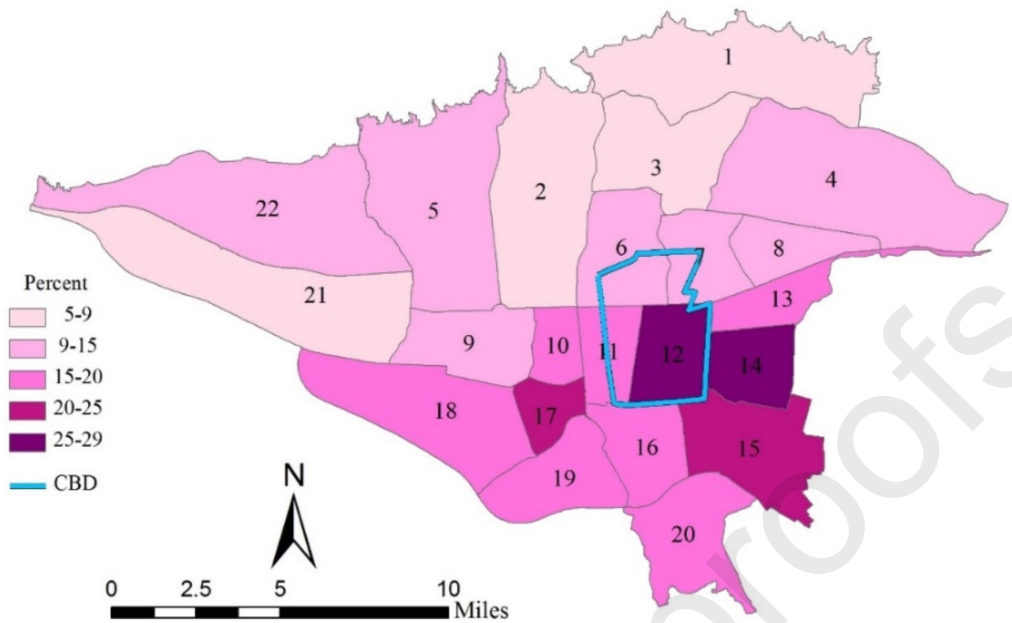

FIGURE 1 Proportion of motorcycle ownership in the regions of Tehran *(3)*.

DATA

The dataset used in this study, includes three main sections. The first section is related to motorcyclists' work-tours. These work-tours contain motorcyclists' trips to workplace and return to their home. However, these work-tours may contain non-work stops as well. Second section includes some information regarding the features of motorcycles used in the work tours. Finally, in the third section socio-demographic status of motorcyclists is collected and archived. Table 1 displays the descriptive statistics of the data. In this table, explanatory variables of study and their share in the sample are presented in three categories.

In addition, Figure 2 shows the frequency of monthly fuel cost and travel distance variables in respondents' simple and complex work-tours. These variables have been plotted in form of two-dimensional joint plot which shows the simultaneous frequency of two variables. In this figure the dark and middle parts show the high frequency, while outer parts with less darkness show the low frequency. This figure shows that most of motorcyclists in simple work-tours travel within the distance of less than 20 km, which is along with spend of 200,000 to 300,000 IRR on fuel per month, while the distance of motorcyclists with complex work-tour is more than 20 km and the fuel price spent by them per month is in a wider range from 200,000 to 400,000 IRR. It should be mentioned that at the time of survey, one US dollar was almost equal to 33,000 IRR, the currency of Iran. In addition, the respondents in the survey have stated the monthly fuel cost.

TABLE 1 Descriptive Statistics of the Data

Socio-demographic characteristics		Motorcycles' characteristics	
Variables and Levels	**Percentage**	**Variables and Levels**	**Percentage**
Age		***Engine size***	
18-29	34%	125 cc and less	69%
30-39	36%	More than 125 cc	31%
40-49	21%	***Ownership duration (years)***	
50-59	8%	Less than 2	34%
+60	1%	2-4	34%
Married		4-8	24%
Yes	72%	More than 8	8%
No	28%	***Usage duration (years)***	
Education		Less than 2	24%
High school degree or less	57%	2-4	29%
College or some college degree	40%	4-8	36%
Post graduate degree	3%	More than 8	11%
Occupation		***Fuel price ($/month)***	
Employee	20%	0-7.5	40%
Salesman	30%	7.5-15	45%
Self-employee	35%	15-22.5	10%
Other	15%	22.5-30	5%
Car driving license			
Not have	15%		
Less than 2 years	2%		
2-5 years	15%		
5-10 years	22%		
More than 10 years	46%	**Trip characteristics**	
Motorcycle riding license		***Motorcycle parking in workplace***	
Not have	17%	Yes	52%
Less than 2 years	5%	No	48%
2-5 years	22%	***Frequency of changing oil***	
5-10 years	22%	Every month	28%
More than 10 years	34%	Every 2 months	28%
Number of cars in household		Every 3 months	30%
0	27%	More than 3 months	14%
1	59%	***Tour start time***	
+2	14%	Before 7 am	14%
Number of motorcycles in household		Between 7-9 am	56%
1	85%	After 9 am	30%
+2	15%	***Tour end time***	
Home location		Between 14-16 pm	5%
CBD	29%	Between 16-19 pm	23%
Extended CBD	18%	After 19 pm	72%
Out of CBD	53%		

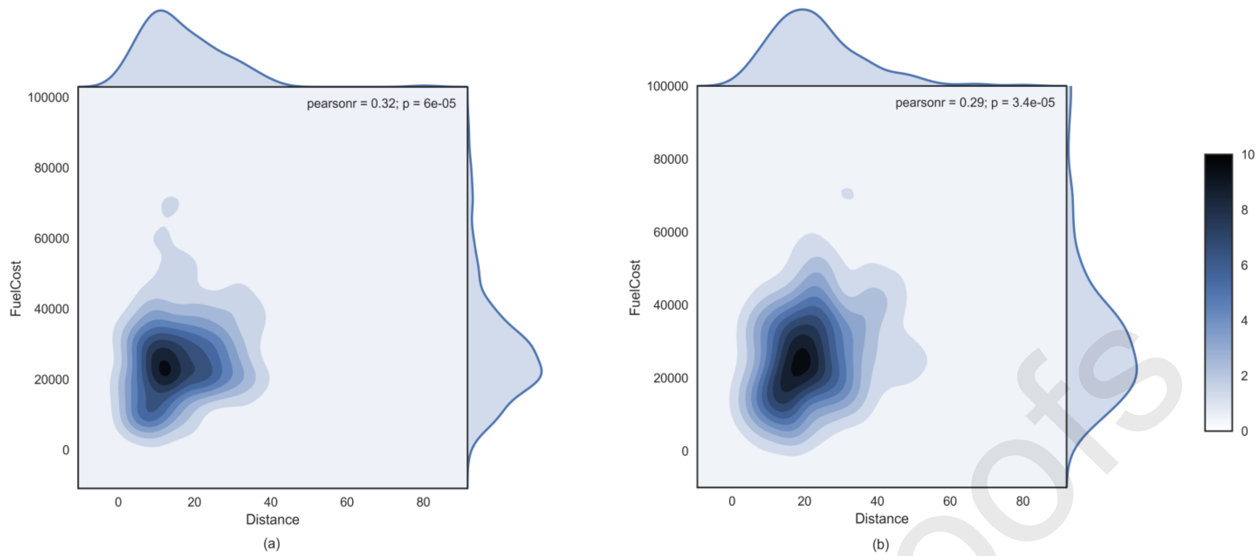

FIGURE 2 Joint frequency of fuel cost and distance: a) Simple tour, b) Complex tour

METHODOLOGY

Hazard models, also known as duration models, are generally used to demonstrate the timing of variations or incidence of an event *(41)*. In recent years, the use of these models has been taken into consideration, especially in the travel duration modeling. Duration models allow more flexible specification to overcome the problems generated by censored data of duration and time-varying explanatory variables compared to the other econometric models *(41, 42)*. Karimi et al. used a latent segmentation approach to distinguish regular shoppers from erratic shoppers based on their travel duration *(43)*. In another study, hazard models are employed to compare non-routine inter-shopping duration of baby boomers and young-old seniors *(44)*.

In this study, T is considered as a dependent variable which shows the motorcycle usage time. In hazard models, it is assumed that T is a continuous random variable with probability density function $f(t)$ and cumulative distribution function $F(t) = \Pr\{T < t\}$, giving the probability that the event has occurred by duration t. Generally, it is convenient to use complement of the cumulative distribution function namely survival function as Eq. 1.

$$S(t) = \Pr\{T \geq t\} = 1 - F(t) = \int_t^{\infty} f(x)dx \qquad (1)$$

which gives the probability that an event, in this study motorcycle usage time, has not finished within duration t. An important function in duration models is the hazard function $h(t)$ defined as Eq. 2.

$$h(t) = \lim_{dt \to \infty} \frac{\Pr\{t \leq T < t + dt | T \geq t\}}{dt} \qquad (2)$$

The Eq. 2 can be expressed as a function of $f(t)$ and $h(t)$ as Eq. 3.

$$S(t) = \frac{f(t)}{h(t)} \qquad (3)$$

This equation shows the hazard function relationship with survival function. In general, hazard function is classified as three types; parametric, semi-parametric, and non-parametric of which Accelerated Failure Time (AFT) model is placed in the first category. In parametric type of survival analysis, a distribution for baseline hazard is considered. In AFT model, the natural logarithm of the time duration, log T, can be related to the covariates through a linear structure as Eq. 4.

$$\log(t) = \beta X + \sigma\varepsilon \qquad (4)$$

where X is a vector of covariates, β is a vector of regression coefficients, ε is the error term and σ is the scale parameter. Different AFT models can be developed based on various distribution assumptions for the error term. Typically, four distributions including exponential, Weibull, Log-Logistic, and Log-Normal is considered for AFT models. Procedure of estimating the models and determining the best distribution is accomplished through applying Akaike's information criterion AIC as Eq. 5.

$$AIC = -2L(\beta) + 2P \qquad (5)$$

where $L(\beta)$ is the log-likelihood in the fitted and intercept only models, and p is the number of estimated parameters. Best-fitted model has a smaller value of AIC.

In all of the models developed in this study, models with lognormal distribution have the smaller AIC and therefore, models with lognormal distribution have been chosen as the final models to interpretation. So, only the equation of lognormal model is presented in this part. When ε is assumed to have a standard normal distribution, the density function of t is lognormal and expressed as Eq. 6.

$$f(t) = \frac{1}{\sigma}\sqrt{\frac{1}{2\pi}}\frac{1}{t}\exp\left(-\frac{1}{2\sigma^2}(\log t - \beta X)^2\right);\ t>0 \qquad (6)$$

During the modeling process, various variables were chosen using a systematic process; the variables without enough statistically significant values were omitted from the model (based on t-test, the final variables were significant at 10% level in lognormal distribution). Table 2 describes the main dependent variables used in the final models and their definition.

TABLE 2 Main Explanatory Variables and Their Definition

Variables' name	Description
H_OE	1: if respondent lives in the extended-CBD; 0: otherwise
WAccess	Access time to the nearest public transit station (minute)
FuelCost	Fuel cost per month (IRR)
Distance	Traveled distance (km)
TourStrtT7-9	1: if respondent starts his tour between 7-9; 0: otherwise
PkSpace	1: if respondent has motorcycle parking space in his workplace; 0: otherwise
M_Age	Respondent's motorcycle age (year)
TripNum	Respondent's trip number
*Mlic10_*	1: if respondent has a motorcycle license more than 10 years; 0: otherwise

RESULTS

The Akaike's information criterion is determined for each of the four Log-Normal, Log-Logistic, Weibull and Exponential distributions for both simple and complex tours. These values are 153.88, 221.88, 220.93 and 464.07 for the best simple tour model and 98.32, 160.18, 168.78 and 599.92 for the best complex tour model, respectively. The results show that the Log-Normal distribution have resulted in the smallest AICs for both simple and complex work-tours and has been chosen as the final model for each of the studied work-tours.

Table 3 shows the results of final models developed to examine the effect of independent variables on motorcyclists' usage time based on tour complexity. For this study, among 503 motorcyclists, 220 had simple tours, while other 283 had complex work-tour. To calibrate the models, 70 percent of each category has been chosen randomly for modeling process and 30 percent is dedicated to model validation. Therefore, 153 and 199 motorcyclists divided the total number of tours into simple and complex tours, respectively.

TABLE 3 Modeling Results

Variables	Simple tour		Complex tour	
	Coef.	P-value	Coef.	P-Value
Constant	3.164	<0.001	3.428	<0.001
H_OE	-0.129	0.064		
WAccess	0.007	0.046		
FuelCost	$4.11e^{-6}$	0.050	$3.64e^{-6}$	0.001
Distance	0.026	<0.001	0.020	<0.001
TourStrtT7_9	0.138	0.031		
PkSpace	-0.102	0.097		
M_Age			-0.011	0.087
TripNum			0.056	<0.001
*Mlic10_*			0.077	0.096
Loglikelihood	-68.94		-42.16	
Loglikelihood ratio	99.26		153.12	
AIC	153.88		98.32	
No of observations	153		199	

Simple Tours

Considering the respondents with simple tours in which the respondents' travel distance is the distance between their home and workplace, the results show that those motorcyclists who live in the extended-CBD of the city (*H_OE)*, have shorter motorcycle usage time. Given the fact that these people are working in the CBD of the city, this finding is logical, because the distance between their home and workplace is shorter than that of other motorcyclists who live out of the extended-CBD. The results also indicate that those motorcyclists who have longer access time to the nearest public transit station (*WAccess)*, have longer motorcycle usage time. As access time to public transit stations is increasing by moving from the CBD to suburban areas (due to high density of stations in the CBD), it can be concluded that those motorcyclists who live in the suburban areas of the city have longer access time to public transit stations and, as a result, have longer distance to get to their workplaces. The model results demonstrate that individuals, who start their trips between 7-9 am *(TourStrtT7_9)* have longer motorcycle usage time. It seems reasonable since this longer usage time could be a consequence of traffic congestion in typical traffic peaking between 7 am and 9 am in Tehran *(4)*. The results also indicate that those motorcyclists who have motorcycle parking space in their workplaces *(PkSpace)*, have shorter motorcycle usage time. This result is also reasonable because respondents, who do not have motorcycle parking space in their workplace, have to ride more to find a suitable parking space. Furthermore, results show that individuals with longer distance between their workplace and home *(Distance)*, have longer motorcycle usage time, which is logical considering direct relation between distance and travel time. For the motorcyclists with higher spent fuel cost *(FuelCost)*, the results indicate longer motorcycle usage time. This is also logical, due to the direct relationship between fuel cost and travel time.

Complex Tours

Considering the respondents with complex tours in which the respondent has more than one stop outside the home location, the results indicate that motorcyclist with longer traveled distance and more spent fuel cost per month has longer motorcycle usage time as it assessed in the previous section. Another result of the model is that the greater the age of the motorcycle (*M_Age)*, the shorter the motorcycle usage time. This could be because of the fact that by increasing motorcycle age, its efficiency declines. In this case, motorcyclist might prefer to use the motorcycle for only short tours or eliminate unnecessary trips from his work-tour. The results also indicate that respondents who have more daily trips (*TripNum)* has longer motorcycle usage time. In addition, respondent who has received their motorcycle riding license more than 10 years ago (*Mlic10_)*, has longer motorcycle usage time. Logically, these motorcyclists are expected to be older and more experienced which cause them to ride slowly and carefully and, therefore, have longer usage time.

Model Validation

As mentioned earlier, in this study 70 percent of variables were chosen for modeling process and the 30 percent of the variables were used for model validation. A method to evaluate the proposed models is the scatter diagram between the actual and estimated values *(45)*. Figure 3 shows the scatter diagram between the actual and estimated motorcycle usage time in simple and complex work-tours. As shown in Figure 3, the slope of the fitted lines between actual and estimated values are close to 1.0 and R-squared values are 0.40 and 0.43 for simple and complex tours, respectively. It is worth noting that in behavioral studies low and moderate values of R-squared are expected and completely accepted *(46)*.

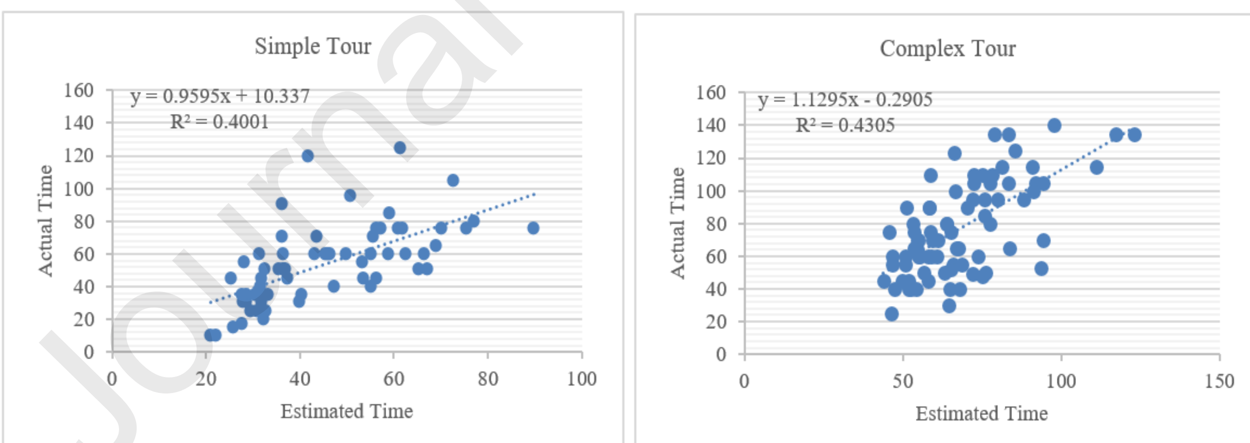

FIGURE 3 Comparison of actual and estimated motorcycle usage time

In order to have better sense about performance of AFT models, we developed two linear regression models using Ordinary Least Squares (OLS) method. The final developed models include 5 independent variables of *WAccess, FuelCost, Distance, TourStrtT7_9,* and *PkSpace*. The R-squared of plotting actual against estimated values for linear regression models of Simple and complex tours are 0.2216 and 0.2431, respectively, which is significantly smaller than those of AFT models.

DISCUSSION

Nowadays, there is not any TDM policy to manage or reduce the motorcycle usage in the city of Tehran. In addition, the evaluations show that the two TDM policy implemented on private cars in this city have not had the significant effects on reducing traffic congestion and air pollution resulting from private cars *(4)*. One reason for this could be not paying attention to private car users' characteristics and behavior. Transportation policy makers can use the results of theoretical studies to solve similar problems in societies. As an example of theoretical results, Figure 4 shows the motorcyclists' travel time with respect to travel distance for both simple and complex tours.

As shown in Figure 4, by increasing travel distance, motorcycle usage time increases in both simple and complex tours. This is logically acceptable because the travel time has a direct relationship with travel distance and increasing in travel distance will increase the travel time. In addition, the curvature of the graph in both simple and complex tours is incremental especially in long tours. This shows that for longer tours, the travel time in simple and complex tours increases faster than the shorter tours. One reason for this could be that in long tours motorcyclists are probably running into more traffic congestion than motorcyclists with shorter tours, which increases their delays and travel time.

Another finding shown in Figure 4 is that for a given travel distance; the travel time of motorcyclists with complex tour is more than that of simple tour. However, this difference is negligible and reaches zero at the distance of 80 km. It means that, despite the more delays due to the greater number of stops in complex tours, the travel time of motorcyclists with simple and complex tours is almost the same in the distance of 80 km. This is possibly because, in long simple tours with 80 km distance, the home location of motorcyclists is located in 40 km farther than CBD area of the city, which there are some population areas such as Karaj city in west and Rudehen city in East. Therefore, it seems that the congestion at the home location is responsible for the rapid increase in their travel time comparing to shorter distances in simple tours. From what has been discussed, one can conclude that improving public transit in suburb areas of the city through increasing the number of stations and reducing the headways in public transportation system can encourage motorcyclists who had simple tours from suburb areas to CBD of Tehran to use public transit instead their motorcycles.

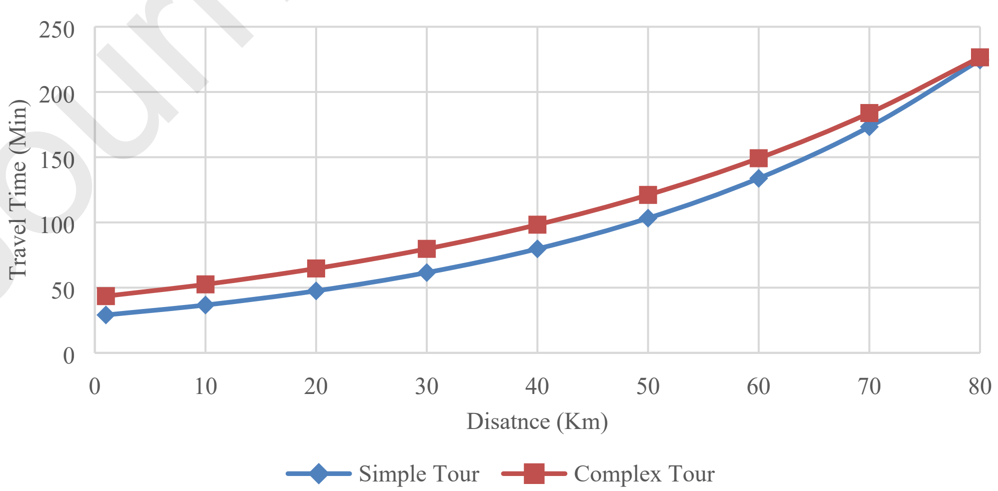

FIGURE 4 Changes in motorcycle usage time versus Distance

CONCLUSION

The results of this study indicated the difference between factors affecting motorcycle usage time in simple and complex work-tours. The results showed that the variable *(H_OE)* has been significant only in simple tour model. This finding is logically expectable because in simple tours respondents have only one destination which is located in CBD, so it has shorter distance from extend-CBD than other parts of the city. As a result, living in extend-CBD of the city decrease the usage time of motorcycles in simple tours. However, in the complex tour, the destination of the first trip could be anywhere, whether inside the CBD or not, so even if the house of a motorcyclist is in the extended-CBD, it does not guarantee to reduce the distance of tour.

Another variable, which has only been significant in simple tour model, is access time to public transit (*WAccess)*. As explained in the previous section, this variable implicitly implies the distance of the home location from the city's central area. Therefore, those who have the longer access to public transit probably live in suburban areas of the city and consequently should have longer motorcycles usage time to get to their workplace in the CBD. While, in the complex tours, destination of all trips except work trip are unknown, and consequently, in spite of the increase in the distance between the home and workplace, the total travel distance may increase, decrease, or even be consistent. Therefore, this variable does not have any significant impact on motorcycle usage in the complex tours.

The variable *(TourStrtT7-9*) has only been significant in the simple tours. It should be accentuated that typically, the paths toward city center have the highest congested traffic at morning peak hours, and the paths away from the city center have the highest congested traffic at evening peak hours. Therefore, in the simple work-tours in which respondents have only one destination located in CBD, motorcyclists have higher potential to get involved in the morning peak hour congestion than complex tour in which the destination of first trip could be anywhere in the city.

Having parking space for motorcycles in workplace *PkSpace*, have only been significant in simple tour model. This is possibly because of the fact that in simple work-tours motorcyclists need to have only one parking space in their workplaces, while in complex tours more than one parking space is needed through the entire tour.

Motorcycle age *(M_Age*), has been only significant in complex work-tours. It seems logical that by increasing the motorcycle age, its utility for doing unnecessary trips is reduced. However, since simple tours include only two trips in which the location of home and workplace are fixed, motorcyclists could not decrease motorcycle usage by eliminating unnecessary trips.

Another variable, which has only been significant in complex tour model, is trip numbers (*TripNum)*. It seems logical because in simple work-tours there are only two trips, while complex tours include more than two trips.

Finally, the last variable, which has only been significant in complex tours, is *(Mlic10_)*. As previously mentioned, this variable implies the motorcyclists' age and riding experience, which cause them to drive carefully and slowly. Therefore, this variable shows its effects in complex tours. On the other hand, in simple tours with repetitive routs, motorcyclists are commuting the same rout every day in such a way that being experienced in riding motorcycle will not have a significant effect on motorcycle usage time.

As shown in Table 4, it can be seen that two continues variables namely monthly fuel cost (*FuelCost),* and tour distance (*Distance),* has been significant in both models. Therefore, in order to compare their effects on simple and complex work-tours, their elasticity has been evaluated.

The elasticity of variable *(Distance*) for simple and complex tour is 0.37 and 0.45, respectively. This means that given a percent change in tour distance, the motorcycle usage time in complex tours is more than that of simple tours. In general, as motorcyclists are getting closer to their origins or destinations, they usually ride slowly. This is because of the fact that motorcyclists have to ride in narrow or congested area in their origin or destinations and find a suitable parking place. By regarding this fact, and since motorcyclists in complex tours have several destinations, it can be concluded that they have more usage time for a given distance than motorcyclists in simple tours.

Another result, which can be concluded from elasticity calculation, is that for a percent change in monthly fuel cost, the effect of this variable is almost the same in both models (both are 0.1). Therefore, the differences between simple and complex tour, do not have a considerable effect on monthly fuel cost. With additional examination on the database, it was found that there is a high correlation between the motorcycle engine size and the monthly fuel cost. Accordingly, since motorcycles' engine size in both simple and complex tours have the same distribution, the effects of the fuel cost is same in both models.

Results of this study can be implemented by policymakers in order to control usage of motorcycle and reduce adverse impacts of it such as air pollution, congestion and accidents. It is also worth noting that approach of this study can be implemented on other motorcyclists of Tehran such as motorcyclists who are giving ride to passengers or shipping goods in the CDB of Tehran for further traffic management solutions.

This study can be extended and improved in future. According the limited sample size of current study which consists of 503 motorcyclists, increasing the sample size would improve the reliability of the results. In addition, by expanding the study area to the whole city, the practical usefulness of the findings can be ensured. Furthermore, the study can be extended by considering trip-based approach to analyze and compare the results of which with tour-based approach. It is also recommended to extend the study area for other trip purposes too.

Comparing the models and results of this study with those of other studies in similar cities of Iran could be essential to verify the validity of the models of this study. However, since to the best of authors knowledge, such studies are not available at the moment, survival analysis on motorcycle usage time in other cities and regions with similar socio demographic situation is needed to be considered in future studies.

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