Willingness-to-Pay Method to Estimate Effect of Accessibility on Property Prices

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The economic evaluation and the financing of transportation projects require comprehensive estimation and determination of all transportation-related external costs. The effect of accessibility on property values and the hedonic price of environmental attributes related to the transportation system are among the most important external effects. In this study, the willingness to pay (WTP) for improved accessibility and environmental quality was determined by the use of a stated preference (SP) technique. With SP data collected in Tehran, Iran, a multinomial logit model was developed, and WTP was estimated with this model. Because the WTP for environmental attributes was estimated with qualitative measures, a fuzzy transformation was used to estimate the WTP for a unit increase in environmental quality.

A common approach used to assess and evaluate transportation projects is to quantify all external costs of the transportation system. Although this approach has been criticized in some recent studies, it is still widely used in practice (*1*). The effect of accessibility on property values is one of the important externalities of the transportation system. Meanwhile, the increase in property and land values is also a potential factor that should be considered when transportation projects are being financed. Several studies have looked into those effects. For example, Riley has shown that the rise in house prices in total could be fourfold a rail line's building cost (*2*). This is especially important in developing countries, where many new transportation and infrastructure projects are being considered. Several other studies have examined the impact of public transportation projects on property values (*3–6*).

One can postulate that a successful public transport system may increase the value of its surrounding land. Value capture is the concept that governments may be able to capture at least part of this increase in land value along public transport corridors and use these funds to subsidize the system. Salon and Shewmake studied this effect by focusing on the impacts of public transport on land development, estimating the increases in land value attributable to public transport, and performing case studies of the use of value capture mechanisms to finance public transportation systems (*7*). They found that the best strategies for implementing value capture policies are not the same everywhere. They depend on the jurisdiction's institutional capabilities, as well as the general health of the local economy and the local land development industry.

Previous research has shown different results for both the magnitude and the sign of the impact of accessibility and the provision of transportation infrastructure on property prices. For instance, a study on the relationship between proximity to rail stations and house prices undertaken in Atlanta, Georgia, showed a negative effect on the north side and a positive effect on the south side of an area surrounding a rail station (*8*). Although some studies have shown a significant influence consisting of an increase in house prices of up to 120% (*9*), other studies have shown only a 5% increase in prices (*10*).

Most previous studies have paid attention to rail and highway systems (*11–13*), as they are the most influential modes and are more important from a financial point of view; only recently have some studies considered bus systems. Those evaluations were a result of the implementation of bus rapid transit systems in some major cities around the world, for example, in Tehran, Iran. It appears that bus rapid transit projects have shown mixed results according to their effects on property values. The studies of Rodriguez and Targa (*14*) and Munoz-Raskin (*15*) have shown increases in house prices in the proximity of bus rapid transit systems and their feeder routes in Bogota, Colombia. However, Cervero and Duncan found no significant effects on multifamily house prices in Los Angeles, California (*16*). In another study, both negative and positive effects were reported in Quebec City, Quebec, Canada (*17*).

Alongside some comparative studies (*18, 19*), the most widely used method that is commonly used to study the effect of accessibility on house and property prices is application of the hedonic price model (*9, 16, 20–24*). The application of hedonic price models is widely accepted by researchers around the world and for various land use cases. For example, Adair et al. have developed a hedonic price model for different submarkets in Belfast, United Kingdom (*11*). More recently, Du and Mulley applied a geographic weighted regression model to quantify the effect of transport accessibility on property values (*25, 26*). This method has been used to overcome some of the methodological issues associated with hedonic price models. It has been shown that these models violate some of the assumptions of regression models (*12, 13*). The approach has limitations, however, in that spatial autocorrelation and spatial heterogeneity are known to be two of the most important assumptions that are frequently violated by hedonic price models (*25*). Some previous studies, however, such as the study of Rodriguez and Targa (*14*), have used measures to control for these correlations.

Cortright evaluated the effects of walkability on housing prices using a walk score and 95,000 real estate transactions and controlling for house characteristics (size, number of bedrooms, number of

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baths, and age of the building), as well as neighborhood characteristics (e.g., proximity to the central business district, average income, and accessibility to jobs) (*27*). He found that walkability had a statistically significant, positive impact on house values in 13 of the 15 markets that he examined. In a typical metropolitan area, each one-point increase in the walk score was found to be associated with a \$700 to \$3,000 increase in home values, after other observable factors were controlled for. For example, if all other factors are held constant, a shift from a 50th to a 75th percentile walk score increases a house's value by between \$4,000 and about \$34,000, depending on the market. The biggest gains were in large cities with the highest densities and the best transit systems, such as San Francisco, California, and Chicago, Illinois.

Pivo and Fisher also examined the effects of walkability on property values and investment returns (*28*). Walkability was defined as the degree to which a destination within walking distance of a property encourages walking for recreational or functional purposes. They found that, when all else is equal, the benefits of greater walkability were capitalized into higher office space, retail space, and apartment values. On a 100-point scale, a 10-point increase in walkability increased those values by 1% and 9%, depending on the property type.

One of the issues encountered in most previous studies is the data acquisition problem. In some cases, the lack of accurate and timely data, such as in Tehran, may significantly affect the analysis. Changes in property values, however, could sometimes be mistakenly attributed to the transportation system, for example, in cases in which a change in other factors that affect property values happens at the same time, such as the construction of more high-quality houses. On the contrary, the value of a house may decrease because it has aged, but evaluation of the data alone might imply that the value of a house has decreased as a result of increased accessibility, although it is actually reduced because of the increased age of the house.

The deterioration of air quality and noise levels because of proximity to transportation systems, especially highways, may also reduce property values. In previous research undertaken by the authors, negative impacts because of the deterioration of air quality and noise levels were measured. Proximity to highways may therefore cause major noise disturbances that can surpass the benefits caused by greater accessibility, especially in close proximity to highways. The same results were seen in some previous studies, such as those of Debrezion et al. (*29*) for train lines and Cervero and Kang (*30*) for bus stations.

Findings similar to those described above have been obtained with many behavioral models, which have used uncontrolled data for modeling purposes.

The study described in this paper used a stated preference (SP) survey to estimate the willingness to pay (WTP) for greater accessibility to both public transit systems and highways. Some other studies on the effect of transportation systems on property values have also used SP data, such as the studies of Shiftan and Suhrbier (*31*), Levine and Frank (*32*), Gayda (*33*), and Hunt et al. (*34*). Different discrete choice model structures have also been used to model WTP for greater accessibility and environmental equality.

The major innovations of this study involved the modeling of property values in a developing Middle Eastern country. The SP approach was used to model changes in property values as a result of improvements to the transportation system. In addition, both public and private transportation projects were considered together with the environmental issues involved with the projects. Finally, fuzzy numbers were used in the model to account for the nondeterministic behavior of the respondents.

Although each of the innovations mentioned above might have been considered in previous research, the study described in this paper has made use of all of them simultaneously and in coordination with each other. The major limitation of the proposed model is its lower level of accuracy when it is subjected to greater changes in accessibility, in which nonlinear behaviors are expected to occur. Meanwhile, the model presented in this paper suffers from the limitations associated with the SP data. Furthermore, this study focused on residential land uses and did not consider industrial or commercial buildings.

The rest of the paper is organized as follows: the next section presents the experimental design and the sample properties. The results of the models are then given, and finally, conclusions and future directions for research are presented.

EXPERIMENTAL DESIGN AND SURVEY

To understand better how individuals trade off between the characteristics of the transportation system, environmental quality, and housing costs, an SP experiment was developed. As the focus of the study was investigation of the effects of explanatory variables for housing costs in general (and not specific types of houses), an unlabeled design was used.

Five variables were used to represent the characteristics of the transportation system. These variables represent the average travel time by various modes of transportation. The modes considered in this study are walk, metro, auto, taxi, and bus. Air pollution and noise level factors were also used to represent the environmental quality of the house. As mentioned above, in an earlier study undertaken by the authors, environmental attributes were not considered, but the omission of environmental attributes led to misleading results. For instance, as the distance to highways was reduced, property values would have decreased. This reduction was potentially the result of the higher levels of noise and air pollution in the vicinity of the highway and not the result of greater accessibility. The inclusion of environmental attributes has eliminated such effects and, as will be seen in the next section, has resulted in more realistic results.

SP surveys typically involve the use of trial and error to refine the stimuli (*35*). In the first trial, the number of levels for all attributes was chosen to be three. The number of alternatives per scenario was also three. A pilot test with three alternatives per scenario showed that the respondents could not process this amount of information; that is, as each alternative had eight attributes, the consideration of three alternatives per scenario required the respondents to process 24 units. In addition, the survey respondents were not familiar with this type of survey. Therefore, the main study was designed with two alternatives per scenario. Meanwhile, the number of levels was decreased to obtain a smaller design. Therefore, two levels were considered for transportation attributes, and air quality (an important issue at the time of the survey, as Tehran suffers from serious air quality issues, especially in the winter) and noise were entered into the design with three levels each. Qualitative measures were used for pollution and noise because the respondents did not have a sense of quantitative values for noise and air quality. A graphical representation of the scenarios is shown in Figure 1.

The levels for each measure were selected and tested in a pilot survey, which was designed to be as simple as possible, because residents of Tehran are unfamiliar with SP surveys. The same issue may occur in other developing countries as well.

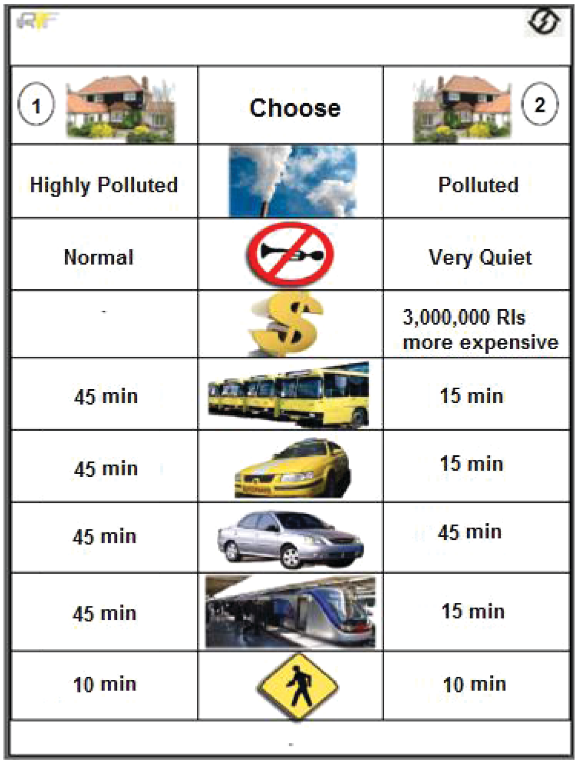

FIGURE 1 Graphical representation of scenarios (Rl = Iranian rials; \$1 = 30,000 rials in February 2013).

The number of scenarios in the design was chosen to be 16. To avoid survey fatigue, three randomly chosen scenarios (from the total of 16 scenarios) were given to each respondent. The $2^5 * 3^3/2/16$ choice experiments described above were designed by use of the %choiceff macro in SAS. Because no good evidence from prior studies was available, a β_0 design (a design in which all parameters are assumed to be zero) was implemented. The *D*-error was used in this research to optimize the experiment design and was calculated as described in Equation 1.

$$D\text{-error} = \left|(X\acute{X})^{-1}\right|^{1/K} \tag{1}$$

where

X = design matrix,
K = number of design attributes,
$\acute{X}$ = transpose of matrix X, and
X^{-1} = inverse of matrix X.

The *D*-error value of the final design was 0.44, and the final design is presented in Table 1.

The final survey was conducted in Tehran in February 2013. The city of Tehran is divided into 22 municipalities. The respondents were chosen in proportion to the number of residents in each municipality. A total of 807 respondents participated in the survey, and 2,421 observations were collected during the experiment. Although typical limitations of SP studies, such as the lack of attention or false understanding, may exist in the observations, no evidence that these limitations were present in the current survey existed. As the respondents who participated in the SP survey were the heads of their households, it was assumed that they kept this role in mind when they answered the questions. No data on the gender of respondents was recorded, and it was assumed that each respondent's behavior was a proxy of that for the family.

Of the 807 families, 448 (55.5%) owned their homes, 294 (36.4%) were renters, and 65 had other types of living arrangements. The average area per household in the sample was 89 m^2, which is close to the average for the city (95 m^2 in 2006). The average size of the family for the sample was 3.93 persons, which is close to average for Tehran (four persons per family). Also, the average level of car ownership for the sample was 0.28 auto per person, which is slightly more than the average for the city (0.25). These sociodemographic characteristics of the sample show that they represent those of the city's population fairly well. The distribution of important sociodemographic characteristics for the sample is presented in Figure 2.

The sample size required for SP studies can be estimated by Equation 2 (*36*):

$$N \geq \left(\frac{1.96.\text{SE}_1\beta_k^*}{\beta_k^*}\right)^2 \tag{2}$$

where

N = minimum required sample size,
β_k^* = prior estimate of kth parameter, and
SE_1 = standard error of prior estimate of kth parameter.

The equation was applied to a model estimated with the data gathered during the pilot survey. The data set included 400 observations. On the basis of these estimates, a sample size of 200 respondents proved to be enough to estimate all parameters in the model. Therefore, 800 respondents were surveyed.

MODEL RESULTS

A binary discrete choice model was used to estimate the utility of the choice model. The model was estimated by the use of BIOGEME software (*37*). After different models were tested, the final model with the parameters presented in Table 2 was selected. In this model,

dtAuto = average travel time with auto,
dtBus = average travel time with bus,
dtMetro = average travel time with metro (rail),
Price = land value,
Air12 = effect of a change in air quality from clean air to polluted air,
Air23 = effect of a change in air quality from clean air to very polluted air,
Noise12 = effect of a change in noise pollution from quiet to moderate noise, and
Noise23 = effect of a change in noise pollution from quiet to very noisy.

Other models, such as the random parameter mixed logit model, were also examined, but the results were not satisfactory and the parameters of the random distribution were not found to be significant, their signs did not appear to be reasonable, or both.

The different statistical goodness-of-fit measures of the model are presented in Table 3. Table 3 shows that access to the transportation system, that is, highways, bus networks, and metro systems, has a significant effect on the property choices of the respondents.

TABLE 1 Experimental Design for Property Value Estimation in Tehran

	First Option								Second Option							
Scenario	Cost	Travel Time by Auto	Travel Time by Taxi	Travel Time by Bus	Travel Time by Metro	Travel Time on Foot	Air Quality	Noise Level	Cost	Travel Time by Auto	Travel Time by Taxi	Travel Time by Bus	Travel Time by Metro	Travel Time on Foot	Air Quality	Noise Level
1	1	2	2	2	2	1	3	2	2	2	1	1	1	1	2	1
2	1	1	1	1	1	1	3	3	3	2	2	2	1	2	1	2
3	2	1	1	2	1	1	1	2	1	2	2	1	1	2	2	3
4	1	2	1	2	1	1	1	1	3	1	2	1	1	2	3	1
5	3	2	2	1	2	1	1	3	1	1	1	2	2	2	2	2
6	3	2	1	1	1	2	1	2	3	1	2	2	2	1	2	1
7	1	1	2	2	1	1	3	3	1	2	1	1	2	2	1	1
8	2	1	2	2	2	2	1	3	3	1	1	1	2	1	2	1
9	1	2	2	1	1	1	1	1	2	1	1	1	2	2	1	3
10	2	2	2	2	1	1	2	1	1	1	1	1	1	2	1	1
11	3	2	1	2	2	1	1	3	2	2	2	1	2	2	3	1
12	1	2	1	1	2	1	3	2	2	1	2	2	2	2	1	3
13	1	1	2	1	2	2	2	2	3	1	1	2	1	2	3	1
14	2	1	2	1	1	1	1	2	2	2	1	2	2	2	3	1
15	1	2	1	1	2	1	3	2	1	1	2	2	1	2	1	1
16	1	1	2	1	2	1	1	1	1	2	1	2	1	2	2	3

NOTE: Data represent a level for each attribute. In this study, most attributes are divided into two or three levels.

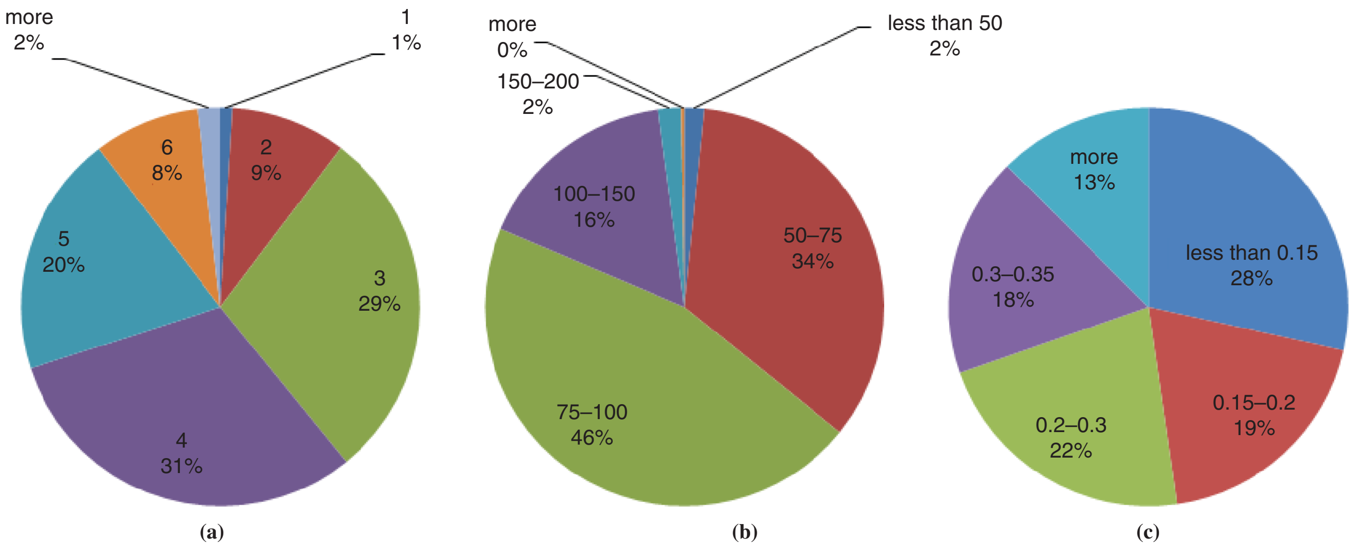

FIGURE 2 Sociodemographic characteristics: (*a*) family dimension, (*b*) house area, and (*c*) car ownership.

WTP was computed as the ratio of the travel time coefficients to the price coefficients. The following resulted:

- A 1-min improvement in travel time by auto (highway or road network) would increase the users' WTP by 160,000 rials per square meter ($1 = 30,000 rials in February 2013, when the survey was done). On the basis of the average cost of property in Tehran, this was an approximately 0.4% increase at the time of the survey.
- A 1-min improvement in travel time by bus would increase the users' WTP by 120,000 rials per square meter. On the basis of the average cost of property in Tehran, this was an approximately 0.3% increase.
- A 1-min improvement in travel time by metro would increase the users' WTP by 100,000 rials per square meter. On the basis of the average cost of property in Tehran, this is an approximately 0.25% increase.

The results are reported as the improvement of the transportation system per minute and are in agreement with the lower bound of the results given in previous research. This finding can be attributed to the relatively higher level of accessibility in urbanized areas.

Previous research on highway accessibility showed that improved accessibility to highways significantly influences property values. Cervero and Landis showed that this impact could be as large as 25% (*38*). Palmquist also reported a 15% to 17% increase in property values because of improved highway accessibility (*39*). Therefore, the 0.4% increase in property value due to a 1-min decrease in travel time, which is equal to about 4% for a typical 10-min reduction in travel time, is less than the increase reported in the literature. However, as the exact amount of travel time savings was not reported in those studies, no clear justification for the differences can be made, but the smaller increases in property values could also be attributed to the higher level of connectivity and accessibility in dense urban areas such as Tehran.

A 1% improvement in the bus system in Tehran was shown to increase the land value by 0.075%. This result is similar to the result from studies in Seoul, South Korea, that have reported a 0.128% increase in property values (*30*), and those in Beijing, which reported a 0.06% increase in property values (*40*). The results presented in this paper are greater than those reported by Mendieta and Perdomo in 2007, which estimated a 0.12% to 0.38% increase in property value as the travel time was reduced by 5 min in Bogota (*41*).

Furthermore, the study by Rodriguez and Mojica, also for Bogota, reported a 15% to 20% increase in property values (*42*). The results of the present study suggest that a 50- to 70-min improvement in the average travel time per trip on the bus network would provide a similar increase in Tehran. Therefore, it can be seen that the values given in this paper are higher than those given by Mendieta and Perdomo (*41*) but still less than those given by Rodriguez and Mojica (*42*).

When the metro system is considered, it was shown that a 1% improvement in travel time results in a 0.0625% increase in property value. This is in the range reported in the Netherlands, which was between 0.03% and 0.09% (*29*), and near that for Quebec City, which reported a 0.07% to 0.11% increase in property values (*17*).

It could be seen that access to public transport has less of an effect on property values than road network improvements. This finding could be the result of the fact that in Tehran more people use automobiles than public transportation, as well as the fact that in

TABLE 2 Result of Modeling of SP Property Choice Model

Parameter	Value	Robust SE	Robust *t*-Test Value	Robust *p*-Value
Air				
Air12	−0.767	0.0834	−9.2	0
Air23	−1.44	0.073	−19.7	0
CONST1	fixed	fixed		
CONST2	−0.411	0.0663	−6.19	0
Noise				
Noise23	−0.886	0.0736	−12.04	0
dtAuto	−0.0146	0.00234	−6.25	0
dtBus	−0.0108	0.00183	−5.89	0
dtMetro	−0.00974	0.00255	−3.81	0
Price	−0.000928	0.000115	−8.04	0

NOTE: Number of estimated parameters = 8; number of observations = 2,421; null log likelihood = 1,678.109; constant log likelihood = −1,642.709; initial log likelihood = −1,678.109; final log likelihood = −1,234.07; CONST1 = constant term in utility function of first option; CONST2 = constant term in utility function of second option.

TABLE 3 Summary of Goodness-of-Fit Measures of the Model

Measure	Formula	Value
Likelihood ratio test (R)	$R = 2 \times (\text{LL}(\beta) - \text{LL}(0))$	888.079
McFadden's rho-square (LRI)	$\rho^2 = \text{LRI} = 1 - \frac{\text{LL}(\beta)}{\text{LL}(0)}$	.2650
Adjusted rho-square	$\bar{\rho}^2 = 1 - \frac{\text{LL}(\beta) - K}{\text{LL}(0)}$	.2600
AIC	$\text{AIC} = -2 * \text{LL}(\beta) + 2 * K$	2,484.14
Veal–Zimmermann (R^2_{VZ})	$R^2_{\text{VZ}} = \left(\frac{\delta - 1}{\delta - \text{LRI}}\right) \times \text{LRI}, \delta = \frac{n}{2\text{LL}(0)}$	.4625
R^2_{ML}	$R^2_{\text{ML}} = 1 - \exp\left[\frac{2(\text{LL}(0) - \text{LL}(\beta))}{n}\right]$	.3071
Crag–Uhler	$1 - \exp\left(\frac{-R}{n}\right)$	0.3071
Adjusted Estrella	$1 - \frac{\text{LL}(\beta) - K}{\text{LL}(0)} \wedge \left(\frac{-2}{n} * \text{LL}(0)\right)$	0.3411
Cramer's λ	$\lambda = (\text{average } \hat{F}_i \vert y_i = 1) - (\text{average } \hat{F}_i \vert y_i = 0)$	0.3044
McFadden's overall prediction success index (σ)	$\sigma = \sum_{i=1}^{j} \left(\frac{N_{0i}}{N_{00}}\right) \times \left(\frac{N_{ii}}{N_{0i}} - \frac{N_{0i}}{N_{00}}\right)$	0.2215

NOTE: LRI = likelihood ratio index; LL(β) = log likelihood of utility function at convergence; LL(0) = log likelihood at zero; K = number of parameters in the model; AIC = Akaike information criterion; n = sample size; R^2_{ML} = Cox = Snell R^2; $\hat{F}$ = predicted value of dependent variable, y_i = result of indication function, which is 1 if alternative is chosen and 0 otherwise; N_{0i} = expected number of individuals who are predicted to choose i; N_{00} = total number of individuals; N_{ii} = expected number of individuals who are observed to choose i and also predicted to choose i.

Tehran houses with higher values do not have good access to public transit. Therefore, on the basis of the income effect, it could be anticipated that as income increases, the effect of public transportation on property values could decrease.

The reduction of a WTP for an increase in public transport accessibility follows the same pattern as modal shares. This pattern of WTP is because improvements to public transportation facilities reduce the dependence of families on vehicles and thereby improve their quality of life, even for families with high levels of vehicle ownership. However, as mentioned before, it may have less of an effect than accessibility to a vehicle. Thus, the lower value of accessibility to bus transit could be attributed to the higher levels of overall accessibility to the bus transit system. This higher level of accessibility reduces the value of improvements to the bus system.

Similarly, environmental attributes have been shown to have significant effects on property prices. As the environmental variables were presented qualitatively, the use of any transformation of those qualitative terms depends on a theory describing how people quantify them. Although different transformations (e.g., exponential, logarithmic, and polynomial) were tested, on the basis of the results of the analysis, the final model that is presented in Table 2 was selected. To estimate the model, for each n-level variable, $(n - 1)$ binary variables were entered into the (dis)utility function to make the estimation feasible.

The following results could be anticipated by the model:

- The respondents' WTP to reduce air pollution from very polluted to moderate pollution was 7,250,000 rials per square meter. This increase is equal to an 18% increase in the value of property.
- The respondents' WTP to reduce air pollution from a moderate level of pollution to clean air was 8,270,000 rials per square meter. This WTP results in a 21% increase in the value of property.
- Although no significant increase in property values could be seen with a change from quiet to a moderate noise level, the respondents' WTP to reduce the noise level from very high to moderate was 9,550,000 rials per square meter. This WTP results in a 24% increase in the value of property.

These observations confirm the nonlinear structure of the WTP to reduce both pollution and noise levels.

A fuzzy transformation technique was used to quantify the environmental effects, as the questions about environmental attributes that the respondents were asked required qualitative responses. This technique was used because it was recommended for this study that more accurate air quality or noise pollution levels not be used to describe the quality of air and noise pollution, as it was believed that the respondents did not have an awareness of these qualitative levels. For instance, if a respondent were asked about a noise level of 70 dB and an air quality level of 80 ppm for particulate matter less than 2.5 μm in diameter, he or she would find it difficult to comprehend exactly the noise and pollution levels. However, the respondents had a good understanding of qualitative measures. Therefore, the modeler had to find a method to quantify those qualitative linguistic measurements indicated by the respondents. Therefore, those qualitative linguistic measurements were considered by the use of fuzzy numbers, which is a well-known tool used to cope with this kind of problem. A mixed logit model was also tested to overcome the issue of qualitative measures, but the results were not satisfactory.

A triangular fuzzy number was assigned to each environmental pollution level, as shown in Figure 3. On the basis of these fuzzy numbers, the unit price of environmental pollution could be estimated by use of the membership of each level. Figure 4 shows the effect that a unit increase in environmental quality has on property values after defuzzification.

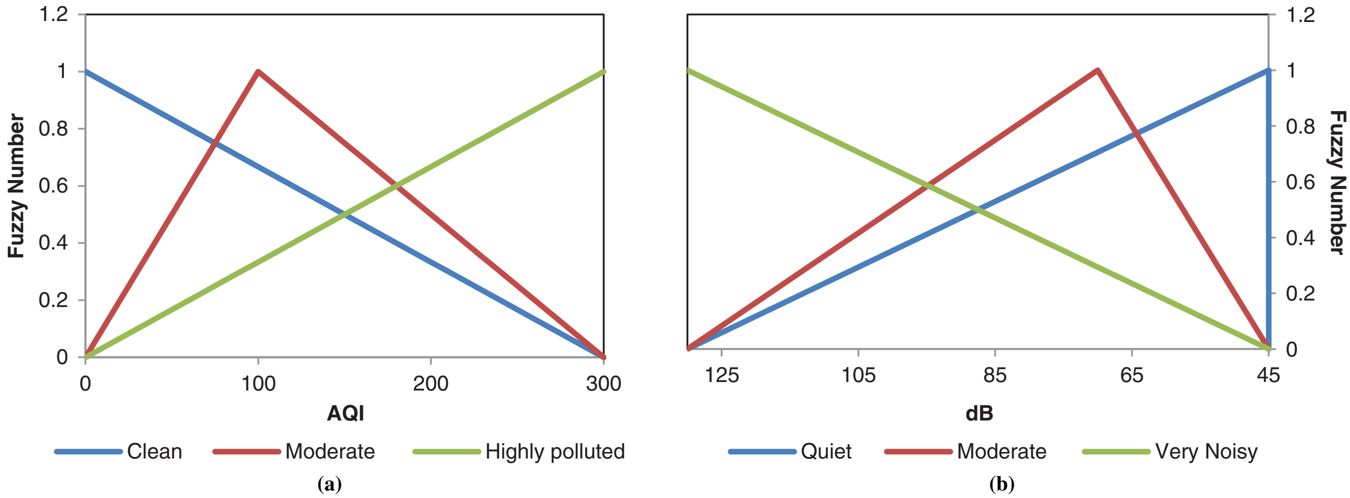

FIGURE 3 Fuzzy numbers assigned to (*a*) air quality and (*b*) noise (AQI = air quality index).

According to Nelson, a reduction in property values of 0.16% to 0.63% per decibel could be expected because of noise levels (*43*). This result is similar to that obtained in this study, which suggests that a 0.28% reduction in property value per decibel is expected in Tehran. Meanwhile, different studies have used different measures of air pollution, such as the amount of particulate matter or carbon dioxide, and monetary reductions in property values have been reported. Therefore, the effect of air pollution on property values obtained in this study could not be compared with effects obtained in previous studies. The results of this study indicate that a one-unit reduction in the air quality index would result in a 0.3% increase in property value up to an air quality index of 100 and a 0.26% increase in property value with air quality index values greater than 100.

CONCLUSION

In this paper, a multinomial logit model was developed with SP data collected in Tehran. By use of the proposed model, the WTP for unit increases in accessibility and environmental quality was estimated. Accessibility to three modes of transport, including road, bus, and rail, was simultaneously considered, and discrete choice models were used to estimate the WTP for greater accessibility. The effects of both air quality and noise on property values were modeled to consider the external effect of transportation systems. The results show that better accessibility can increase property values by an average of about 0.3% in Tehran. Environmental quality was shown to have a nonlinear cost structure. Lower environmental quality may induce a higher cost on the residence, as the value of the property is reduced and people are willing to pay extra for reduced levels of environmental pollution. Because qualitative measures for environmental impacts were used, a fuzzy logic approach was used to quantify them.

On a practical level, the results of this paper could be used as a tool for cost–benefit analyses of large transportation projects and to determine subsidies for public transit systems, especially in the Middle East and developing countries, where budget constraints are more problematic. Meanwhile, these values could be used as a measure to trade off air quality and noise levels with accessibility in different environmental projects. The innovations offered by this study could include the use of SP data instead of the revealed preference data that were previously used to control for attribute levels.

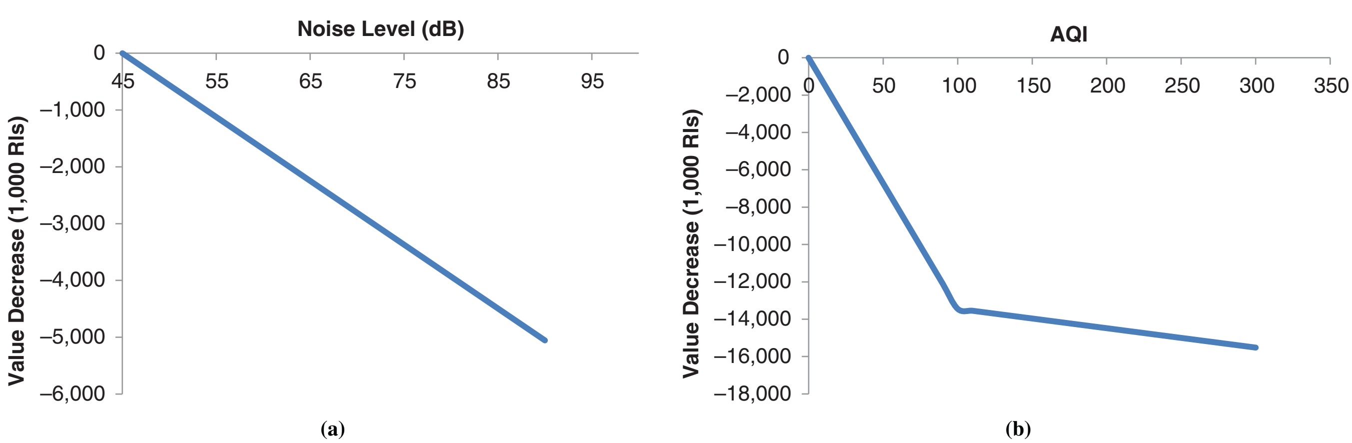

FIGURE 4 Property value reductions due to (*a*) noise and (*b*) air quality deterioration.

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