Effects of Trip Purpose on Transit Fare Elasticiy, Case Study of Isfahan

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Abstract:
This paper explores the effects of trip purpose on price elasticity of bus mode. Data for the research was collected through passenger field survey in Isfahan, Iran. Due to the nature of the data, nonlinear regression and nonparametric statistics tools were used for analysis. It was found that the logarithmic function best explains the relationship between percentage of change in demand and percentage of change in fare. This implies that increase in the fare has a diminishing return to scale on demand. Average values of elasticity were calculated as (-0.33) for educational trips, (-0.27) for shopping trips, (-0.26) for commuting trips, (-0.66) for leisure trips, (-0.26) for medical trips, (-0.35) for returning-to-home trips, and (-0.54) for other trips. Highest values were observed for leisure trips and lowest values for shopping and commuting trips. Kruskal-Wallis and Mann-Whitney U tests were employed to analyze the equity of elasticity values among trip purposes. Results show that differences are significant and therefore, trip purpose does have significant effect on the value of fare elasticity of transit demand.

Keywords: Transit, demand elasticity, trip purpose, non-parametric test

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Abstract

1. Introduction

Promotion of public transportation is one of the main solutions to enhance network performance and move towards sustainable transportation. Public transportation planning requires prediction of the behavior of actual and potential passengers within different time horizons. In fact, pre-evaluation of the effectiveness of urban management decisions requires the prediction of the public behavior. Demand for a specific mode of travel is determined by its relative utility compared to alternative modes. Utility of public transportation is mainly determined by travel time, reliability, out-of-pocket cost, comfort, accessibility, safety, and security. Bus mode due to high-passenger capacity (compared with private mode), extensive network and flexibility (compared with other transit modes) is the backbone of the urban transit system in many urban contexts.

Price elasticity of demand is a term in economics often used when discussing pricing policies. This index is a measure of the relationship between a change in the quantity demanded of a particular good and a change in its price. The formula for calculating price elasticity of demand is shown in the equation (1). It is defined as the ratio of percentage change in ridership (D) to a one percent change in fare (P).

$$\varepsilon_p^D = \partial D/\partial p \times p/D \qquad (1)$$

If the absolute value of fare elasticity is greater than one, demand is elastic and any increase in fare would cause a larger decline in demand. In general, if the quantity demanded of a good is very responsive to a change in the good's price, the good is considered to be elastic. An absolute fare elasticity of less than one implies that demand is inelastic and demand is unit elastic when price elasticity of demand equal to one [Ortúzar, 2011]. Price elasticity of demand is an essential parameter to estimate revenue and demand of a bus transit system as a result of increase or decrease in the fare. Generally, if the absolute value of fare elasticity is greater than 1, any increase in fare would cause a larger decline in ridership (Returns to Scale of demand) and decrease total fare revenue. Also, an absolute fare elasticity of less than 1 implies than a fare increase will result in increased revenue.

Methods used for estimating transit fare elasticity could be categorized into "Shrinkage Analysis", "Preference Survey" and "Econometric Studies" [Linsalata, 1991]. In Shrinkage analysis approach, the fare elasticity is measured by observing the ridership levels prior to and after a fare change. Preference Survey method is based on survey and respondents are exposed to various scenarios and their travel behavior is examined in the event of any scenario. Then fare elasticity can be calculated by obtaining information on the modes of travel. Econometric studies use historical data to estimate the transit demand function and the fare elasticity is calculated by equation (1).

In the following sections, demand behavior is evaluated than fare in public transportation of the new insights and fare elasticity will be calculated based on various trip purposes by using preference survey. After determining the fare elasticity for each trip purpose, equality between each pair of them is investigated by performing statistical analysis.

2. Literature Review

As a flexible tool, fare adjusts the level of income by affecting the behavior of the passengers. In recent decades, technology advances pave the way for fare rate setting. Literature on fare determination and models dates back to 1960s [Oldfield,1974] ‹[Curtin,1968]‹ [White,1978]. Curtin (1968) developed a simple measure to analyze the impact of fare changes on transit ridership known as the Simpson-Curtin formula. He found an average fare elasticity of -0.33. Although this fare formulation wasn›t sensitive to peak and off-peak hour or scale of the city, it has been extensively used [Linsalata, 1991]. A number of fare elasticity studies calculate the impact of fare changes on demand in different time horizons, including immediately after the execution, short-term and long-term [Dargay and Hanly,1999],[Goodwin,1992]. Litman (2015) suggested the elasticity of transit ridership with respect to fares is usually in the –0.2 to –0.5 range in the short run and increases to –0.6 to –0.9 over the long run by comparing several studies [Litman,2015]. Nowak and Savage (2013) calculated the cross elasticity between the price of gasoline and transit ridership in Chicago, USA. They found that when gas prices were less than $3 a gallon, fare elasticity was less than 0.05 and when prices exceeded $3 a gallon, the elasticity was larger, in the range of 0.12–0.14. Sirikijpanichkul and Winyoopadit (2013) evaluated the effects of fare policy on the ridership with different ages and trip length in Bangkok, Thailand. They found that the old (older than 45 years) and long-distance passengers have higher price elasticity of demand than the young and short-distance passengers. Wardman and Grant-Muller (2011) presented fare elasticity of the demand for business and leisure trips in long-term and short-term for Great Britain. Their results showed that elasticity of long-term trip more than short-term trip and elasticity of business trips lower than leisure trips. Hensher and Li (2011) estimated fare elasticity by information on bus rapid transit (BRT) systems throughout the world. In this study evaluated the price sensitivity and frequency of service and found that fare elasticity was -0.38 and headway elasticity was -0.3. Wang and et al. (2015) proposed a methodology based on transit smart card data and assess influence of the fare elasticity of demand and fare elasticity of income for Beijing Metro. The results demonstrated that trips with a distance of around 5 km were very sensitive to fare and the range of the elasticity's was -0.23 to -1.3. Transit Cooperative Research Program considered fare elasticity of demand for public transport as an indicator to compare cities and public transportation system. It states that peak-hour ridership's are much less (approximately half) responsive to fare changes than commuters travelling during off-peak hours and concluded that transit riders in small cities were more responsive to fare increase than those in large cities. Also, fare elasticity in cities with a strong public transportation system is lower than other cities [TCRP, 2003]. Preston and James (2000) estimated elasticities for bus demand with respect to passenger waiting times. The average value appears to be -0.65 for adult passengers at peak-hour with journeys to central destinations, but this values for off-peak was -0.85. Fare elasticity of all passengers at peak and off-peak hours to central journey was -0.65 and no difference between this index at peak and off-peak hours. Liu and Ferreira (2010) presented a study on estimating the latent demand for rail transit in Perth, Australia. As part of this study, they evaluated the sensitivity of the transit ridership to the change of fuel price through four methods: theoretical point elasticity, log arc elasticity, mid-point arc elasticity and shrinkage ratio. They found that the range of elasticity is 0.004 to 0.016 that is lower than the values reported by previous studies. Mitrani et al. (2002) calculated the cross elasticity of rail demand to bus fares and it value was 0.13.

Linsalata (1991), Nowak and Savage (2013) and Preston and James (2000) adopted observed preference method and Sirikijpanichkul and Winyoopadit (2013), Wang et al. (2015), and Liu and Ferreira (2010) used expressed preference method for their analysis.

3. Methodology

This study consists of survey sample selection, data collection, data analysis, statistical tests and conclusion. Data collection and information are described in section (4). After the survey and data entry, statistical analysis was performed. In this section, first the Normal distribution of the data was examined for each trip purpose using Kolmogorov-Smirnov test. One-sample Kolmogorov-Smirnov test is used for measuring the goodness of fit. It evaluates the degree of agreement between an observed distribution and a completely specified theoretical continuous distribution and cumulative distribution of sample to be compared with the known cumulative distribution. The hypothesis regarding the distributional form is rejected if the test statistic is greater than the critical value. Since the test rejected the Normal distribution of the data, Kruskal-Wallis test and Mann-Whitney U test were used for comparing the values of elasticities among trip purposes. The Mann-Whitney U test is used to compare differences of dependent variable between two independent groups. This test is often considered the nonparametric counterpart of the independent student t-test. The Kruskal-Wallis test is a nonparametric test used to determine if there are statistically significant differences between two or more groups of an independent variable. In other words, it is considered as the nonparametric counterpart of the Fisher test. It was used to check the fundamental assumptions i.e. Normal distribution of data and equality of variance among trip purposes.

4. Data Collection

Isfahan bus transit network is composed of 97 lines with an approximate length of 2K kilometers serving 900K passengers daily which makes its share in the city's transportation equal to twenty percent. The transit lines all over the city are mostly radial and circumferential. Since this study did not expect significant changes in transit fare, the approach was based on expressed preferences.

In order to fulfil the first requirement, a survey was conducted among transit passengers in Isfahan among six major lines of the bus transit system. Information of these six lines is presented in table (1). The survey sample was 300 passengers.

Table 1. Lines determined for sampling

Line Number	Daily Demand ((prs	Length ((km	Type of Bus Route
23	10870	5	radial
31	11553	10.5	circumferential
34	40824	9.5	circumferential
43	28484	9	radial
68	18750	9.4	radial
91	49664	20.5	Combined

The survey questionnaire contained questions on gender, income, trip purpose, age. Moreover, respondents were asked about how much they were paying for fare and how much more they were willing to pay before switching to their other alternative modes if any (consumer surplus). Therefore, price elasticity of transit demand was calculated with the ratio of the percentage change in quantity demanded to the percentage change in price.

5. Data Analysis

After the survey was conducted during peak and off-peak periods, data were categorized based on trip purpose. The groups of trip purpose included education, shopping, commuting, bureaucratic, leisure, medical, return to home and other. Then, the percentage change in fares and the corresponding percentage change in demand were calculated for each purpose. Since the fares were different in different lines, percent of fare increase and percentage of demand reduction were calculated separately for each line.

The gender evenness was observed among respondents (55% women versus 45% men). The frequencies of trip purposes in the sample are shown in Figure (1).

The results show that most of the passengers choose $ 0.17 as the threshold value for paying bus fares. The frequencies of different values chosen by passengers are presented in Figure (2).

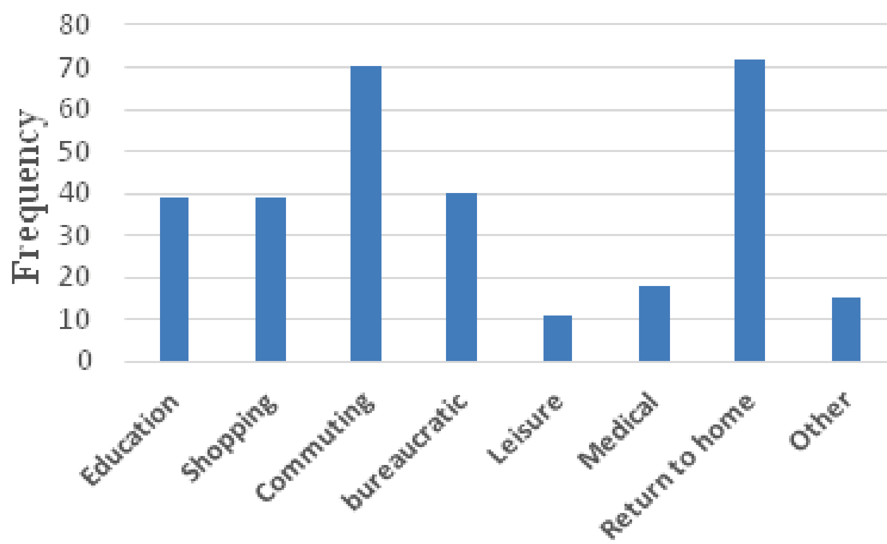

Figure 1. The frequencies of trip purposes

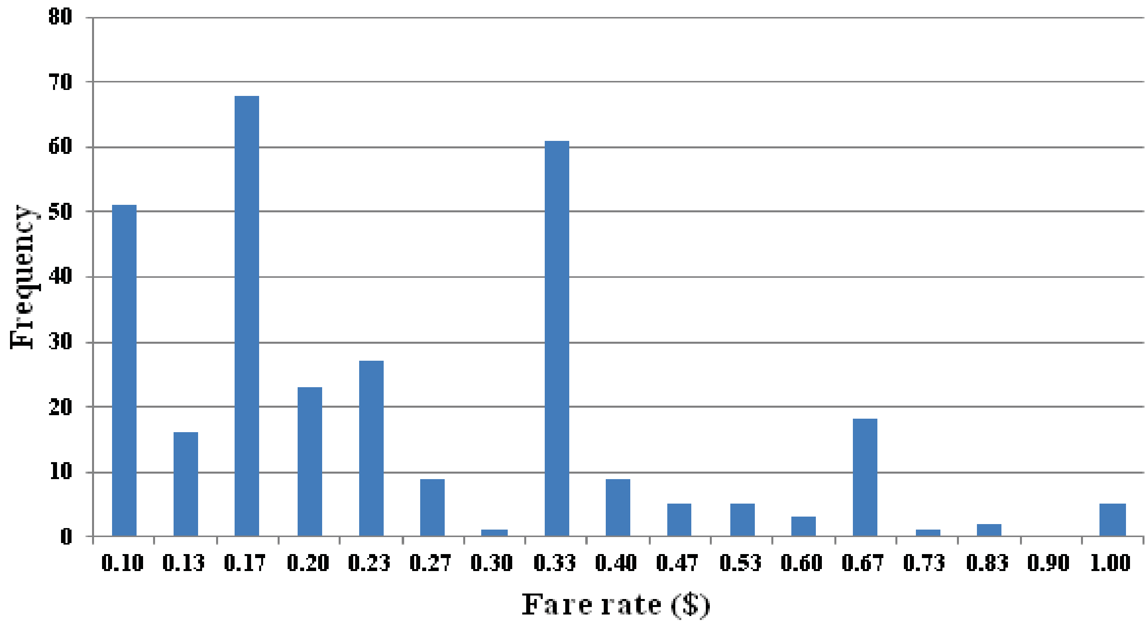

Figure 2. The frequencies of threshold fare values

In order to calculate the elasticity, linear functions, logarithmic, normal, polynomial and the Fourier curves were fitted to each data category. Coefficient of determination (R^2) and the simplicity of the model (fewer parameters) were the criteria for selection of the best fit therefore, logarithmic function was chosen as the best fit. In other words, changes in demand by increasing the amount of fare reduces continuously and the decline is not constant. Table (2) shows the formula to calculate the elasticity of different trips purpose, where the percentage decline in demand (D) is based on the percentage change in fare (p).

Table 2. The curve fitting formulae for different trip purposes

Trip Purpose	Equation	R2
Education	D=-30.3 ln p+91.5	0.93
Shopping	D=-29.8 ln p+98	0.97
Commuting	D=-27.2 ln p+84.8	0.95
Bureaucratic	D=-22.8 ln p+58.1	0.95
Leisure	D=-23.7 ln p+45.7	0.95
Medical	D=-24.8 ln p+74.2	0.9
Return to home	D=-23.4 ln p+60.5	0.92
Other	D=-23.7 ln p+49.3	0.96

The results are plotted in Figure (3). As the rate of change in the questionnaire started from 30%, the figures are plotted for the percentage changes in demand more than thirty percent.

The figure (3) shows that leisure trip has the maximum elasticity value. Shopping trip purpose has the lowest elasticity up to one hundred percent change in fare and medical trips for changes more than that. Also, the curves for bureaucratic and return-to-home trips almost coincide and shopping, business, bureaucratic and return-to-home trips curves are close to each other by increasing the fare changes. In the trips with education purpose, elasticity is relatively low for less than about ninety percent of fare changes.

In order to calculate the average value of elasticity (arc elasticity), percentage change in the slope of demand curve with respect to the percentage change in the amount of fare was calculated for various trip purposes and values for trip purposes are shown in Table (4).

Statistical analysis was used to compare the values. In order to determine the suitable type of statistical tools, Kolmogorov-Smirnov (K-S) test was conducted [Conover, 1999]. The results of the Kolmogorov-Smirnov test in SPSS showed that test value was 2.1 and p-value <0.05. Hence, data distribution was not normal and non-parametric tools must be used. Therefore, Kruskal-

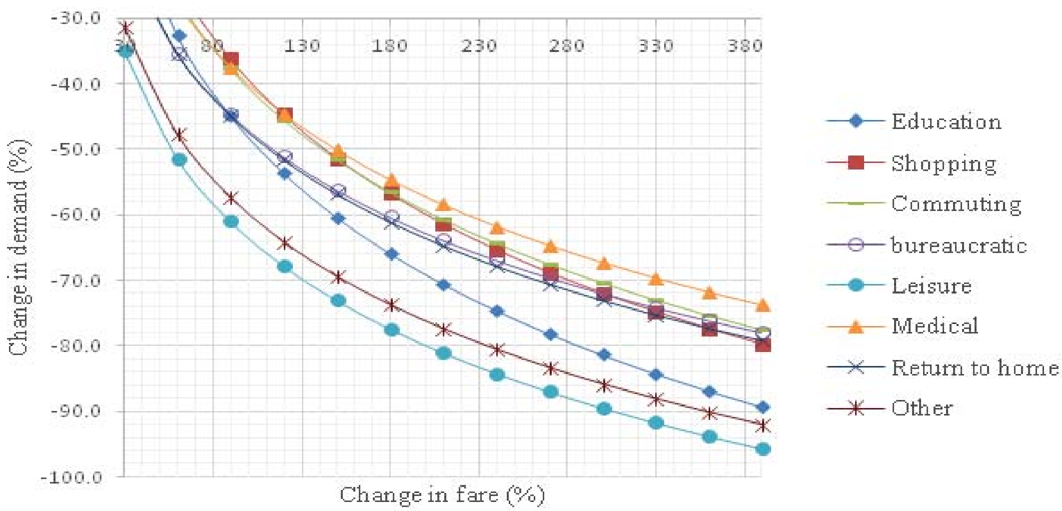

Figure 3. Elasticity curves for trips purposes

Table 3. Fare Elasticity of Demand (Average Value)

Trip Purpose	Education	Return to home	Medical	Leisure
Fare Elasticity	-0.33	-0.35	-0.26	-0.66
Trip Purpose	Bureaucratic	Commuting	Shopping	Other
Fare Elasticity	-0.35	-0.26	-0.27	-0.54

Table 4. Results of Mann-Whitney U test for education trips

Groups		p-value	Value
Education	Shopping	0.143	102
	Commuting	0.03	116
	Bureaucratic	0.885	132
	Leisure	0.023	29
	Medical	0.037	55
	Return to home	0.669	148
	Other	0.063	48

Table 5. Results of Mann-Whitney U test for trips (significant value)

Pairwise comparisons	p-value	value
Shopping-leisure	0.007	22
Shopping-other	0.018	38
Commuting-leisure	0.002	25
Commuting-other	0.004	41
Beurecratic-leisure	0.043	31
Leisure-medical	0.005	12
Leisure-return to home	0.022	33
Medical-other	0.012	22

Wallis test was used to test the equality of values. Chi-square statistic with 7 degrees of freedom was equal to 21.4 which yielded a p-value of 0.003.
Therefore, null hypothesis (equality of mean values) was rejected and the elasticity value was not equal for all trip purposes. According to rejection of the equality of elasticity in various trip purposes, the value of trip elasticities were analyzed by pair-wise comparisons. Mann-Whitney U test was used for this purpose. As an example, Table (4) compares the elasticity values of education trip to other trips purpose.
The results of the education trips analysis show that the trips with leisure, medical and commuting purpose are significant in Mann-Whitney U test and the elasticity value of them is not equal to education trip purpose. Also the results show that equal elasticity hypothesis of education trip to other trip purposes (shopping, bureaucratic, return-to-home and other) is not rejected.
Table (5) shows the summary of the results of the analysis for trips purpose pairs that were significantly different in the t-test. The results indicate that elasticity value on trips with leisure purpose was not statistically different from other purpose.

6. Conclusion

In this paper the analysis of fare elasticity of demand based on trip purpose was presented. The results of fare elasticity based on expressed preference approach show that highest values were observed for leisure trips and lowest values for shopping and commuting trips. Mann-Whitney U test were employed to analyze the equity of elasticity values among trip purposes because the data distribution was not normally. Mann-Whitney U test shows that elasticity of trip purpose is not equal and elasticity value between all trip purposes (except leisure trips) is significant statistically. Average values of elasticities were calculated as (-0.33) for educational trips, (-0.27) for shopping trips, (-0.26) for commuting trips, (-0.66) for leisure trips, (-0.26) for cure and medical trips, (-0.35) for beurecratic and returning-to-home trips, and (-0.54) for other trips.
Values between zero and one for elasticity indicate that demand is inelastic and percent change in demand is less than the percent change in price. It was found that the most suitable function to explain the relationship between percentage of change in demand and percentage of change in fare is logarithmic and elasticity value is not constant. This implies that increase in the fare has a diminishing return to scale on demand. With using the obtained values can realize passengers viewpoint about bus transit and predict the financial and traffic plan. The elasticity values show that passengers' response (about price) for mandatory trips more than other passengers. In the financial plan, it can be noted that bus fare increase has the most decline for leisure trip. Due to the fact that most of these trips are done in the evening and night, increased prices would be minor increase in traffic volume of private cars in these hours. Also, reduced bus fare will have little effect on the increased bus passengers in Isfahan according to inelastic demand in various trip purposes. On the other hand, a slight increase in fare does not lead to significant drop in public transportation demand. As a result, it seems logical to suggest an increase in bus fare at morning peak hours for education and commuting purposes.

7. References

- Conover, W. D. (1999) "Practical nonparametric statistics", 3rd edition, John Wiley & Sons, Inc. New York, pp. 428-433.

- Curtin, J. F. (1968) "Effect of fares on transit riding Highway", Research Record, 213, pp. 8-18.

- Dargay, J. M. and Hanly, M. (1999) "Bus fare elasticities: Report to the Department of the Environment, Transport and the Regions", ESRC TSU, December.

- Evans Iv, J. and Pratt, R. (2003) "TCRP Report 95: Traveler response to transportation system changes", Transportation Research Board of the National Academies, Washington, DC.

- Goodwin, P. B. (1992) "A Review of new demand elasticities with special reference to short and long run effects of price charges", Journal of Transport Economics and Policy,Vol. 26, pp. 155–170.

- Hensher, D. A. and Li, Z. (2011) "Ridership drivers of bus rapid transit systems", Institute of Transport and Logistics Studies.

- Linsalata, L. P. A. J. (1991) "Fare elasticity and its application to forecasting transit demand", American Public Transit Association.

- Litman, T. (2015) "Transit price elasticities and cross-elasticities"

- Liu, Y. and Ferreira, L. (2010) "Estimating the latent demand for rail transit: a case study in Perth, Western Australia" , In Cowled, Craig J.L. (Ed.) Proceedings of The First International Postgraduate Conference on Engineering, Designing and Developing the Built Environment for Sustainable Wellbeing, Queensland University of Technology, Brisbane, pp. 289-294.

- Mitrani, A., Kincaid, I., Edwards, D. and Hobbs, G. (2002) "London undeground and bus demand analysis" 1970-2000'

- Nowak W. P. and Savage, I. (2013) "The cross elasticity between gasoline prices and transit use: evidence from Chicago", Transport Policy,Vol 29, pp. 38-45.

- Oldfield, R. (1974) "Elasticities of demand for travel" , Transport and Road Research Laboratory Report SR11.

- Ortuzar, J. D. and Willumsen, L. G. (2011) "Modelling transport" John Wiley & Sons.

- Preston, J. and James, T. (2000) "Analysis of demand for bus services", Transport Studies Unit, University of Oxford.

- Sirikijpanichkul, A. and Winyoopadit, S.(2013) "Price elasticity of demand and transit fare strategy: a case study of Bangkok mass transit system." Proceedings of the 4th International Conference on Engineering, Project and Production Management (EPPM 2013).

- Wang, Z. J., Li, X. H. and Chen, F. (2015) "Impact evaluation of a mass transit fare change on demand and revenue utilizing smart card data", Transportation Research Part A: Policy and Practice,Vol. 77, pp. 213-224.

- Wardman, M. and Grant-Muller, S. (2011) "Price elasticities of travel demand in great britain: a meta-analysis" , Transportation Research Board Annual Meeting, 2011 Paper #11-3544.

- White, P. R. (1978) "Passenger response to service factors", in "Factors Affecting Public Transport Patronage" TRRL Report SR4 13.