FACTORS ASSOCIATED WITH TRAFFIC VOLUME AND VEHICLE KILOMETERS TRAVELED BY VEHICLE TYPE ON INTERCITY EXPRESSWAYS

Masayoshi Tanishita

Department of Civil and Environmental Engineering, Chuo University

1-13-27 Kasuga, Bunkyo-ku, Tokyo 112-8551, Japan

E-mail: tanishi@civil.chuo-u.ac.jp

ABSTRACT

This paper analyzes the factors associated with traffic volume and vehicle kilometers traveled (VKT) by vehicle type on distance-based tolled intercity expressways. Toll price and other elasticities were estimated via a monthly time series regression model considering residual autocorrelations, non-stationarity, and structural change. Three major results were obtained: (1) In addition to toll price, income and fuel price also affect car use, and the elasticities are almost the same as in preceding studies, although they vary among expressways. (2) For trucks, fuel price does not affect usage, and Index of industrial production elasticities are almost proportional to the average trip length. (3) The elasticities of traffic volume and VKT differ. This implies that average trip length is also affected by these factors.

Keywords: toll and fuel price elasticities, vehicle type, intercity expressway

1. INTRODUCTION

Road pricing is one of the most efficient and equitable measures of transportation demand management (TDM). Since it also generates revenue, it serves as an important tool for cost recovery on road- and bridge-building projects. In Japan, the Japan Highway Public Corporation (JH) had been constructing and managing intercity expressway networks using a distance-based toll system[1]. More than 9,000 kilometers of intercity expressways have been constructed, the major costs of which have been borne by the beneficiaries (road users). On October 1, 2005, JH was divided into three private enterprises: East Nippon Expressway Co., Ltd. (NEXCO East Japan), Central Nippon Expressway Co., Ltd. (NEXCO Central Japan), and West Nippon Expressway Co., Ltd. (NEXCO West Japan). Each of the private enterprises now has the power to decide its toll price, within standards.

Toll price elasticity is one of the essential values for toll price decisions, because the toll affects enterprise revenues, user benefits, and other natural and social environments. Although there is much literature on toll price elasticity, most of the studies focus on total traffic volume. Therefore, elasticities of vehicle mileage and differences by vehicle type have not been analyzed intensively, primarily due to data limitation.

In this paper, the factors associated with traffic volume and vehicle kilometers traveled (VKT) by vehicle type are analyzed considering autocorrelations, non-stationarity, and structural change of time series data (only eight expressways have been considered). Income and price elasticities are estimated through the analysis. This paper is organized as follows. Chapter 2 presents the review of price elasticities. Chapter 3 includes the methodologies and data. Chapter 4 presents the results of the analysis and discusses the findings on the basis of estimated results. Finally, chapter 5 concludes the paper and presents the future challenges.

2. REVIEW

Odeck and Brathen (2008) have reviewed the research on price elasticity of roads. Table 1 shows the results of previous research according to Odeck and Brathen.

Odeck and Brathen (2008) showed that long-term elasticity was not low. In Japan, Yamagami (1991) analyzed the relationship between economic factors and highway traffic. He showed that industrial production affected truck volume, passenger cars were highly correlated with income and expenditure, and, finally, toll price elasticity was around –0.1. At that time, because the average vehicle mileage (represented by the ratio of traffic volume to vehicle kilometers) remained stable at around 50km, he concluded that there was no difference between traffic volume and VKT. Takagi and Aizu (1991) focused on short-term elasticity. Elasticity was markedly high for Chuo Expressway, and reversed signs were observed for some expressways. This demonstrates the difficulty of short-term analysis. Yamamoto (1995) obtained similar results with large variance using Hanshin expressway data.

Regarding elasticity of fuel prices, which was not specific to any particular highway, Graham and Glaister (2004) and Goodwin et al. (2004) conducted a meta-analysis. As a result, in the short term, the elasticities of traffic volume and travel distance were –0.15 and –0.16, respectively. In the long term, they were –0.19 and –0.31, respectively. Differences are seen between traffic volume and travel distance because of changes in travel modes, destinations, and locations.

Few studies estimate the elasticity of VKT focusing on toll roads. This study analyzes the factors associated with traffic volume and VKT by vehicle type.

Table 1 – Previous studies on price elasticity of traffic volume

Author (Year)	Target	Elasticity
Weustefield and Regan (1981)	USA: 16 roads	–0.03 to –0.31
Weustefield and Regan (1981)	USA: 15 bridges	–0.15 to –0.31
White (1984)	UK: Southampton bridge	–0.14 to –0.29
Goodwin (1989, 1992)	Review	–0.45 (Average)
Ribas et al. (1988)	Spain: 3 intercity expressways	–0.15 to –0.48
Jones and Hervik (1992)	Norway: Oslo ring road/Alesund	Oslo: –0.22, Alesund: –0.45
Harvey (1994)	USA: SF Golden Gate bridge/NJ turnpike	Bridge: –0.05 to –0.15, Turnpike: –0.1
Wilbur Smith and Associates (1995)	USA	–0.1 to –0.35
Hirsheman et al. (1995)	USA: NY 6 bridges 2 tunnels	–0.09 to –0.50 (mean: –0.25)
Mauchan and Bonsall (1995)	UK: West Yorkshire simulation model	–0.4 (High-speed intercity: –0.25)
Grifford and Talkington (1996)	USA: SF Golden Gate bridge	–0.15
INRETS (1997)	France: trips over 100km	–0.22 to –0.35
UTM (2000)	USA: NJ turnpike	–0.20
Yoshida Matsumura and Kono (1981)	Japan: Tokyo metropolitan expressway (intra-city)	Cars: –0.07 to –0.27 Large trucks: –0.27 to –0.32
Yamauchi (1987)	Japan: Meishin expressway	Cars: –0.26 to –0.30 Large trucks: –0.23 to –0.25
Yamagami (1991)	Japan: total intercity expressways	–0.1
Takagi and Aizu (1991)	Japan: 13 intercity expressways	After 3 months: +0.1 to –1.1 4–6 months: +0.5 to –0.8 Short term: –0.3 to –0.5
Yamamoto (1995)	Japan: Hanshin expressways (intra-city)	Holidays Weekdays Cars: –0.2 0 to –0.2 Large trucks: –0.6 to –0.7 –0.7 to –0.9
Tanishita (2005)	Japan: 10 intercity expressways	Short term: 0 to –0.4

Note: The author added Japanese results based on Odeck and Brathen (2008) Table 1.

3. METHODOLOGY AND DATA

Using monthly data, time series regression analysis was conducted, considering serial correlation, non-stationarity, and structural change for each expressway and each vehicle type. Serial correlation is a problem that does not satisfy the independence assumption in regression residuals. If we ignore the serial correlation, t-values of estimated parameters for ordinary least squares (OLS) become large. In this case, the residual auto regressive (AR) or moving average (MA) process should be included in the estimation. In addition, we must take care not to make spurious correlations when we analyze time series data. If regression residuals show non-stationarity regardless of high t-values, a (logarithm) difference operator should be used for the analysis.

Another issue in time series data analysis is the structural change during the period. In this study, a residual cumulative sum (CUSUM) test was conducted. If structural changes were observed, “dating,” or estimation of the timing of a structural break, was conducted. Then regression analysis was revised, introducing a dummy variable to capture parameter change in the intercept and/or slope. Akaike Information Criterion (AIC) was used for model selection.

Traffic volume and VKT at expressway i and time t (Y_{it}) are explained using the explanatory variables (Xijt) and monthly dummy (Mit).

$$\log (Y_{it}) = a_i + \Sigma b_{ij} \log (X_{ijt}) + M_{it} + \varepsilon_{it} \quad (1)$$

Where ai, bij are parameters, εit represents the iid error term. For the estimation procedure, OLS was first used to estimate this expression, followed by a test for serial correlation of error term and steadiness. If correlation was observed, assuming ARMA structures, generalized least squares (GLS) was used for estimation. If the residuals were also non-stationary time series, regression was revised using differences (Δ) to verify that the residuals were stationary.

$$\Delta \log (Y_{it}) = a_i + \Sigma b_{ij} \Delta \log (X_{ijt}) + M_{it} + \varepsilon_{it} \quad (2)$$

Variables with statistically insignificant and unexpected signs were removed from the estimation. Finally, I confirmed the steadiness of the residuals and that there were no structural changes. The b_{ij} represents the value of elasticity.

Table 2 shows eight subjective expressways, the locations of which are shown in Figure 1 including Meishin Expressway (Komaki-Osaka)[2]. Traffic volume and VKT data were collected for five vehicle types—mini-car, normal car, medium truck, large truck, and extra-large truck—from July 1989 to Dec. 2006 (211 months). Meanwhile, the toll (yen/km) was raised three times for medium and large trucks (April 1995, January 1996, and April 1997) and once for cars and extra-large trucks (April 1995).

Explanatory variables in the model are toll (yen/km), the average prices of gasoline and diesel in the prefectures where expressways are located (yen/liter), the average Gross Regional Product in the prefectures where expressways are located (yen), index of industrial production (IIP), and the number of tourists in Okinawa (persons). Toll price discount (night and early morning discount began in January 2005) is also included as a dummy variable. All monetary terms (income and price) are converted to 2005 values using the real consumer price index. Table 3 shows the sources of the data.

Before showing the results of regression analysis, original data is displayed regarding traffic and VKT. Figure 2 shows a boxplot that represents traffic volume trends of mini-cars and normal cars on Tomei Expressway. While a growing number of mini-cars are observed, the number of normal cars is not growing. Though figures are omitted due to page limitation, similar trends were observed on other expressways. However, it is difficult to understand the decrease in traffic volume under income (GRP) growth. I believe that modal shift from normal cars to mini-cars affects this phenomenon, but the aim of this paper is not the analysis of this modal shift. Therefore, in this paper, mini-cars and normal cars are aggregated as passenger cars.

Figure 3 shows a scatter plot between IIP and traffic volume (left) and VKT (right) of large cargo trucks on Tomei Expressway. We can confirm a positive correlation in both figures. Similar results were obtained on other expressways. It is not clear to confirm the effects of the toll price discount.

Table 2 – Eight expressways

Route (Origin–Destination, length)	Route (Origin–Destination, length)
Tomei (Tokyo–Aichi, 346.8km)	Kan-etsu (Tokyo–Niigata, 246.3km)
Tohoku (Saitama–Aomori, 679.5km)	Joban (Tokyo–Miyagi, 230.0km)
Chuo (Tokyo–Aichi, 366.8km)	Miyazaki (in Miyazaki Pref., 80.7km)
Higashi-Kanto (Tokyo–Ibaraki, 74.5km)	Okinawa (in Okinawa Pref., 57.3km)

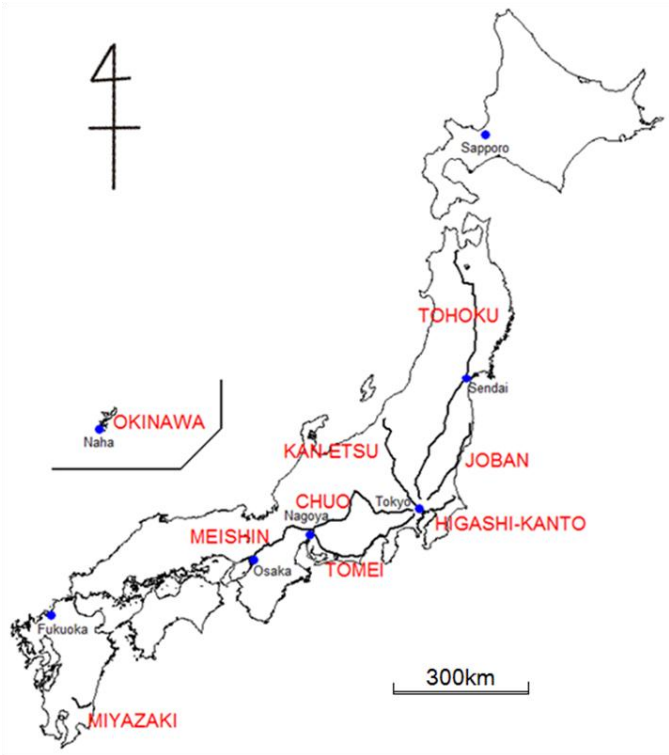
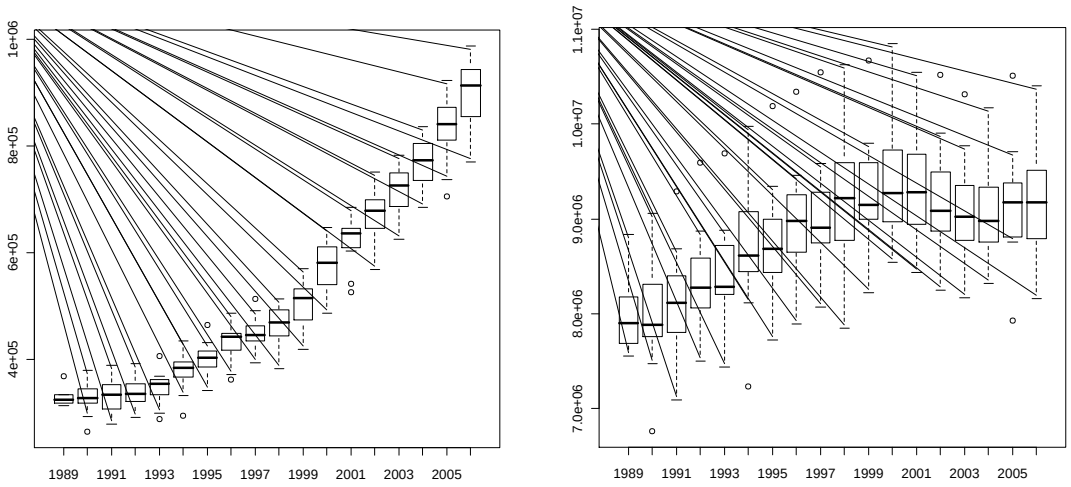


Figure 1 – Locations of eight expressways

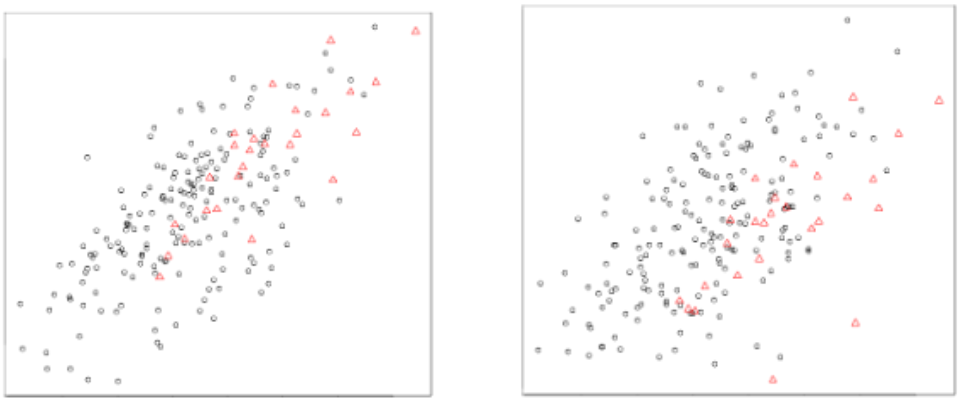
Table 3 – Data

Data (unit)	Source/Organization
Traffic volume	Automobile and Highway (Express Highway Research Foundation Japan)
Vehicle kilometers traveled (vehicle-km)	Automobile and Highway (Express Highway Research Foundation Japan)
Gross Regional Product (million yen)	Annual Report on Prefectural Accounts (Cabinet Office)
Toll Price (yen/km)	Annual Report of the Japan Highway Public Corporation
Fuel price (yen/liter)	Oil Information Center (Japan Institute of Energy Economics)
Index of Industrial Production	Ministry of Economy, Trade and Industries
Number of tourists to enter the area of Okinawa	Bureau Tourism Resort Okinawa



Mini-cars Normal Cars

Figure 2 - Boxplot of traffic volume trends for mini-cars and normal cars on Tomei Expressway

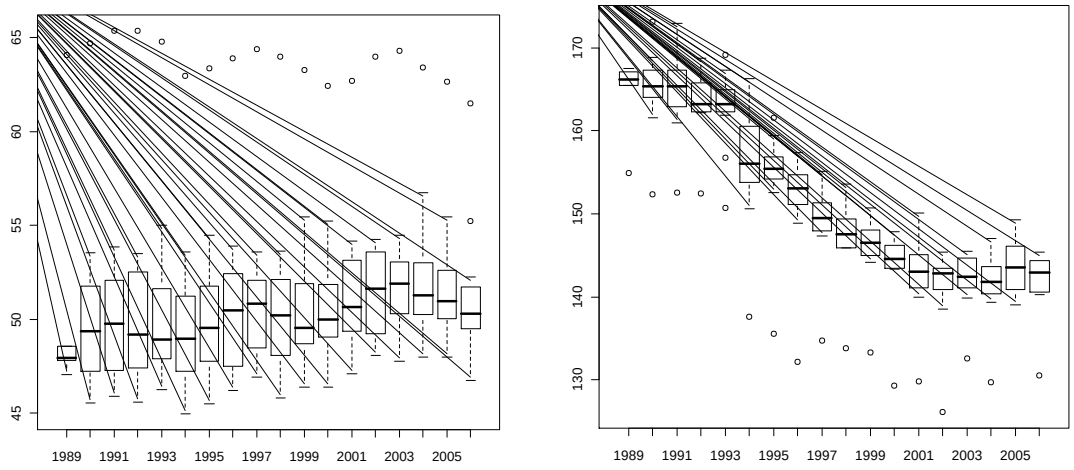


Traffic volume VKT

Figure 3 - Scatter plot of index of industrial production (horizontal axis) and traffic volume and VKT of large cargo trucks on Tomei Expressway

Note: ○ represents months before the introduction of toll discount; △ represents months after toll discount introduced.

Finally, trends of average mileage of passenger cars and large trucks are shown for Tomei Expressway (Figure 4). Points on the upper outskirts of passenger cars represent data for August. The lower outskirts represent data for February. Especially for large trucks, average driving distance has been decreasing. Yamagami (1991) expressed that average drive distance was stable, but this assumption does not hold true in recent years. Therefore, not only traffic volume but also VKT is analyzed in this paper.



Passenger Cars Large Cargo Trucks

Figure 4 - Boxplot of average driving distance trends (Tomei Expressway)

4. RESULTS

Table 4 shows the estimated results[3]. Findings are shown in the following.

1) Traffic Volume

a) Passenger cars

In OLS estimates, residual autocorrelations were observed in all cases except for Joban Expressway, and non-stationarity of residuals was shown for Miyazaki and Okinawa Expressways.

- Structural changes were observed only for Tomei Expressway. I re-estimated the model, including the breaking date[4]. As a result, toll price was not a significant variable. In addition, a change in gasoline price elasticity was observed. After around Oct. 1999, gasoline price did not affect traffic volume either. As shown in Figure 2, the traffic volume of normal cars was not growing. One possible reason is that the income of car users on Tomei Expressway is high, so they are not particular about their expenditure (toll and fuel cost). Another possible explanation is that since Tomei Expressway has the heaviest traffic, traffic volume is restricted and not affected by toll and gasoline price. This is yet to be confirmed.
- Toll price elasticity was estimated at 0 to –0.69 in the short term and 0 to –1.20 in the long term. Significant differences were observed among expressways. The weighted average of long-run toll price elasticity was –0.46.

Table 4 - Parameter estimation results

□Traffic Volume

Dependant variable: log(Traffic Volume)			Tomei		Chuo		Tohoku		Kan-etsu		Joban		Higashikanto		Miyazaki		Okinawa	
			Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value
Cars		GRP	0.23	2.75	0.74	4.18	0.89	6.16	0.57	6.76	0.81	8.35	0.71	7.92				
		Toll			-0.69	-4.29	-0.35	-2.05	-0.44	-3.55	-0.54	-5.14						
		Gas Price	-0.27/0	-9.70	-0.21	-5.96	-0.17	-4.60			-0.25	-4.56	-0.19	-6.45				
		Discount dummy					0.04	3.36			0.05	3.32	0.03	2.59				
		Long Term	0.30		0.43		0.28		0.38				0.53					
		GRP	0.33		1.28		1.23		0.92				1.51		0.66	2.46		
		Toll			-1.20		-0.48		-0.71						-0.73	-1.72	-0.47	-10.68
		Gas Price	-0.39/0		-0.37		-0.23						-0.41		*-0.06*	*-0.42*	*-0.05*	*-0.67*
		Tourists											0.06				0.06	2.03
		Rediduals standard error	0.019		0.031		0.026		0.033		0.026		0.022		0.053		0.034	
Trucks (Long Term)	Medium	IIP	0.79	13.37	0.97	10.44	0.76	14.69	0.82	14.62	1.36	4.10	0.79	13.89	0.71	8.09	0.55	4.41
		Toll	-0.41	-2.85	*-0.28*	*-1.19*	-0.49	-3.67	-0.34	-2.33	-0.65	-11.37	-0.53	-3.70	-0.85	-3.24	-0.29	-4.82
		Diesel Oil Price	*-0.02*	*-0.24*	*-0.05*	*-0.42*	*-0.02*	*-0.31*			-0.08	-1.83	*-0.02*	*-0.40*				
		Rediduals standard error	0.019		0.029		0.017		0.018		0.018		0.018		0.029		0.040	
	Large	IIP	0.91	12.72	1.15	7.58	0.88	12.55	0.94	11.89	0.35	2.60	1.02	12.43	0.58	6.14	0.51	2.69
		Toll	-0.46	-1.84	*-0.13*	*-0.31*	-0.72	-3.37	*-0.43*	*-1.61*	-1.17	-7.84	-0.62	-2.20	-1.14	-3.00	-0.21	-2.10
		Diesel Oil Price	*-0.10*	*-1.09*	-0.33	-2.48	-0.11	-1.75	*-0.005*	*-0.06*	*-0.05*	*-0.75*					*-0.08*	*-0.49*
		Rediduals standard error	0.020		0.050		0.022		0.026		0.022		0.025		0.031		0.062	
	Extra Large	IIP	0.43	3.08	0.34	1.95			0.32	2.53	*0.75*	*1.33*	0.79	13.94				
		GRP					0.72	2.15							1.04	1.88	*0.44*	*0.97*
		Toll	*-0.48*	*-1.05*	*-0.17*	*-0.33*	*-0.51*	*-1.26*	*-0.40*	*-0.72*	-0.81	-8.29	-0.54	-3.79	-3.25	-3.92		
		Diesel Oil Price			-0.42	-2.72					*-0.10*	*-1.41*	*-0.02*	*-0.47*	*-0.30*	*-1.00*	*-0.32*	*-1.63*
		Rediduals standard error	0.045		0.059		0.042		0.051		0.028		0.018		0.095		0.080	

Monthly dummy is omitted. Values at Long term shows sum of autoregressive parameters. Italic shows statistically insignificant at 5%.

IIP: Index of Industrial Production Tomei: Structural change is observed at Oct. 1999.

□Vehicle Kilometers Traveled

Dependant variable: log(VKT)			Tomei		Chuo		Tohoku		Kan-etsu		Joban		Higashikanto		Miyazaki		Okinawa	
			Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value	Parameter	t-value
Cars		GRP	0.83/0.23	3.31	0.93	3.87	0.87	6.04	0.75	6.45	0.84	9.66	0.71	6.61				
		Toll			-0.81	-3.77	-0.36	-2.15	-0.61	-3.75	-0.60	-6.30						
		Gas Price	-0.3/-0.0	-10.50	-0.27	-5.70	-0.17	-4.99	*-0.07*	*-1.86*	-0.16	-3.09	-0.18	-5.54				
		Discount dummy									0.05	3.53	0.03	2.37				
		Long term			0.33		0.45		0.26		0.27		0.51					
		GRP			1.39		1.60		1.01		1.14		1.46		0.58	2.62	0.27	1.78
		Toll			-1.20		-0.66		-0.82		-0.82				*-0.53*	*-1.41*	-0.46	-11.28
		Gas Price			-0.40		-0.32		-0.09		-0.22		-0.37		*-0.15*	*-1.41*	*-0.10*	*-1.51*
		Discount dummy									0.06		0.06					
		Rediduals standard error	0.028		0.033		0.036		0.042		0.027		0.024		0.053		0.042	
Trucks (Long Term)	Medium	IIP	0.63	7.29	1.07	8.72	0.67	12.78	0.67	12.52	1.20	3.72	0.74	13.60	0.59	6.57	0.52	3.94
		Toll	-0.52	-2.51	*-0.13*	*-0.42*	-0.50	-3.88	-0.42	-3.07	-0.64	-11.45	-0.52	-3.91	-0.46	-2.05	-0.25	-3.94
		Diesel oil price	*-0.01*	*-0.06*	*-0.07*	*-0.55*	*-0.02*	*-0.48*			*-0.06*	*-1.35*	*-0.02*	*-0.47*			*-0.03*	*-0.24*
		Rediduals standard error	0.030		0.040		0.017		0.017		0.017		0.018		0.028		0.042	
	Large	IIP	0.65	5.34	1.09	7.32	0.75	11.45	0.83	11.01	0.46	3.24	0.93	12.56	0.48	5.64	0.40	2.25
		Toll	-0.75	-1.79	*-0.51*	*-1.51*	-0.54	-3.70	-0.54	-2.23	-1.14	-7.24	-0.53	-2.68	-0.76	-2.83	-0.39	-4.43
		Diesel oil price	*-0.07*	*-0.43*	*-0.12*	*-1.00*	-0.13	-2.42	*-0.02*	*-0.26*	*-0.07*	*-1.04*			*-0.03*	*-0.35*	*-0.05*	*-0.36*
		Rediduals standard error	0.040		0.072		0.022		0.023		0.027		0.023		0.026		0.066	
	Extra Large	IIP	0.45	3.87	0.56	3.98			*0.01*	*0.07*	0.25	0.37	0.80	7.85				
		GRP					1.17	4.03							1.30	2.49	*0.46*	*0.96*
		Toll	*-0.52*	*-1.37*	*-0.24*	*-0.66*	*-0.31*	*-0.77*	*-0.62*	*-1.17*	-0.70	-5.82	-0.76	-2.25	-1.41	-1.92		
		Diesel oil price	*-0.09*	*-0.55*							*-0.08*	*-0.86*	*-0.02*	*-0.23*	-0.50	-1.85	-0.46	-2.35
		Rediduals standard error	0.038		0.079		0.055		0.091		0.034		0.039		0.102		0.082	

Monthly dummy is omitted. Values at Long term shows sum of autoregressive parameters. Italic shows statistically insignificant at 5%.

IIP: Index of Industrial Production Tomei: GRP paramter change is observed at JAN1993 and Gas price parameter change is observed at OCT1999.

- Gasoline price affects many expressways, but the elasticity is modest. The maximum value is estimated at –0.39 in the long term. The weighted average of long-run toll price elasticity was –0.18 (when insignificant parameters set as zero) to –0.19 (no adjustment).
- In Okinawa, the number of tourists is a more effective variable than GRP.
- Toll discount was not observed to have an impact.

b) Trucks

- In OLS estimates, all expressways showed non-stationarity of residuals. Therefore, making use of the difference operators, the regression model was re-estimated. Except for Chuo Expressway, diesel price is not a significant variable. The toll discount dummy is not statistically significant. As the toll discount is applied within a day, we cannot capture the impacts when using monthly data.
- For medium and large trucks, toll price and industrial production are major factors.
- On IIP elasticity, medium trucks varies from 0.55 to 1.36 (weighted average by traffic volume: 0.88) and large trucks varies from 0.35 to 1.15 (weighed average: 0.89).
- Toll price elasticity is –0.28 to –0.85 for medium trucks (weighted average: –0.41 (when insignificant parameters set as zero) to –0.44 (no adjustment), and –0.13 to –1.17 for large trucks (weighted average: –0.45 to –0.51).
- Extra large vehicles could not obtain a good result. In this category, tour buses and container trailers are included. I can not find good variables to explain.

2) VKT

a) Passenger cars

- As with traffic volume, structural changes were observed in the OLS estimates for Tomei Expressway. Introducing the structural change dummy, toll price was not a significant variable. As a result, income elasticity dropped sharply in Oct. 1993, and from July 1999, almost zero gasoline price elasticity was estimated. Miyazaki and Okinawa Expressways, as well as for traffic volume, was estimated by taking the differences.
- Gasoline price elasticity tends to be greater than traffic volume. This implies that not only traffic volume, but also travel distance were affected by gasoline price. The weighted average of long-run gasoline price elasticity was –0.19 (when insignificant parameters set as zero) to –0.21(no adjustment).
- On toll price, four of eight expressways were not statistically significant. Values of the elasticity tended to be slightly larger than those of traffic volume. The weighted average of long-term elasticity was –0.54 to –0.55.

b) Trucks

- In OLS estimates, all expressways showed non-stationarity of residuals, the same as traffic volume.
- Compared with traffic volume, the IIP elasticities of large and medium trucks are small (weighted average: 0.75). Toll price elasticities were –0.13 to –0.64 for medium trucks

(weighted average: –0.44 to –0.46) and –0.39 to –1.14 for large trucks (weighted average: –0.58 to –0.66).

For extra-large vehicles, as well as for traffic volume, estimates were not good.

3) Characteristics of elasticity

In this section, estimated long-term elasticities of passenger cars and large trucks are examined in the context of the relationship between traffic volume, VKT, average mileage, expressway length, and GRP. Although only eight expressways were studied, the following relationships were observed (Figures 5–8).

a) Passenger cars

○ *Gasoline price elasticity*

Expressways that are not directly linked with Tokyo show zero elasticity (Figure 5, left). Meanwhile, on VKT, the Tomei Expressway, Higashi Kanto, showed a tendency to increase the longer the average distance, except on the central road. The longer the distance, the more the impact of fuel prices can be interpreted as a fair result from a potentially large sample (Figure 5, right).

○ *Toll price elasticity*

In terms of traffic volume, the more traffic per route length, the smaller the elasticity values tend to be (Figure 6, left). Meanwhile, for VKT, the longer the route length, the larger the increase the elasticity (Figure 6, right).

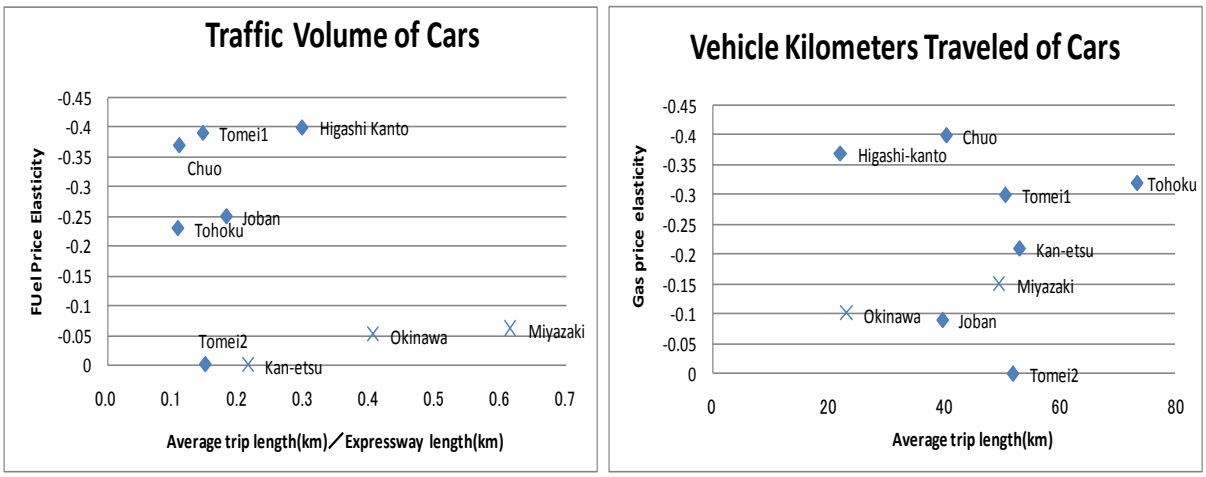
b) Large trucks

○ *IIP elasticity*

Both traffic volume and VKT show positive correlations with average trip distance per expressway length, and the values are high.

○ *Toll price elasticity*

I could not find a clear relationship between toll price elasticity and other variables (Figure 8). We can say that the elasticity lies around –0.4 to –0.8.



Tomei 1: July 1989–September 1999, Nagoya 2: October 1999–December 2006

×represents the hypothesis that elasticity is zero is not rejected at the 10% level of significance.

Figure 5 - Long-term gasoline price elasticity for passenger cars

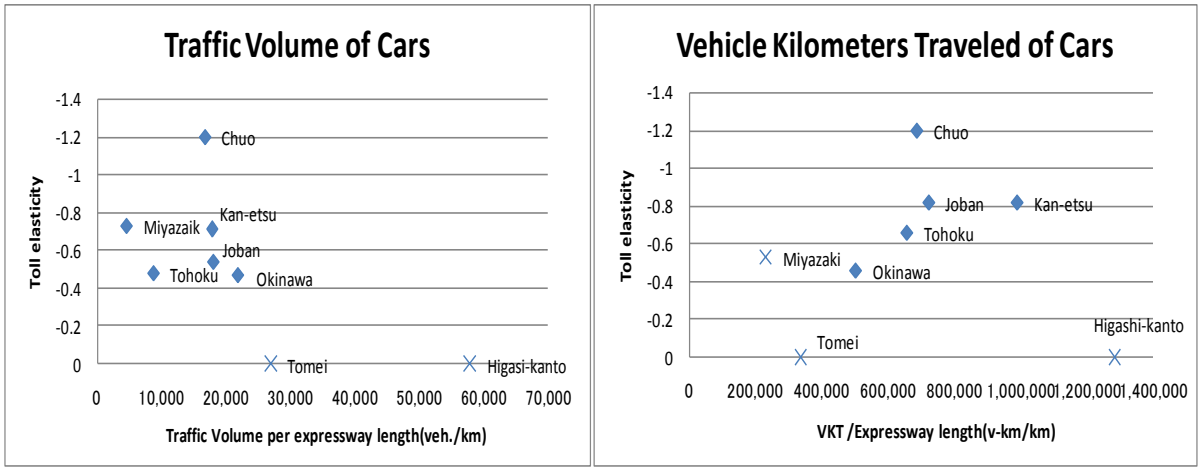


Figure 6 - Long-term toll elasticity for passenger cars

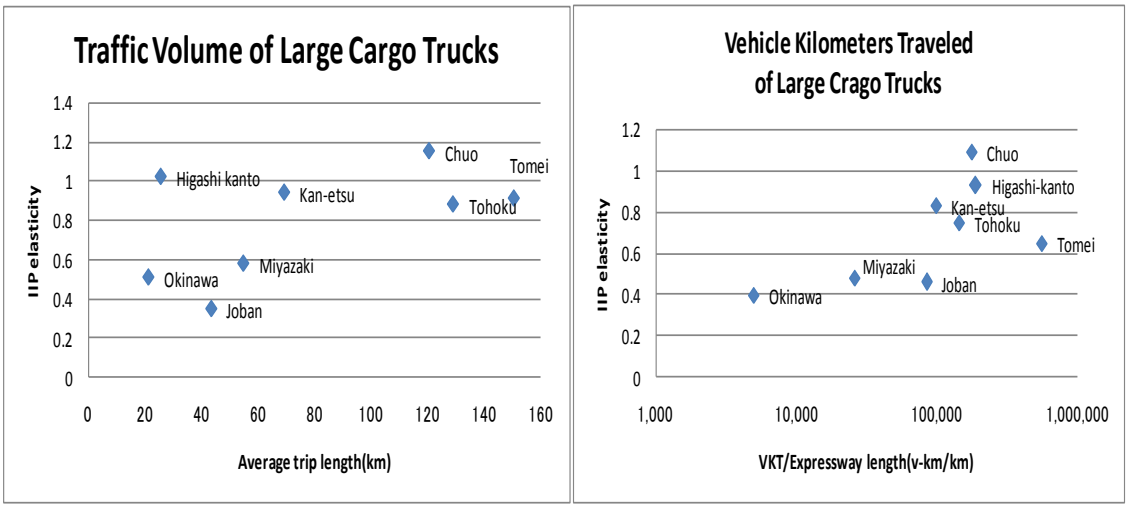


Figure 7 - IIP Elasticity of large cargo trucks

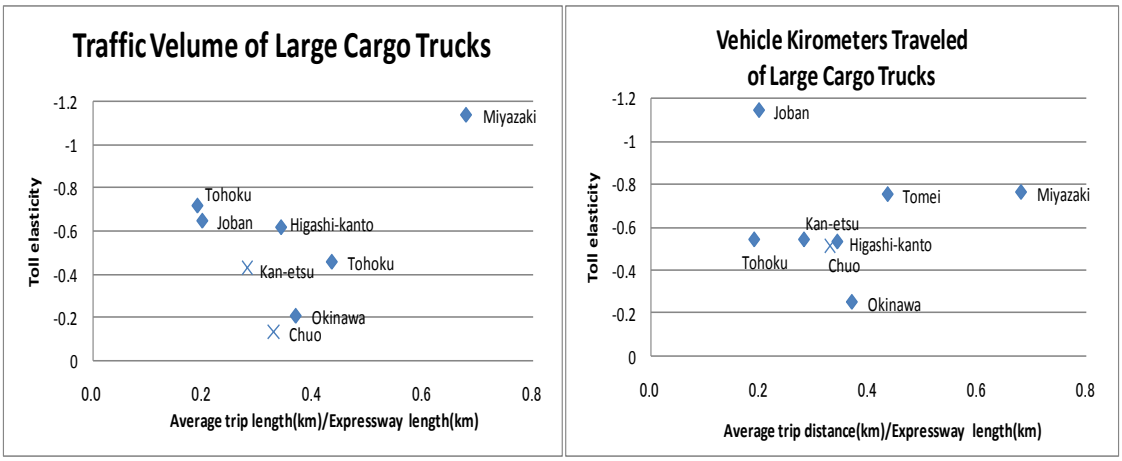


Figure 8 - Price elasticity of large cargo trucks

5. CONCLUSION

This paper analyzes the factors associated with traffic volume and VKT by vehicle type on distance-based tolled intercity expressways. Toll price and other elasticities were estimated via a monthly time series regression model considering error autocorrelations, non-stationarity, and structural change.

Almost all time series data for the eight expressways studied showed residual autocorrelations of OLS estimation with monthly dummies. In addition, traffic volume and VKT for trucks showed residual unit roots. As the stationarity assumption was not satisfied, assuming the long-run equilibrium, regression analysis was conducted by considering the difference. Structural changes were seen only for Tomei Expressway. As a result, toll price was not an associated factor, and the impact of gasoline prices was estimated at almost zero

after Oct. 1999. One possible reason is that income of car users on Tomei Expressway is high, they do not care about money (toll and fuel cost). Another possible explanation is that as Tomei Expressway has the heaviest traffic, traffic volume is restricted and not affected by toll and gasoline price.

Though estimated elasticities vary among expressways, the weighted averages of long-term elasticity by traffic volume are shown in Table 5.

Table 5 - Weighted averages of long-term elasticity

	Toll price		Gasoline price		IIP	
	Traffic volume	VKT	Traffic volume	VKT	Traffic volume	VKT
Passenger cars	–0.46	–0. 54 to –0.55	–0.18 to –0.19	–0.19 to –0.21		
Medium trucks	–0.41 to –0.44	–0.44 to –0.46			0.88	0.76
Large trucks	–0.45 to –0.51	–0.58 to –0.66			0.89	0.75

Note: The range shows the value (a) when insignificant parameters set as zero, and (b) no adjustment.

On toll price elasticity of passenger cars, results of –0.3 to –0.5 were obtained in a previous study [Takagi and Aizu (1991)]. Therefore, this weighted value was within the range. However, the elasticity was around zero on heavy traffic expressways, such as the Higashi Kanto Expressway and the Tomei Expressway, and expressways without direct links to Tokyo. The long-term gasoline price elasticity of passenger cars was estimated at 0 to –0.4. Average distance may affect the elasticity.

Meanwhile, for trucks, fuel price is not a significant variable, and IIP turned out to be strong factor. IIP elasticity tends to be large, together with average distance. In addition, elasticities of large trucks tend to be higher than those of medium trucks.

For both passenger cars and trucks, the elasticity of traffic volume and VKT are different. In the case of prices, the elasticities of VKT are higher than those of traffic volume. This implies that not only the amount of traffic but also the average travel distance is affected by prices.
Finally, the toll price discount dummy is not statistically significant for most expressways. Monthly data analysis could not capture the impacts.

Many issues remain for further research. Extension of the analysis period should be strongly required, including at least a few incidences of toll price raising. Otherwise, we cannot judge the true impact of toll price. However, extension of the research period may cause structural change problems. We should build the model carefully. In this analysis, only Tomei Expressway showed structural change, but the change may be seen in other expressways when including recent data from 2007–2009.

As an emergency economic countermeasure, after March 2009, flat-rate toll system intended for passenger cars equipped with the Electronic Toll Collection System started excluding

expressways in the Tokyo and Osaka metropolitan areas, the Honshu-Shikoku Bridge Expressway and the Tokyo Bay tunnel. On weekdays, a special 30% discount will be applied to expressways, except those in the two metropolitan areas, the bridge expressway and the Tokyo Bay tunnel. These discounts will continue for two years, and the budget is ¥500 billion. In order to verify the impact of this discount, not monthly, but day- and/or hour-based analysis could be required. Finally, not money but time may be a key factor that defines travel demand. Leading U.K. transport economists concluded the elasticity of travel volume with respect to travel time is –0.5 in the short term and –1.0 over the long term (SACTRA, 1994). It is also important to analyze the relationship between activity and travel time.

Acknowledgments: I would like to thank Mr. Yasunari Ukai (Highway Commission) and Ms. Shoko Sakai (Kawasaki City) for their assistance in data collection and Prof. Akifusa Fujioka and the committee members for their useful comments on the relationship between highway traffic and economic indicators.

Notes:

1. In Japan, we also have approximately 700km of fixed-rate toll urban (intra-city) expressways.

2. These eight expressways were selected because there was no extension during the research period.

3. In this paper, fuel price and toll price are regarded as different factors. Motorists pay tolls only when using expressways. On the other hand, motorists have to pay fuel costs regardless of their usage of expressways. This assumption should be examined in future analysis.

4. Even if structural change is considered, parameters are assumed as a constant during the period before and after structural change. An estimation technique that permits varying parameters may be useful for further analysis (e.g., Kalman filter).

References

Brons, M., P. Nijkamp, E. Pels, and P. Rietveld (2007): A meta-analysis of the price elasticity of gasoline demand: A SUR approach, *Energy Economics,* 30 (5), pp. 2105-2122.

Burris, M.W., A. Cain, and R.M. Pendyla (2001): Impact of variable pricing on temporal distribution of travel demand*, Transportation Research Record,* 1747**,** pp. 36-43.

Congressional Budget Office (2008): *Effects of Gasoline Prices on Driving Behaviour and Vehicle Markets*, www.cbo.gov/ftpdocs/88xx/doc8893/01-14- GasolinePrices.pdf (Access: MAY 01, 2009).

Gifford, J.L. and S.W. Talkington (1996): Demand elasticity under time-varying prices: Case study of day-of-week varying tolls on Golden Gate Bridge*, Transportation Research Record,* 1558, pp. 55-59.

Goodwin, P.B. (1989): *Evidence on car and public transport demand elasticities, 1980-1988.* Second Draft, TSU Ref.: 427, Oxford Transport Studies Unit, Oxford.

Goodwin P.B. (1992): A review of new demand elasticities with special references to short *and* long run effects *of* price change*, Journal* of *Transport Economics* and *Policy,* 26 (2), pp. 155-170.

Goodwin, P. B., J. Dargay, and M. Hanly (2004): Elasticities of road traffic and fuel consumption with respect to price and income: a review, *Transport Reviews,* 24 (3), pp. 275-292.

Graham, D.J. and S. Glaister (2004): Road traffic demand elasticity estimates: a review, *Transport Reviews,* 24 (3), pp. 261-274.

Harvey, G. (1994): Transportation pricing behaviour, *Special Report 242 – Curbing Gridlock: Peak Period Fees to Relieve Traffic Congestion* vol. 2, Transportation Research Board, National Academy Press, pp. 89-119.

Hirschman, C., I. McNight, J. Pucher, R.E. Paaswell, and J. Berechman (1995): Bridge and tunnel toll elasticities in New York: some recent evidence, *Transportation,* 22, pp. 97-113.

Holguín-Vera J., M. Cetin, and S. Xia (2006): A comparative analysis of US toll policy, *Transportation Research Part A*, 40, pp. 852-871.

INRIX (2008): *The Impact of Fuel Prices on Consumer Behavior and Traffic Congestion*, INRIX, http://scorecard.inrix.com/scorecard (Access: 01MAY2009).

Jones, P. and A. Hervik (1992): Restraining car traffic in European cities: an emerging role for road pricing, *Transportation Research A,* 26, pp. 133-145.

Jørgensen, F. and J. Dargay (2007): Inferring price elasticities of car use and moral costs of driving without a license, *Transportation Research Part A,* 41, pp. 49-55.

Kawano,Tadahiro: Yoshida Masatoshi, and Matsumura Yuji (1981): Measurement of the elasticity of the capital rate of freeway traffic, *Transportation Studies*, 25, pp.89-108 (in Japanese).

Mauchan, A. and P. Bonsall (1995): Model predictions of the effects of motorway charging in West Yorkshire, *Traffic Engineering* and *Control,* 36, pp. 206-212.

May, A.D.: Road pricing: an international perspective, *Transportation,* 19, pp. 313-333, 1992.

Odeck, James and Svein Bråthen (2008): Travel demand elasticities and users attitudes: A case study of Norwegian toll projects, *Transportation Research Part* A: *Policy* and *Practice,* 42 (1), pp. 77-94.

Oum, T.H., W.G. Waters and J.S. Yong (1992): Concepts of price elasticities of transport demand and recent empirical estimates, *Journal of Transport Economics and Policy,* 26 (2), pp. 139-154.

SACTRA: *Trunk Roads and the Generation of Traffic*, UKDoT, HMSO (London), 1994.

Takagi, Kazutoshi and Yoshikazu Aizu (2005): Revised toll usage after the first year of Heisei, *Expressways and Automobiles*, 34 (1), pp.40-45, 1991 (in Japanese).

Tanishita, Masayoshi: Price elasticity of inter-city motorway traffic, *Expressways and Automobiles*, 48 (11), pp. 38-45 (in Japanese).

UTM (2000): Traffic responses to toll increases remains inelastic, *The Urban Transport Monitor*, 14 (10), Lawley Publications.

Weustefield, N.H. and E.J. Regan: Impact of rate of increase on toll facilities, *Traffic Quarterly,* 34, pp. 639-655, 1981.

Yamagami, Toshihiko: Economic trends and highway traffic, *Expressways and Automobiles*, 34 (11), pp.32-38, 1991 (in Japanese).

Yamamoto, Motoe: Price elasticity of demand in urban expressways*, Journal of Politics and Economics*, 63 (1), pp.471-502, 1995 (in Japanese).

Yamauchi, Hirotaka: Different costs for road vehicles, *Expressways and Automobiles*, 30 (9), pp.24-32, 1987 (in Japanese).