University Transportation Research Center - Region 2

Final Report

ASSESSING BEHAVIOR CHANGES UNDER THE INFLUENCE OF TRAVEL DEMAND MANAGEMENT STRATEGIES – FREIGHT CARRIERS' BEHAVIOR CHANGES IN RESPONSE TO TOLL INCREASES

Performing Organization: Rensselaer Polytechnic Institute

November 2014

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The Region 2 University Transportation Research Center (UTRC) is one of ten original University Transportation Centers established in 1987 by the U.S. Congress. These Centers were established with the recognition that transportation plays a key role in the nation's economy and the quality of life of its citizens. University faculty members provide a critical link in resolving our national and regional transportation problems while training the professionals who address our transportation systems and their customers on a daily basis.

The UTRC was established in order to support research, education and the transfer of technology in the field of transportation. The theme of the Center is "Planning and Managing Regional Transportation Systems in a Changing World." Presently, under the direction of Dr. Camille Kamga, the UTRC represents USDOT Region II, including New York, New Jersey, Puerto Rico and the U.S. Virgin Islands. Functioning as a consortium of twelve major Universities throughout the region, UTRC is located at the CUNY Institute for Transportation Systems at The City College of New York, the lead institution of the consortium. The Center, through its consortium, an Agency-Industry Council and its Director and Staff, supports research, education, and technology transfer under its theme. UTRC's three main goals are:

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16. Abstract

In order to achieve an efficient transportation system, proper demand management strategies are more critical than increasing facility capacity. Previous studies suggest that most of the strategies have substantial impacts on traffic pattern and travel behaviors, but the effects may not be exactly the same as they were initially expected to be. This project focuses on assessing travel demand management strategies to enhance such understanding. Among the existing research, users' behavior in freight transportation is relatively under-investigated, because the empirical data collection is difficult. Therefore, this project fills the void by analyzing exclusively on freight carriers' behavior changes in response to freight travel demand management strategies. A survey was conducted and a regression model was established to provide important insights into the behavior problem.

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1. INTRODUCTION

Over the last several decades, more and more researchers and practitioners have gradually become aware of one fact: in order to achieve an efficient transportation system, proper demand management strategies can be more critical than increasing facility capacity (i.e. providing more supply). Especially with the financial constraints in recent years, adding new infrastructure becomes even more difficult and sometimes infeasible at all.

Over years, various travel demand management strategies have been developed and implemented across the world. Some strategies focus on the optimizing of transportation modes, such as the promotion of bike and bus usage. Others focus on the modifying of travel demand distribution in space and time, such as mixed land use development and flexible working hours. Previous studies suggest that most of the strategies have substantial impacts on traffic pattern and travel behaviors. However, the effects may not be exactly the same as they were initially expected to be. In order to efficiently manage transportation demand, it is critical to thoroughly understand the influence of travel demand management strategies on the involved users. This project focuses on the data collection and analysis that enables such understanding.

Among the research fields of the travel demand management, users' behavior in freight transportation is relatively under investigated. The reason may be that the empirical freight data collection is difficult. Therefore, this project fills this void by focusing exclusively on the behavioral changes in response to freight travel demand management strategies. In particular, a survey is conducted to collect freight carriers' behavioral change given certain hypothetical toll increases on the roads they regularly use.

This final report has four main focus areas. The first one, *Survey Description*, introduces the definition and design of the questionnaire that was sent to the freight carriers. The second one, *Data Description*, focuses on the analyses of the aggregate changes taking place as a consequence of the demand management strategy (e.g., changes in travel frequencies, changes in time of day). The third focus area, *Behavioral Analyses of Toll Passage*, is developed to structure an analytical framework to monitor long-term behavioral changes of the users resulting from the implementation of the strategy. The last focus are, *Behavioral Analyses of Load Factor*, aims to analyze carriers' capacity utilization of their deliveries. The output of this project will provide an objective assessment of the experience that will benefit future implementations.

2. Focus Area I: Survey Description

To investigate the freight carriers' behavioral changes, the first step is to define the research population. The New York State's freight carriers are selected as the survey population and their socio-economic information was obtained from Federal Motor Carrier Safety Administration (FMCSA). This agency runs a Motor Carrier Management Information System (MCMIS) that contains census information of a number of freight entities. The census file includes a number of elements such as the entity's location, cargo classification, and annual mileage, among others.

The survey is designed to collect behavioral change information in response to hypothetical toll increases. Thus, the potentially influenced users need to be defined. Based on the carriers' location, the ones that locate along the toll roads are selected as the final sample in the survey. Finally, about 9,000 entities are found valid as the survey sample. After some cleating and testing of the census data, a Computer Aided Telephone Interviews (CATI) was undertaken of a random sample of the carriers. Finally, 370 carriers' information is successfully collected for the behavioral change project.

The questionnaire contains two major parts, socio-economic and behavioral change. The socio-economic question aims to provide additional carriers' information that is not available in the MCMIS. The behavioral change information is investigated in a before and after framework. Essentially, carriers' behavior is firstly asked under the current travel demand management strategies. Then, carriers are given certain strategy changes and their behaviors are asked again. The potential behavior changes include route choices, time choices, and trip frequencies, etc. The overall process of conducting the survey is outlined as:

- Gather available datasets (MCMIS)
- Identify the main characteristics of the available data sets
- Design the study's socio-economic data collection plan defining the variables to be included, the level of detail, and the corresponding sampling rates
- Design survey instruments
- Define statistical universe and select samples
- Pilot test and revise survey instrument
- Draw sample and conduct CATI

The final questionnaire is given in appendix 1.

3. Focus Area II: Data Description

The impacts of the travel demand management strategy on carriers can be assessed based on the data collected from the survey. Note that each surveyed carrier is asked to answer questions for three different levels of toll increases. The levels of toll increases are picked from 10%, 20%, 40%, 60%, 80%, 100%, 120%, 160%, and 200%. The real toll amount is not considered in the survey. Each respondent repeated to answer the same behavioral change questions three times. The first question of behavioral changes is whether the carriers would like to pass any of the cost to customers. The answers are summarized as shown in Figure 1.

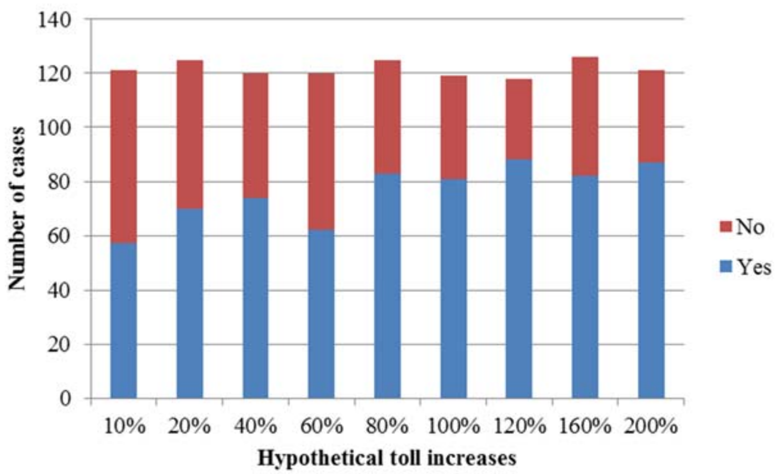

Figure 1 Data description of question B.1

Figure 1 shows a trend that the proportion of carriers that are willing to pass cost increases along with the amount of toll increases. The trend is more obvious at the extreme cases where the lowest proportion of cost passage is at 10% toll increase scenario and the 200% is also associated with a large proportion.

If the carriers are willing to pass cost, they are followed by question B.1.1, about what percentage is the carrier likely to pass to customers. Figure 2 show the average percentage of the cost passage that the carriers are willing to do. The average percent also exhibits an upward trend, but a formal statistical test may be needed to formally infer the trend.

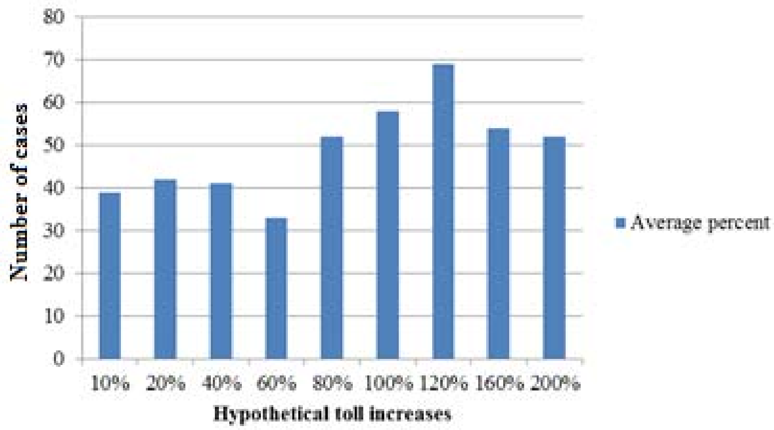

Figure 2 Data description of question B.1.1

Question B.2 asks about the carriers' behavioral change in terms of service frequency. Figure 3 shows a summary of whether the carriers would like to reduce their frequency. Figure 4 shows how much their frequency is going to be reduced if they would like to reduce the frequency.

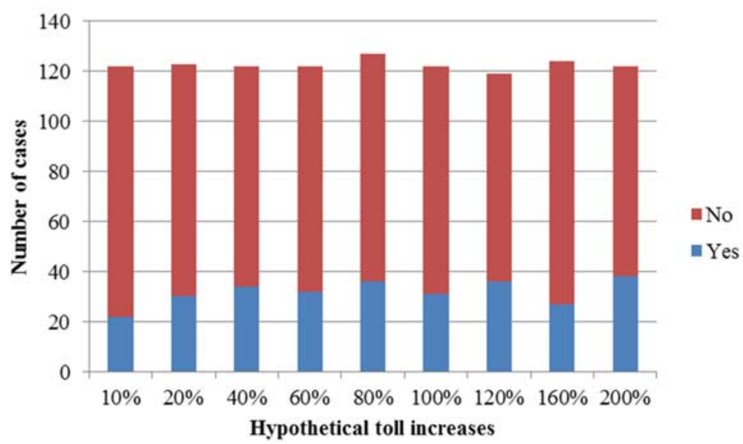

Figure 3 Data description of question B.2

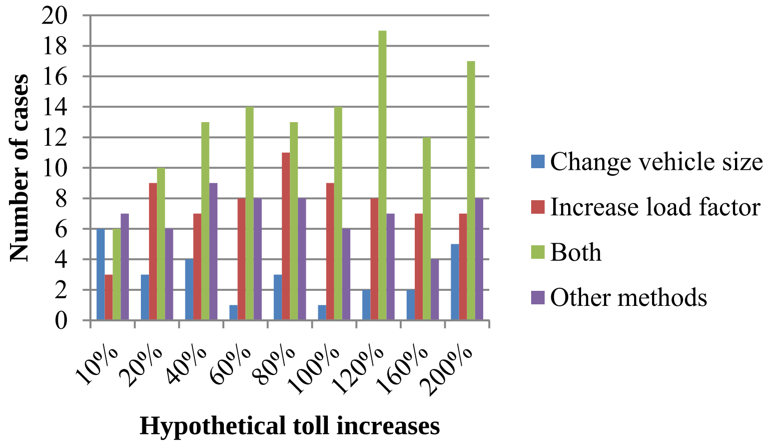

Figure 4 Data description of question B.2.1

Question B.3 asks the carriers about whether and how much they will reduce the miles travelled on the toll road. Figure 5 and 6 summarize the responses in terms of whether to reduce and how much to reduce.

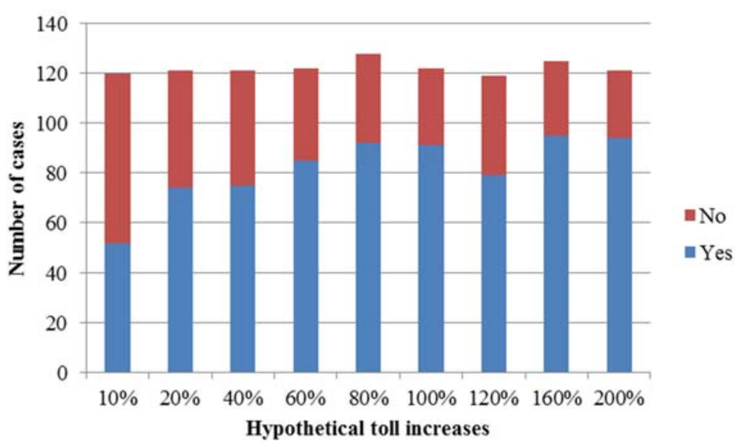

Figure 5 Data description of question B.3

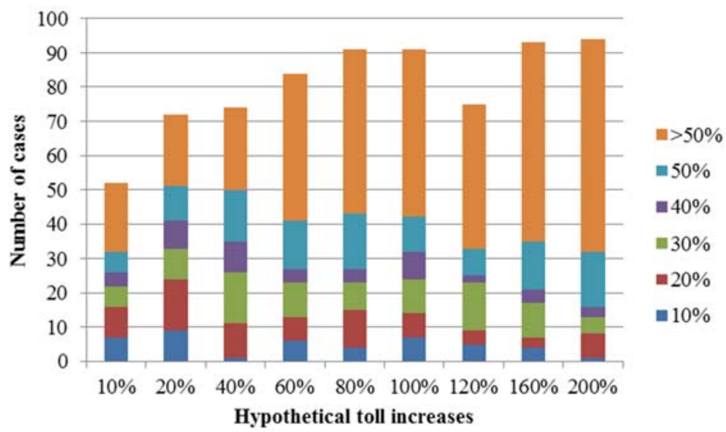

Figure 6 Data description of question B.3.1

Question B.4 asks about the behavioral changes in terms of time of day. Figure 7 provides a summary of whether to change carriers' time of day on the toll road. As most of the responses are "No" (do not change time of day), the data description of how they will change time of day is not presented due to the limited number of samples.

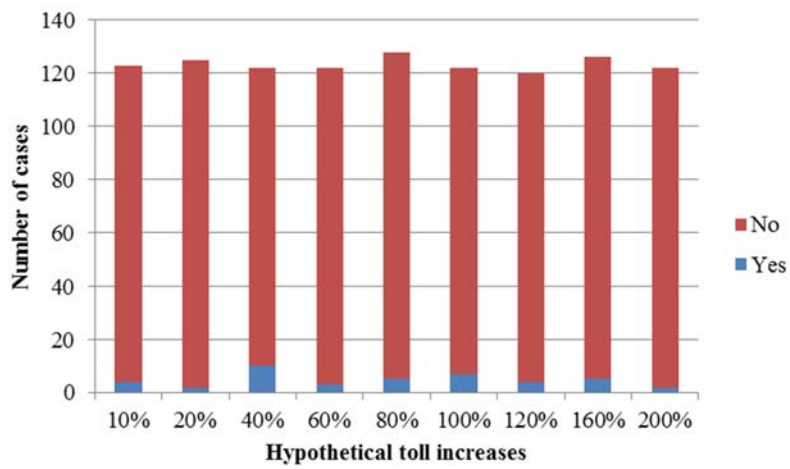

Figure 7 Data description of question B.4

Based on the descriptive statistics, the behavioral change in response to toll increases is mostly seen in terms of toll increase costs passage, delivery frequency, and miles travelled. The time of day is more consistent toward the toll increase change.

4. Focus Area III: Behavioral Analysis – Toll Passage

4.1 Data Description of the regression model

The conditions before and after the implementation of the demand management strategy are quantified in this section to evaluate the travel demand management strategy. Among other things, this modeling process enables to identify the influence of the strategy from the influence of other variables and will help create a long-term database for behavioral research on this subject.

The focus now is on whether carriers would like to pass the toll increase to their customers. The related responses of carriers can be found in questions B.1 in the questionnaire. The first question related to the toll increase passage is

If the toll increases by the selected amount, is your company likely to pass any of the cost to customer?

If their answer is “yes”, the second question of B.1.1 follows.

About what percent of the cost is your company likely to pass to customers?

The respondents are among a series of industry segments and a breakdown of these industry segments is provided in Table 1. Note that each carrier may ship multiple kinds of commodities. Among the industry segments, “construction” takes the largest number of respondents with a total number of 116. “Construction” includes carriers who deliver building materials, mobile homes, and other general construction materials. In the 348 (116×3) responses, 235 would like to pass the toll increase to their customer, which takes 67.5% of the total responses of construction carriers. In these cases, they further provided the percentage of the toll increase that they would like to pass. The average percentage of passage is 82% and its standard deviation is 31%. Moreover, 106 responses would not like to pass the toll increase and the rest 7 (348-235-106=7) responses were missing values. “Machinery”, “agriculture”, and “food” industries also take large proportions of the survey.

Along with the socio-economic information in the census data and survey data, there is a possibility to use regression models to identify the effects of industry segments on carriers’ behavioral changes. Table 2 lists the summary statistics of variables that are used in the regression model.

Table 1 Breakdown of freight carriers by industry sectors (each respondent answers three times on different toll increases)

Name	Number of respondents	Pass to customers	Not pass to customers	Avg percent of passage	Std percent of passage
Construction	116	235(67.5%)	106(30.5%)	82	31
Machinery	68	127(62.3%)	75(36.8%)	85	28
Agriculture	59	84(47.5%)	90(50.8%)	82	30
Food	48	73(50.7%)	66(45.8%)	73	36
Wood	41	79(64.2%)	40(32.5%)	84	28
Paper	36	74(68.5%)	33(30.6%)	70	36
Commodities dry bulk	30	50(55.6%)	34(37.8%)	75	36
Metal	28	60(71.4%)	21(25.0%)	84	27
Liquids/gases	20	42(70%)	18(30%)	96	13
Household goods	17	40(78.4%)	11(21.6%)	63	32
Chemicals	6	18(100%)	0(0%)	96	10
Utility	6	8(44.4%)	10(55.6%)	100	0
Water	2	6(100%)	0(0%)	83	20
Oilfield equipment	2	4(66.7%)	2(33.3%)	67	14
Others	127	239(62.7%)	140(36.7%)	85	28

Table 2 Summary statistics of variables used in the regression model

Name	Definition	Mean	Std.	Min	Max
Dependent variables					
Pass	Binary variable: 1 if carriers pass the toll increase to customers; 0 if not	0.62	0.49	0	1
PctPass	The percentage of the toll increase passage	80.30	31.07	1	100
Independent variables					
Industry segments					
HHG	Binary variable: 1 if the industry segment is household goods; 0 if not	0.05	0.21	0	1
CT	Binary variable: 1 if the industry segment is construction; 0 if not	0.31	0.46	0	1
MLO	Binary variable: 1 if the industry segment is machinery or large objects; 0 if not	0.18	0.39	0	1
LG	Binary variable: 1 if the industry segment is liquids or gases; 0 if not	0.06	0.23	0	1
OE	Binary variable: 1 if the industry segment is oilfield equipment; 0 if not	0.01	0.08	0	1
CDB	Binary variable: 1 if the industry segment is commodities dry bulk; 0 if not	0.07	0.26	0	1
UT	Binary variable: 1 if the industry segment is utility; 0 if not	0.02	0.13	0	1
FOOD	Binary variable: 1 if the industry segment is food; 0 if not	0.02	0.33	0	1
AGR	Binary variable: 1 if the industry segment is agricultural products and supplies; 0 if not	0.16	0.36	0	1
Delivery's Origin/Destination					
D_NYC	Binary variable: 1 if the delivery destination is New York City; 0 if not	0.05	0.21	0	1
O_BUF	Binary variable: 1 if the delivery origin is Buffalo; 0 if not	0.10	0.30	0	1
D_BUF	Binary variable: 1 if the delivery destination is Buffalo; 0 if not	0.09	0.28	0	1
O_ALB	Binary variable: 1 if the delivery origin is Albany; 0 if not				
D_ALB	Binary variable: 1 if the delivery destination is Albany; 0 if not				
O_ROC	Binary variable: 1 if the delivery origin is Rochester; 0 if not	0.09	0.28	0	1
D_ROC	Binary variable: 1 if the delivery destination is Rochester; 0 if not	0.06	0.24	0	1
D_SYR	Binary variable: 1 if the delivery origin is Syraucuse; 0 if not	0.07	0.26	0	1
Other independent variables					
Incr	Hypothetical toll increase (10%, 20%, 40%, 80%, 100%, 120%, 160% and 200%)	0.88	0.60	0.1	2
Freq	The number of times using the toll freeway in a month	17.25	53.98	0	900
Toll	Current toll ($)	11.36	14.84	0	85.22
Trk	The total number of trucks of the freight companies	6.35	31.42	0	576

4.2 Methodology

The data generating process of the two-question analytic framework needs special treatments. The binary response in the first question enables the consideration of a binary outcome model. For respondent $i\left(i=1...N\right)$, the decision of passage $z_i\,(0 \text{ or } 1)$ can be expressed as

$$z_i^* = \alpha' w_i + u_i$$

$$z_i = 1 \text{ if } z^* > 0 \qquad (1)$$

$$z_i = 0 \text{ if } z^* \leq 0$$

where z_i^* is a latent variable, indicating the utility of the toll increase passage. If $z_i^* > 0$, the decision of passage z_i is 1; otherwise, z_i is 0. w_i is a set of explanatory variables in terms of whether carriers would like to pass the toll increase passage, such as the amount of the toll increase, industry segments, and O/D of the delivery. α is the estimable coefficient, indicating the effects of explanatory variables on the utility of passage. u_{it} is assumed to be a normally distributed disturbance term without loss of generality, which leads equation 1 to a binary probit model.

The second question has a response of percentage (the percentage of the toll increase passage). To model percentage numbers, one of solutions is to transfer them into numbers in a wider real domain. This paper performs a logit transformation on the percentage numbers. The transformed linear number y_i is

$$y_i = \ln\left(\frac{y_i \; in\,\%}{1 - y_i \; in\,\%}\right) \qquad (2)$$

Note that many carriers would like to transfer 100% of the toll increase to customers, which is not valid in equation 2. Instead, 99.99% is used as approximation in these cases, resulting in a value of 5 in y_i.

Then, a standard linear regression can be used to analyze the transformed numbers.

$$y_i = \beta' x_i + \varepsilon_i \qquad (3)$$

where x_i is a set of explanatory variables in terms of how much carriers would like to pass the toll increases, β is the corresponding coefficient, and ε_i is the disturbance term.

The binary outcome model and the linear regression can be modeled independently if they are not correlated with each other. However, in the survey, the carriers could answer the second question only when they had answered “yes” in the first question. In other words, the sample selection in the second question was not random so that the dependency between equations is not ignorable. In essence, failure occurs in terms of the linearity of $E\left[y_i \middle| x_i, z_i = 1\right]$ given the sample selection rule, which results in biased estimators if the two equations are treated independently. A classical solution is to apply a seemingly unrelated regressions technique to connect the two regression equations, leading to a so-called sample selection model (Heckman 1979). The sample selection model further assumes

$$\varepsilon_i, u_i \sim N\left[0, 0, \sigma_\varepsilon^2, 1, \rho\sigma_\varepsilon\right] \quad (4)$$

Given the correlation between the two equations, the expectation of y_i in equation 3 can be expressed as

$$E\left[y_i \middle| x_i, z_i = 1\right] = \beta' x_i + \rho\sigma_\varepsilon\left[\phi(\alpha' w) / \Phi(\alpha' w)\right] = \beta' x_i + \rho\sigma_\varepsilon\lambda_i \quad (5)$$

The unknown coefficients in the equations 1 and 3 can be obtained by the Heckman’s two step estimators. The first step is to estimate α in the probit model and calculate the λ_i of each response. The second step is to linearly regress y_i on x_i and λ_i.

A panel data setting could be specified since each carrier has three hypothetical toll increase scenario in the survey data. However, the panel is too short (three) to be identified in practice, leading to identification problem for a panel data sample selection model. Experiments have been tried to estimate the panel data model, but the results are not robust.

The estimation process of this study is undertaken in LIMDEP.

The data is then analyzed using the sample selection model. Results are shown in Table 3. The model’s F-statistic and the likelihood ratio test indicate that the model has a good performance.

4.3 Results Analysis

The data is then analyzed using the sample selection model. The estimated coefficients, t-statistics, corresponding p-values, and marginal effects are shown in Table 3. The model's F-statistic and the likelihood ratio test indicate that the model has a good performance.

The interpretation of the marginal effects provides interesting insights into the problem of freight carriers' behavioral change (toll increase passage) in response to toll increases. Note that the dependent variable is the logit transformed passage percentage and needs additional manipulation when interpreting the marginal effects. In the selection equation, all explanatory variables turn out to have positive marginal effects on the toll increase passage except the industry segment of food. Food carriers are more likely to consume the toll increase by themselves. On the other hand, carriers who deliver agricultural products and supplies are more likely to pass the toll increase to their customers. This is because that agricultural carriers use specifically designed and large trucks. The unique requirements of vehicles prevent agricultural carriers from being easily replaced by competitors so that they can dominate the price in agreements.

As shown by the O/D coefficients in the selection equation, carriers would pass more toll increase costs for deliveries with Buffalo as origin and/or Rochester as destination, as indicated by their significantly positive marginal coefficients. In particular, carriers with deliveries of Buffalo as the origin and Rochester as the destination pass 1.596% and 2.464% more toll increase costs to their customers than deliveries of other origins/destinations. This heterogeneous effect of delivery O/D is associated with the freight demand and supply spatial distribution. For example, the significant destination variable of Rochester reveals an imbalanced demand and supply relationship in Rochester. Demand is higher than supply in Rochester so that the carriers, as the suppliers, dominant the deliveries.

Current toll has a significant estimated coefficient, but an insignificant partial effect. This is because the absolute magnitude of the estimated coefficient is too small to have a strong effect on the dependent variable of another equation (corrected linear equation). The same evidence can also be found in the estimation of number of trucks. These two insignificant marginal effects indicate that carriers' behavioral change is not significantly impacted by the current toll amount and the size of freight companies.

In the corrected linear regression, the coefficients are estimated based on the sample that answered "Yes" in the whether to pass question. As a result, the sample in the corrected linear equation consists of 654 responses. Among the industry segments, carriers who delivery construction, machinery or large objects, liguids/gases, and utility are found to pass more toll increases to their customers as compared to carriers delivering other types of cargoes. On the other hand, carriers who delivery household goods, oilfield equipment, and commodities dry bulk are less likely to pass toll increase costs. This finding is additional evidence that carriers with specifically designed and large trucks play dominant roles in the agreement of setting delivery price.

O/D of delivery in the corrected linear equation indicates different behavioral changes of carriers serving certain areas. Obtaining conclusive findings about general rules of locations is difficult because the investigated locations are very heterogeneous. However, the following inference may be a reasonable one: carriers who deliver to NYC and Buffalo (the first and second largest cities in New York State) tend not to pass toll increase costs, indicated by the negative marginal effects. This finding may reflect the condition that supplies side of the markets in big cities are competitive so that carriers do not have much negotiation power.

The frequency of the delivery is found to be negatively related to the percentage of passage, indicated by its negative coefficient. Carriers with high delivery frequency are more likely to change their delivery behaviors.

The hypothetical toll increase amount variable turns out to be significant in both equations. Its marginal effect is calculated as a combination of them in both equations. The final marginal effect of 2.331% indicates that the willing of toll passage increases 2.331% when the toll doubles. When the toll is high, carriers cannot afford it so that they have to pass a high percentage of toll increase to customers.

The λ is also found significant in the linear equation, which shows its effective functions in terms of providing corrected estimators and connecting the two equations. With the specification of λ, the explanatory variables in the selection equation also serve as explanatory variables for the corrected linear equation. This cross-equation effect is called an indirect effect, contrary to the direct effect in terms of the effects caused by explanatory variables in the corrected linear equation.

Table 3 Estimation results of the sample selection model

Name	Coef.	t-stat	P_value	Partial Effect to PctPass
Corrected Linear Equation (dependent variable: transformed PctPass)				
HHG	-1.555***	-3.93	0.000	-7.225%***
CT	0.391*	1.95	0.051	2.081%*
MLO	0.459*	1.87	0.061	2.443%*
LG	0.954**	2.24	0.025	5.017%**
OE	-4.183***	-2.94	0.003	-21.580%***
CDB	-0.917**	-2.3	0.021	-4.545%**
UT	2.278***	2.63	0.009	10.022%***
D_NYC	-0.758*	-1.68	0.093	-3.814%*
O_BUF	1.036***	2.83	0.005	3.941%*
D_BUF	-1.078***	-3.34	0.001	-5.258%***
O_ALB	-0.524*	-1.76	0.078	-2.689%*
D_ALB	0.959***	3.57	0.000	5.042%***
O_ROC	0.658**	2.10	0.036	3.493%**
D_SYR	0.675*	1.64	0.100	3.581%*
Incr	0.438**	2.21	0.027	2.331%*
Freq	-0.004***	-3.14	0.002	-0.021%***
λ	1.760**	2.53	0.012	8.853%**
constant	1.576***	2.75	0.006	8.016%***
N (number of observation)	654			
F-statistics (17, 636)	5.9		0.000	
Selection Equation (dependent variable: Pass)				
FOOD	-0.330**	-2.53	0.011	-1.716%**
AGR	0.444***	3.76	0.000	2.363%***
O_BUF	0.300**	2.04	0.041	1.596%**
D_ROC	0.463***	2.60	0.009	2.464%***
Incr	0.303***	4.47	0.000	1.612%***
Toll	0.013***	4.29	0.000	0.069%
Trck	0.015**	2.49	0.013	0.069%
constant	-0.103	-1.24	0.216	-0.542%
N (number of observations)	1056			
Log likelihood	-660.987			
Log likelihood at null	-701.603			
Likelihood ratio test	150.172		0.000	

5. Focus Area IV: Behavioral Analysis – Load Factor

In freight transportation, load factor is used to measure the carrier capacity utilization and in this study, it is defined as the percentage of the used vehicle capacity when a delivery vehicle leaves its origin. Efficient freight deliveries with higher load factor and improved vehicle utilization are expected to generate less traffic on road and provide economic and environmental benefits such as reduced traffic congestion, emission and accidents.

This study aims to give a detailed analysis of the determinants of load factors for delivery vehicles using the New York State Thruway. To do so, a beta regression is applied to the survey data, which contains 370disaggregate trip-by-trip observations with detailed information that also allows for delivery vehicle-level analysis.

5.1 Data Description for the Beta Regression

The survey data is used for the load factor study. For the purpose of load factor analysis, observations with missing information on delivery vehicle/trip characteristics are deleted during the data cleaning process and in the end 185 trips made by 185 delivery vehicles are used for the analysis. The data contain information on delivery vehicle type/size, cargo type, fleet size, trip origins and destinations. Table 5 presents the summary statistics of the main variables of interest: on average, the trucks are 65% full (with a load factor of 0.65), both empty trips and full-load truck trips were included in the study, they were recoded into 0.0001 and 0.9999 to allow for the model estimation. The truck size is measured by the number of axles, ranging from one to four in this analysis. In the survey, the respondents were asked about the cargo types in their daily trips, based on the correlation analysis, the original 30 categories are re-grouped into eight categories. Noted that a truck may carry more than one type of cargo in their daily trips, material, machinery and food are the most popular cargo types. The survey also asked the respondents to put in their companies' fleet sizes, the number ranges from one to 23, most of them have relatively small fleet size (less or equal to three trucks). Based on the information of trip origin and destination, the zip codes were geo-located and point distances were estimated based on the coordinate information. On average a truck travels around 122km per trip and there were a number of zero distance trips, representing those short distance trips occurred within the city (share the same zip code).

Table 5. Summary Statistics of variables used in the beta regression model

Name	Definition	Mean	Standard Deviation	Minimum	Maximum
Dependent Variable					
Load Factor	Percentage of delivery vehicle usage	64.78%	29.33%	0.01%	99.99%
Independent Variable					
Vehicle Size					
Number of Axles		2	1	1	4
Cargo Type (base: all other cargo types)					
Food	1 if the cargo type is food, 0 otherwise	13.51%	-	-	-
Material	1 if the cargo type is material, 0 otherwise	34.05%	-	-	-
Vehicle	1 if the cargo type is vehicle, 0 otherwise	9.73%	-	-	-
Machinery	1 if the cargo type is machinery, 0 otherwise	15.68%	-	-	-
Liquids	1 if the cargo type is liquids, 0 otherwise	5.95%	-	-	-
Garbage	1 if the cargo type is garbage, 0 otherwise	3.78%	-	-	-
Utility	1 if the cargo type is utility, 0 otherwise	2.16%	-	-	-
Fleet Size (base: companies with fleet size >3)					
FleetSize1	1 if fleet size =1, 0 otherwise	41.08%	-	-	-
FleetSize2	1 if fleet size is 2 or 3, 0 otherwise	31.35%	-	-	-
Trip Distance					
Distance (in meters)	Average trip distance, estimated by the geo-located coordinates of the origin and destination zip codes	122458	191422	0	2028554

5.2 Methodology

Since the dependent variable "load factor" is in ratios, and restricted to the interval between zero and one, a beta regression model proposed by Ferrari and Cribari-Neto (Ferrari and Cribari-Neto, 2004) is used to conduct the analysis. The model is based on the assumption that the response variable follows a beta distribution, and the flexible nature of beta regression allows for straight forward interpretation in terms of the mean of the response variable and the model is naturally heteroskedastic and allows for asymmetries.

The beta density can have various shapes based on different combination of parameter values, it can be expressed as:

$$f(y;\mu,\phi) = \frac{\Gamma(\phi)}{\Gamma(\mu\phi)\Gamma\big((1-\mu)\phi\big)} y^{\mu\phi-1}(1-y)^{(1-\mu)\phi-1}, 0 < y < 1$$

With 0< μ<1 and ϕ>0; E(y) = μ and Var(y) = $\mu(1-\mu)/(1+\phi)$ and ϕ is defined as the precision parameter.

In this study, let = ($y_1,\ldots,y_n$) be the vector of delivery vehicle load factors that follows a beta distribution, where $y_i \sim B(\mu_i,\Phi_i), i=1,\ldots,n$.

Suppose the mean and the precision parameter of y_i satisfies the following functional relations:

$$g_1(\mu_i) = \eta_{1i} = f_1(x_i^T;\beta);\ g_2(\phi_i) = \eta_{2i} = f_2(z_i^T;\theta)$$

Where:

β and θ are coefficients to be estimated

x_i^T and z_i^T are known/measured independent variables

Both $g_1(\mu_i)$ *and* $g_2(\phi_i)$ are known as link functions that are strictly increasing and twice differentiable, different link functions (e.g., logit, probit and log-log for $g_1(\mu_i)$; square root and logarithmic for $g_2(\phi_i)$) can be specified to achieve the best model fit.

In this analysis, we assume $g_1(\mu_i)$ = $\log\{\mu_i/(1-\mu_i)\}$ and $g_2(\phi_i) = \phi$

The coefficients are estimated by Maximum likelihood (ML), where:

$$l(\beta,\phi) = \sum_{i=1}^{n} l_i(\mu_i,\phi)$$

$$= \sum_{i=1}^{n} (log\Gamma(\phi) - log\Gamma(\mu_i\phi) - log\Gamma\big((1-\mu_i)\phi\big) + (\mu_i\phi - 1)log y_i + \{(1-\mu_i)\phi - 1\}\log(1-y_i))$$

The estimation is performed in R and the results are presented in the following section.

5.3 Results Analysis

Table 6 presents the estimation results from the beta regression model and the estimated marginal effects. By setting the z-value threshold at 1, most selected variables show statistical significance with two exceptions: Number of Axles and Distance. It is natural to assume that smaller delivery vehicles traveling long distance may have larger load factors when they leave the origin, however, this study shows that this might not be true all the time. More complicated settings such as heterogeneity among the delivery vehicles should be taken into account to analyze the effects of these two factors. For cargo type, the result shows that vehicles delivering food, material and machinery tend to have higher vehicle capacity utilization, while the opposite is true for trucks delivering vehicle, liquids, garbage and utility. The result is self-explanatory since food, material and machinery are more easily to be packed, shipped in bulk and have more consistent delivery schedule as compared to other cargo types. For example, trucks delivering towed vehicles are used on demand when there's an accident on road or parking violation occurred, thus it is very difficult to maximize the capacity on truck since "grouping" is simply impossible. As expected, "Vehicle" shows a negative estimated marginal effect of -0.0783, indicating that compare to other cargo types, trucks delivering vehicles tend to have 7% smaller load factor (i.e., the capacity utilization is 7% less on trucks delivering vehicles). Trucks delivering food shows the largest positive marginal effect (0.224) and trucks delivering utility shows the largest negative marginal effect (0.29), indicating that trucks with food on load has 22.4% higher vehicle utilization and utility trucks have 29% lower vehicle utilization. Thus from the behavior change's point of view, policy makers may discuss with the carriers, shippers and receivers to encourage delivery schedules that will maximize the benefits of high load factor delivery, for example, setting up delivery windows for low load factor delivery cargo during off-hours with less traffic. Fleet size is shown to positively associate with the load factor, which can be explained by the fact that with more trucks, the company can arrange and schedule the delivery trips more flexibly to maximize the overall vehicle utilization while companies with a few trucks are limited by their options. The estimated marginal effects for companies with only one truck (-0.0822) and for companies with two or three trucks (-0.111) show that if a company can increase its fleet size, the average truck capacity utilization can be improve by 8% to 11%. Therefore carriers are encouraged increase their fleet size by expanding their own business, acquiring or merging with other small companies, and sharing information and resources with other companies to achieve the maximum vehicle capacity usage.

Table 6. Model Estimation Results (N = 185)

Name	Coef.	Std. Error	z value	Pr>|z|	Partial effect to Load Factor
Constant	5.313E-01	2.79E-01	1.903	0.0571	
Number of Axles	3.24E-02	8.06E-02	0.402	0.6876	7.41E-03
Food	1.16E+00	2.71E-01	4.28	1.87E-05	2.24E-01
Material	3.33E-01	2.11E-01	1.576	0.115	7.48E-02
Vehicle	-3.31E-01	3.19E-01	-1.038	0.2991	-7.83E-02
Machinery	6.59E-01	2.68E-01	2.462	0.0138	1.39E-01
Liquids	-6.46E-01	4.06E-01	-1.593	0.1112	-1.56E-01
Garbage	-6.45E-01	5.07E-01	-1.272	0.2033	-1.56E-01
Utility	-1.20E+00	6.37E-01	-1.884	0.0595	-2.91E-01
FleetSize1	-3.57E-01	2.35E-01	-1.52	0.1285	-8.22E-02
FleetSize2	-4.75E-01	2.50E-01	-1.899	0.0576	-1.11E-01
Distance	3.39E-07	4.91E-07	0.69	0.4899	7.75E-08
	Estimate	Std. Error	z value	Pr(>|z|)	
(phi)	1.05554	0.09341	11.3	<2e-16	

6. Discussions and Conclusions

This project studies the transportation users' behavioral change in response to travel demand management strategies. Thus, the effects of strategies can be better understood and this project benefits for future implementation of travel demand management strategies.

This project first investigated a number of possible freight carriers' behavioral change in response to hypothetical toll increases. Results found that carriers would more likely to pass the toll increase costs to their customers, change delivery frequencies, and/or change the miles travelled. Then, this project uses a statistical model to differential the toll passage magnitudes according to carriers' industry sectors and delivery origin/destination. The marginal effects show that their behavioral changes do perform differently. Thus, future management strategies can borrow the deliverables of this project to improve the efficiency. In addition, a load factor analysis is followed to understand carrier capacity utilization. Results show that carriers' characteristics are correlated with their delivery behaviors.

Future works can continue to investigate freight carriers' behavioral change in terms of delivery frequencies and miles travelled. A joint investigation of multiple behavioral changes is also expected to provide a more comprehensive understanding.

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Appendix Questionnaire

Rensselaer

Abt SRBI

NEW YORK STATE THRUWAY PHONE SURVEY: Web Script

[PROGRAMMER NOTE: The intro and screening sections of the survey are programmed in CATI. The main questionnaire – sections A, B and C are programmed and conducted by interviewers on the web using this script.]

A. Current Company Operation Information

First I would like to ask you some questions about typical vehicle trips using trucks, delivery vans or trailers that are undertaken by your company.

A.1 Does your company use EZ-pass or cash to pay for tolls for these trips that are undertaken for routine business operations?

1. Cash
2. EZ-pass
3. Both

[DO NOT READ
9999 = DK/ref – **SKIP TO A.3.1]**

A.2. On average, about how much total amount of toll does your company pay for such trips per month?

[**IF UNSURE]:** You best estimate is fine.

____________ Dollars [RANGE: $1 – 99998 or more]
0 = someone else pays for the toll

[DO NOT READ
99999 = DK/ref]

For the next few questions, please think of a typical trip that is most frequently undertaken that uses the New York State Thruway. If you can't think of a typical trip, please think about the most recent trip that used the New York State Thruway.

A.3.1.a. To your best knowledge, what is the typical origin of this trip? Can you tell us the zipcode of this origin?

[**IF UNSURE]:** Your best guess is fine.

____________ [RECORD ZIPCODE] **– SKIP TO A.3.2.a**

[DO NOT READ
9999 = DK/ref – **GO TO A.3.1.b.]**

A.3.1.b. To your best knowledge, in which county is the origin located?
[**IF UNSURE]:** You best guess is fine.

____________ [RECORD COUNTY]

[DO NOT READ
9999 = DK/ref]

A.3.2.a. To your best knowledge, what is the typical destination of this trip? Can you tell us the zip code of this destination?

[**IF UNSURE]:** Your best guess is fine.

____________ [RECORD ZIPCODE] **– SKIP TO A.4**

[DO NOT READ
9999 = DK/ref – **GO TO A.3.2.b]**

A.3.2.b. To your best knowledge, in which county is this destination located?
[**IF UNSURE]:** You best guess is fine.

____________ [RECORD COUNTY]

[DO NOT READ
9999 = DK/ref]

Please think of a typical truck, delivery van or trailer that is used for the origin and destination that you just described above. If you can't remember a typical such vehicle, please think of the most recent truck, delivery van or trailer used for this trip.

A.4. How many axles does this vehicle have? [READ LIST] –

IF UNSURE]: Your best guess is fine.

1. 2 Axles
2. 3 Axles

3. 4 Axles
4. 5+ Axles

[DO NOT READ
9999 = DK/ref]

A.5 In a typical month, how many trips does this vehicle complete between this origin and destination that you just described using the New York State Thruway? One complete trip includes an outbound trip and a returning trip. **[IF NEEDED]-** If you cannot recall the typical month, please think of the most recent month.

[**IF UNSURE]:** Your best estimate is fine.

____________ [RECORD NUMBER]
[RANGE: 0 to 9998]

[DO NOT READ
9999 = DK/ref]

A.6. For trips using the New York State Thruway, what is the typical load size in tons per vehicle for the vehicle you just mentioned when it's leaving the point of origin?

[**IF UNSURE]:** Your best estimate is fine.

____________ tons **[**RECORD RESPONSE AS GIVEN]
[RANGE 0- 9998 or more]

[DO NOT READ
9999 = DK/ref]

A.7. For trips using the New York State Thruway, what percent of the capacity of this vehicle is used when it's leaving the point of origin?

[**IF UNSURE]:** Your best estimate is fine.

____________ Percent [RECORD RESPONSE AS GIVEN]
[RANGE 0-100]

[DO NOT READ
9999 = DK/ref]

A.8.1 What is your best estimate of miles per gallon for this vehicle when driven on the highway?

[**IF UNSURE]:** Your best estimate is fine.

____________ MPG [RECORD RESPONSE AS GIVEN]
[RANGE 1-99]

[DO NOT READ
9999 = DK/ref]

A.8.2 What is your best estimate of miles per gallon for this vehicle when driven on local roads?

[**IF UNSURE]:** Your best estimate is fine.

____________ MPG [RECORD RESPONSE AS GIVEN]
[RANGE 1-99]

[DO NOT READ
9999 = DK/ref]

For the next few questions we would like you to think about the section of the New York State Thruway that this truck, delivery van or trailer uses for the typical origin and destination points that you described above.

A.9.1 Typically from where does this vehicle enter the Thruway when going to the destination? Please provide the name of the toll plaza OR town OR city.

[**IF UNSURE]:** Your best guess is fine.

____________ [RECORD RESPONSE AS GIVEN]

[DO NOT READ
9999 = DK/ref]

A.9.2 And typically where does this vehicle exit the Thruway when going to the destination? Please provide the name of the toll plaza OR town OR city.

[**IF UNSURE]:** Your best guess is fine.

____________ [RECORD RESPONSE AS GIVEN]

[DO NOT READ
9999 = DK/ref]

A.9. 3 To your best knowledge, is the same route used for the return trip most of the time?

1. Yes - **Go to B.1**
2. No - **Continue**

[DO NOT READ
9999 = DK/ref] **– Go to B.1**

A.9.4 For your returning trip, typically from where does this vehicle enter the Thruway when returning from the destination? Please provide the name of the toll plaza OR town OR city.
[**IF UNSURE]:** Your best guess is fine.

____________ [RECORD RESPONSE AS GIVEN]
[DO NOT READ
9999 = DK/ref]

A.9.5 And, for your returning trip, typically from where does this vehicle enter the Thruway when returning from the destination? Please provide the name of the toll plaza OR town OR city.

[**IF UNSURE]:** Your best guess is fine.

____________ [RECORD RESPONSE AS GIVEN]
[DO NOT READ
9999 = DK/ref]

B. Response to Toll Increase

[**PROGRAMMER NOTE:** RANDOMLY PICK 3 VALUES FROM 10%, 20%, 40%, 60%, 80%, 100%, 120%, 160%, and 200% FOR EACH RESPONDENT AND REPEAT B.1 to B.5 FOR EACH VALUE.]

We'd like to know how you would adjust your operations if there is a toll change on the Thruway facilities. You will be asked to answer the questions in this section for **three** different levels of toll increase – an increase of (chosen value 1), (chose value 2) and (chosen value 3).

[PROGRAMMER NOTE]:

[SHOW FOR ROTATION 1]: First, we want you to consider how you might adjust your business operations if the toll increased by (chosen value 1);

[SHOW FOR ROTATION 2]: Now, we want you to consider how you might adjust your business operations if the toll increased by (chosen value 2);

[SHOW FOR ROTATION 3]: Now, we want you to consider how you might adjust your business operations if the toll increased by (chosen value 3);]

B.1 If the toll increases by (Chosen value for rotation), is your company likely to pass any of the cost to customers?

1. Yes - **Continue**
2. No – **GO TO B.2**.
9999 –DK/ref – **Go TO B.2**

B.1.1 About what percent of the cost is your company likely to pass to customers?

[**IF UNSURE]:** Your best estimate is fine.

____________ **[**RECORD RESPONSE AS GIVEN**]**
[RANGE 1-100]
9999 = DK/ref

B.2. Is your company likely to load more so that you use the Thruway less frequently?

1. Yes - **Continue**
2. No - **GO TO B3**
9999- DK/ref – **GO TO B3**

B.2.1 To your best knowledge, which of the following will your company use to load more -

1. Change vehicle size
2. Increase load factor or percentage of the capacity of the vehicle used
3. Both, increase percentage of the capacity of the vehicle used, AND Change vehicle size
4. Some other method
______________________________[RECORD VERBATIM]
9999 – Dk/ref

B.3 Is your company likely to change any of the routes to reduce the miles travelled on the Thruway?

1. Yes **– Continue**
2. No – **GO TO B.4**
9999- DK/ref – **GO TO B.4**

B.3.1. To your best estimate, by how much is your company likely to reduce the miles travelled on the Thruway?

[**IF UNSURE]:** Your best estimate is fine.

1. About 1% to 10%
2. About 11% to 20%
3. About 21% to 30%
4. About 31% to 40%
5. About 41% to 50%
6. More than 51%

9999- DK/ref

B.4. Is your company likely to change the time of the day when you typically use the Thruway facility?

1. Yes **- Continue**
2. No – **GO TO B.5**
9999- DK/ref **GO TO B.5**

B.4.1 To your best guess, which of the following describes the time your company is likely to use more for trips using the New York State Thruway?

[**IF UNSURE]:** Your best estimate is fine.

1. On weekdays during peak hours
2. On weekdays during off-peak hours
3. On weekends at any time

9999 – DK/ref

B.5 Is your company likely to implement any other operations changes? Please describe:

____

[RECORD VERBATIM]

[Return to "SHOW FOR ROTATION # before B.1 until all three rotations for the three toll increase scenarios have been completed]

C. INCENTIVE

C.1 Thanks you for your responses. We would like to send you a $10 check as a thank-you for your time. Can I please have your full name and a mailing address?

1. Yes – **Continue**
2. No – **End Survey:** "Your responses have been very helpful. Thank you very much for participating in the study".

INTERVIEWER NOTE: Please confirm spelling of name and entire mailing address

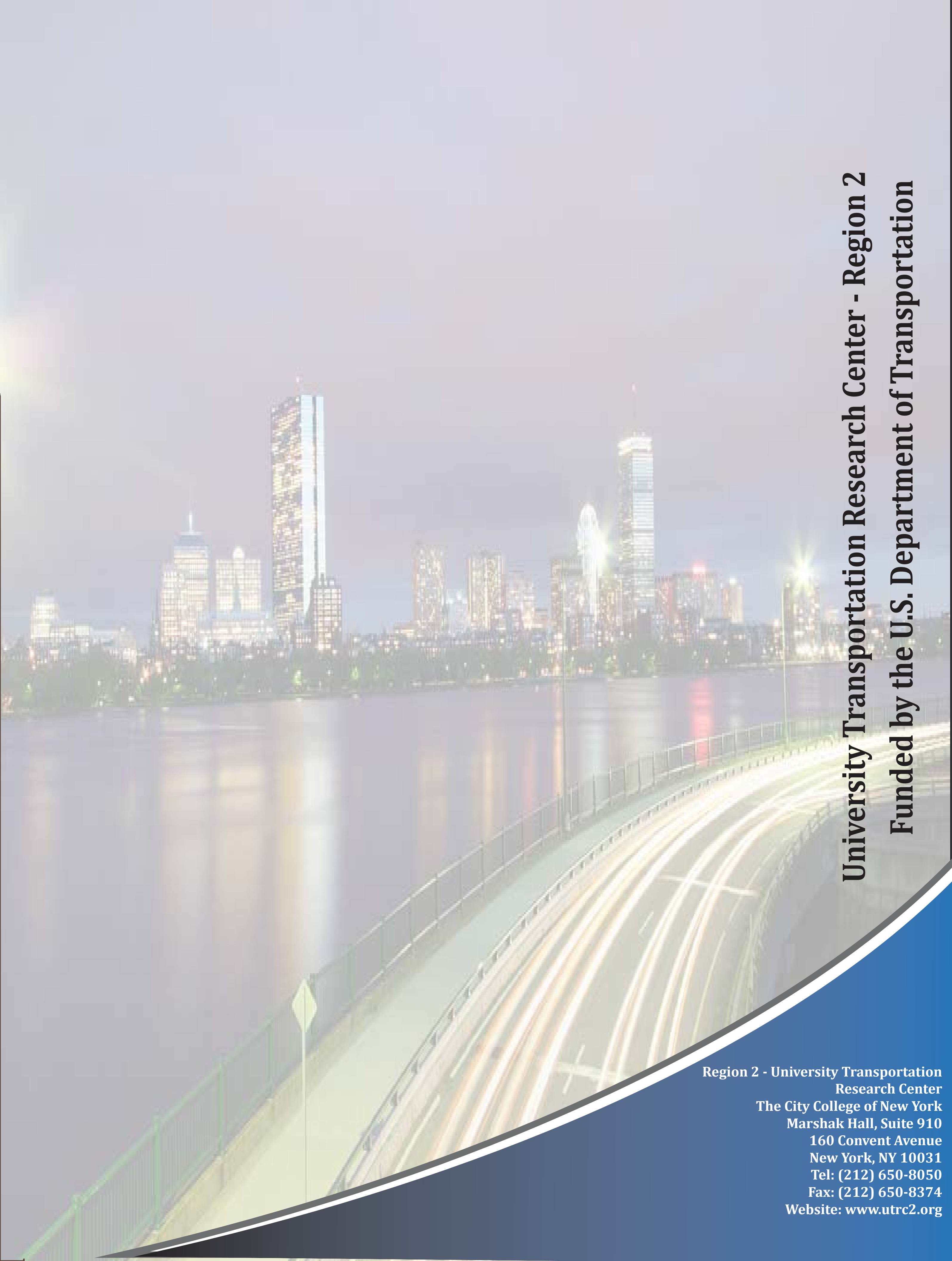
1. [ENTER FULL NAME]
2. [ENTER MAILING ADDRESS – street, apt. or suite #]]
3. [ENTER CITY]
4. [ENTER STATE]
5. [ENTER ZIP]

INTERVIEWER NOTE: Read "Your responses have been very helpful. Thank you very much for your participation in the study".

C.2.

1. WEB SURVEY COMPLETED ON PHONE (Interviewer: Select after completing interview on the phone)

2. SCREEN OUT



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