University Transportation Research Center - Region 2

Final Report

Evaluation of the Cooperative Multi-Carrier Delivery Initiatives

Performing Organization: Rensselaer Polytechnic Institute

December 2013

Sponsor:
University Transportaton Research Center - Region 2

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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:

Research

The research program objectives are (1) to develop a theme based transportation research program that is responsive to the needs of regional transportation organizations and stakeholders, and (2) to conduct that program in cooperation with the partners. The program includes both studies that are identified with research partners of projects targeted to the theme, and targeted, short-term projects. The program develops competitive proposals, which are evaluated to insure the mostresponsive UTRC team conducts the work. The research program is responsive to the UTRC theme: "Planning and Managing Regional Transportation Systems in a Changing World." The complex transportation system of transit and infrastructure, and the rapidly changing environment impacts the nation's largest city and metropolitan area. The New York/New Jersey Metropolitan has over 19 million people, 600,000 businesses and 9 million workers. The Region's intermodal and multimodal systems must serve all customers and stakeholders within the region and globally.Under the current grant, the new research projects and the ongoing research projects concentrate the program efforts on the categories of Transportation Systems Performance and Information Infrastructure to provide needed services to the New Jersey Department of Transportation, New York City Department of Transportation, New York Metropolitan Transportation Council , New York State Department of Transportation, and the New York State Energy and Research Development Authorityand others, all while enhancing the center's theme.

Education and Workforce Development

The modern professional must combine the technical skills of engineering and planning with knowledge of economics, environmental science, management, finance, and law as well as negotiation skills, psychology and sociology. And, she/he must be computer literate, wired to the web, and knowledgeable about advances in information technology. UTRC's education and training efforts provide a multidisciplinary program of course work and experiential learning to train students and provide advanced training or retraining of practitioners to plan and manage regional transportation systems. UTRC must meet the need to educate the undergraduate and graduate student with a foundation of transportation fundamentals that allows for solving complex problems in a world much more dynamic than even a decade ago. Simultaneously, the demand for continuing education is growing – either because of professional license requirements or because the workplace demands it – and provides the opportunity to combine State of Practice education with tailored ways of delivering content.

Technology Transfer

UTRC's Technology Transfer Program goes beyond what might be considered "traditional" technology transfer activities. Its main objectives are (1) to increase the awareness and level of information concerning transportation issues facing Region 2; (2) to improve the knowledge base and approach to problem solving of the region's transportation workforce, from those operating the systems to those at the most senior level of managing the system; and by doing so, to improve the overall professional capability of the transportation workforce; (3) to stimulate discussion and debate concerning the integration of new technologies into our culture, our work and our transportation systems; (4) to provide the more traditional but extremely important job of disseminating research and project reports, studies, analysis and use of tools to the education, research and practicing community both nationally and internationally; and (5) to provide unbiased information and testimony to decision-makers concerning regional transportation issues consistent with the UTRC theme.

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16. Abstract

In the last several years there has been a surge of interest in fostering more sustainable logistical operations in urban areas. Under the umbrella of the generic term City Logistics, these initiatives try to take advantage of the coordinating power of a municipal government to convince urban delivery companies to participate in collaborative schemes that by reducing truck trips, increasing the utilization of trucks, or both, may reduce the negative externalities associated with urban truck traffic. While most research on this topic focuses on freight models (Holguin-Veras, et al, 2001), freight transport networks (Yamada, et al, 2010) and urban freight project evaluation (Thompson and Hassall, 2005), not much research has been conducted to understand the behaviors of urban carriers and freight receivers in response to the cooperative multicarrier delivery initiatives and assess its impacts on a disaggregate level. Some researchers had studied the behavioral modeling between freight agents (Thompson and Hassall, 2005). It is important to investigate the interactions between freight agent and how those relations impact decision making and policy implementation. To investigate a cooperative multicarrier delivery initiative and assess its impacts on a disaggregate level, this report is divided into two parts. The first part studies freight delivery patterns in New York City and related influential factors. Results would serve the feasibility study of implementing FCC in New York City. The second part focuses on studying the decision-making process for developing urban freight consolidation centers (FCC) using experimental economics approach. Players acting as different stakeholders are given cash bonus to mimic the decision making process.

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1. EXECUTIVE SUMMARY

In the last several years there has been a surge of interest in fostering more sustainable logistical operations in urban areas. Under the umbrella of the generic term City Logistics, these initiatives try to take advantage of the coordinating power of a municipal government to convince urban delivery companies to participate in collaborative schemes that by reducing truck trips, increasing the utilization of trucks, or both, may reduce the negative externalities associated with urban truck traffic.

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To investigate a cooperative multicarrier delivery initiative and assess its impacts on a disaggregate level, this report is divided into two parts. The first part studies freight delivery patterns in New York City and related influential factors. Results would serve the feasibility study of implementing FCC in New York City. The second part focuses on studying the decision-making process for developing urban freight consolidation centers (FCC) using experimental economics approach. Players acting as different stakeholders are given cash bonus to mimic the decision making process.

2. INTRODUCTION

With the fast development of emerging technologies during the past several decades, there has been an increasing interest in studying more efficient and more sustainable logistical operations in urban areas. The urbanization and globalization process provides us great convenience and economic prosperity. At the same time, it also brings up lots of problems such as traffic congestion and air pollution. As a result, a number of researchers have begun to study efficient and sustainable transportation systems. For freight transport, it is very important to implement city logistics measures for effective and environmentally-friendly transport as trucks impose large negative impacts on the environment.

In big cities like New York City, a tremendous amount of goods are delivered and transshipped every day. The efficiency of the freight system has a critical impact on a region's economic competitiveness. At the same time, the freight system creates noise and pollution and burdens the already congested urban road network. In order to improve the efficiency and reduce the negative impacts of the freight system, many strategies have been proposed, such as exclusive truck routes, off-hour delivery strategies, and urban freight consolidation centers (FCC). Zhou and Wang (2013) defined an FCC as a facility that consolidates freight deliveries from outside of the city, and transships to local receivers using smaller trucks with full loads. It could decrease the number of truck deliveries, increasing truck load factor and reducing congestion and pollution (BESTUFS, 2007; Browne, et al, 2005). It addresses the "last mile" problem, which is often the most expensive part of a delivery given that scale of economies diminishes after a vehicle leaves the road network (Lewis, et al, 2010).

Despite these advantages, many challenges exist when addressing urban freight transport problems. One of these challenges is modelling urban freight transport activities involving several stakeholders associated with urban freight transport. There are several stakeholders associated with urban freight transport, thus it is necessary to consider the behavior of these stakeholders in examining and evaluating city logistics measures. Yamada et al. (2010) considered five stakeholders: freight carriers, shippers, residents, administrators and motorway operators. It was assumed they each had their own objectives and they selected their behavior to achieve these objectives.

In order to assess the feasibility of these strategies and implement them effectively, it is necessary to first investigate freight delivery patterns and fully understand truckers' behavior. The first part of the report focuses on investigating the freight delivery patterns of New York City and related influential factors. Freight delivery data was collected from a field survey conducted by a research team at the City College of New York between January and June of 2013. It consists of information from direct observation such as delivery characteristics, including the location, vehicle configuration and information from interviews on truck drivers including tour origins and destination; start time and duration; number of stops; distances traveled; and major roads used. A set of statistical models are applied to analyze freight delivery patterns and potential influential factors.

The second part of this report focuses on studying the decision-making process for developing urban freight consolidation centers (FCC) among multiple freight agents. An experimental economics approach is used to mimic the decision process among multiple freight agents. Graduate students are recruited acting as different stakeholders. They are given cash bonus for participation and additional profit related to their behavior in the game.

3. FREIGHT DELIVERY PATTERNS IN NEW YORK CITY

3.1 Introduction

In order to assess the feasibility of these strategies and implement them effectively, it is necessary to first investigate freight delivery pattern and fully understand truckers' behavior. Many studies have been conducted in attempt to understand freight patterns. Models addressing this issue can generally be categorized into commodity-based and trip-based. The former focuses on the flow of goods while the latter focuses on vehicles trips (Holguin-Veras and Thorson, 2000). Building on the NCFRP 606 report (NCFRP 606, 2008), Chow et al. (2010) further classified freight models into seven groups: economic flow factor models, O-D factor models, truck models, four-step commodity models, economic activity models, logistic models, and vehicle touring models. Among these, the vehicle touring models are probably the most practically viable as they focus on movement of vehicles and decisions of carriers, allowing a direct depiction of the transportation system. Vehicle tours can be characterized from many different perspectives. For example, the truck tour-based microsimulation model used in Calgary, Canada (Hunt and Stefan, 2007) simulate tours in terms of time period, travel purpose, vehicle type, start time, stop location and stop purpose. Independent variables used to predict these characteristics include number of stops, travel time, zone accessibility, population and employment, etc.

This study also examines freight delivery patterns from the perspective of truck tours. A set of statistical models are developed to investigate the truck tours using information collected through a field survey in New York City. These models explain truck tours by analyzing truck routes, dwell time at each stop, load factor, departure time, and total number of stops. In addition, truckers' willingness to use FCC is also analyzed.

3.2 Data

As mentioned above, the dataset examined in this study was compiled from a field survey conducted by a research team at the City College of New York between January and June of 2013. Researchers were dispatched to neighborhoods throughout Manhattan to observe truck delivery characteristics, including the location, vehicle configuration, arrival and departure times, vehicle owner (as displayed on the truck) and where possible, the vehicle load factor and commodities being delivered. The researchers also conducted in-depth field interviews with drivers engaged in delivery operations; these surveys consisted of 21 questions examining tour origins and destination; start time and duration; number of stops; distances traveled; major roads used; vehicle load factor at the truck's first stop; costs incurred; and company size. Researchers also asked the driver's opinion on whether his employer would potentially consider participating in a future urban consolidation center. The survey form is presented in the Appendix. Finally, the raw data contains 94 records, and the variables generated from the survey are summarized in Table 1.

Table 1 Direct observation data summary

Variable	Description	No. of valid records	Mean	Std. dev	Min	Max
	Truck information					
Axles	Number of axles: 2,3,4,5	94	2.160	0.555	2	5
Tires	Number of tires: 4,6,10,14,18	94	6.362	2.155	4	18
Van	van truck	7	--	--	--	--
SU	single unit truck	83	--	--	--	--
Trailer	tractor-trailer truck	3	--	--	--	--
LF_obs	Observed load factor, i.e., percentage of capacity used	75	0.433	0.321	0	1
	Company information					
Name	Company name	87	--	--	--	--
Zip	Zip code of the company address	69	--	--	--	--
Loc	Location of the company	93	--	--	--	--
	Trip information					
Arrival	Arrival time: 6:00 am to 23:00	70	11:56	2h59 m	6:00	23:00
Dept	Departure time: 7:15 to 24:00	67	12:33	2h38m	7:15	24:00
Dwell	Dwell time: derived from the difference between arrival and departure time	62	41.44	48.56	0	240
	Commodity type					
Food	1 if commodity type=food; 0 otherwise.	94	0.362	0.483	0	1
Drink	1 if commodity type=drink; otherwise 0.	94	0.149	0.358	0	1
Other	1 if commodity type is neither food nor drink; 0 otherwise.	94	0.213	0.411	0	1
	Trip information					
LF_first	Load factor at first stop	83	0.804	0.228	0.1	1
T_leave	Time leaving depot	67	7:06	2h48m	2:00	18:00
T_start	Derived from *T_leave*: 0 if leaves between 7pm to 6am; 1 if leaves between 6am to noon; 2 otherwise	67	0.582	0.581	0	2
T_first	Time arriving first stop	64	9:46	3h57m	2:30	18:00
T_final	Final stop time	61	15:29	2h45 m	6:00	18:00
Duration	Duration of the entire delivery tour: the difference between leave time and final stop time	46	517.4	173	120	1020
N_stop	Number of total stops	62	35.5	92.1	1	540
Mileage	Daily mileage (mile)	48	84.8	115.4	5	600

Route	Index of truck route	34	1.529	0.992	0	3
	Cost information					
C_fine	Daily fine cost($)	41	47.90	59.16	0	300
C_fuel	Daily fuel cost($)	43	112.8	270.4	16	1800
C_total	Total cost($)	32	164.5	318.2	28	1820
	Size information					
Employee	1 if employee>=50, 0 otherwise	53	0.623	0.489	0	1
Fleet	1 if fleet size>=20; 0 otherwise	37	0.432	0.502	0	1
	Attitude towards FCC					
Will	Willingness to participate joint distribution: 1-definitely not; 2-unlikely; 3-neutral; 4-possible; 5-likely	28	2.357	1.471	1	5

3.3 Models and Results

3.3.1 Overview

The road used for delivery implies the truck tours' spatial distribution; dwell time, total number of stops and load factor are important indicators of delivery efficiency; and start time implies the temporal distribution of truck tours. Respondents' willingness to participate in a FCC is an important attitudinal indicator for assessing the feasibility of FCC implementation. Considered together, these factors characterize truck tours from different (and complementary) perspectives, and reveal information to evaluate the feasibility of the FCC concept.

It is recognized that these factors are likely to be interrelated. Ideally a sophisticated model should be developed to explore them simultaneously; however, the dataset's small sample size does not support such complex model development. In order to avoid over-parameterization, the study develops a set of simple-form statistical models with a limited number of controlled variables, each addressing one factor. The controlled variables include truck and company information, tour information, costs, and commodity type. The factors to be analyzed, models to be used and potential controlled variables are listed in Table 2.

Table 2 Overview of factors and models

Key indicators	Models	Controlled Variables
Truck route	MNL	Duration, total stops, fuel cost, commodity type
Dwell time	Duration model	Total stops, fleet size, fine cost, mileage, commodity type
Total number of stops	Poisson	Dwell time, load factor, mileage, commodity type, fleet size
Load factor at first stop	Censored linear	Truck configuration, total stops, commodity type
Start time	MNL	Truck configuration, total stops, commodity type
Willingness	Ordered logit	Number of employees, fleet size, fine cost, commodity type

The small sample size and the limited information require careful tradeoff between the models' behavior consistency and statistical validity. As the first stage of an on-going research effort, this study only presents results from the first round of the modeling efforts. The selection of controlled variables and model specification will be further refined in later studies.

3.3.2 Truck route

In the survey, drivers were asked to identify any major routes used when entering the city that day; options included four major routes: I-78 (Jersey City-Manhattan), I-95 (Newark-Jersey City-Manhattan), I-278 (Queens/Brooklyn-Manhattan), and I-495 (Long Island-Queens/Brooklyn-Manhattan). When aggregated, the routes depict freight traffic's spatial distribution. It is therefore important to understand which routes truck drivers take and what, if any, connection exists between the route used and other factors. Figure 1 shows the sample truck routes reported by drivers and Figure 2 summarizes their frequencies.

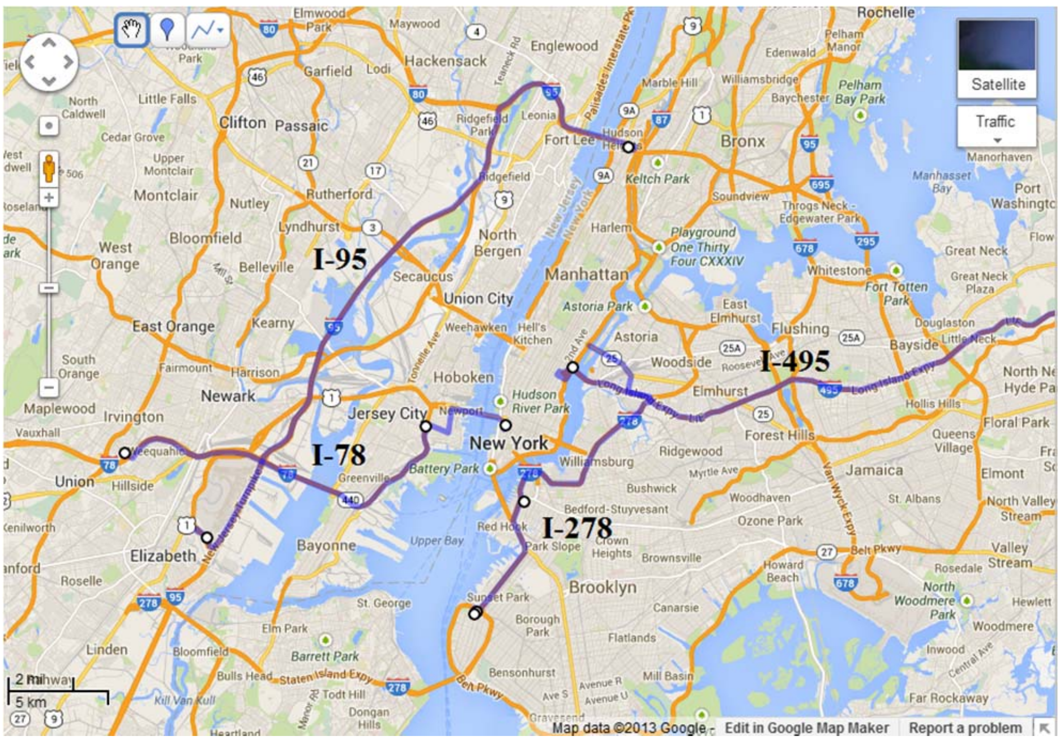


Figure 1 Truck routes in New York City

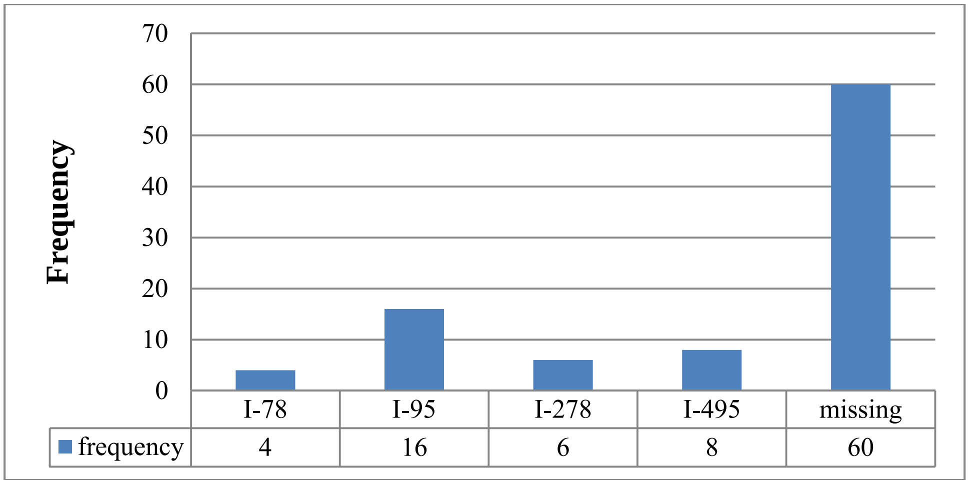


Figure 2 Truck routes distribution

Of the 34 valid records, nearly half of the drivers interviewed traveled on I-95 between their origin and delivery destination. Fewer drivers used the other major highways. A multinomial logit (MNL) model is developed to study the connections between truck routes and other tour characteristics. Discrete choice models are widely used in transportation research, including freight research. For example, Garrido and Mahmassani (2000) used a space-time MNP to forecast freight demand. Three space-time probit models were estimated (summer, spring and winter) and the results provided a good forecast of a freight demand in different periods. Rich et al. (2009) studied mode choice and freight crossing using a weighted logit model. Decoupling of agents and shipments was successfully established. For this study, *Route* is set as the dependent variable; duration (minute), total number of stops, fuel costs, and commodity type are chosen as independent variables. Results from MNL are summarized in Table 3.

Table 3 Estimation results of the truck route choice model

Route	0	1 (Base case)	2	3
Duration	-0.0046(-0.61)	--	-0.0060* (-1.07)	-0.0209***(-2.01)
N_stop	0.0301(0.20)	--	0.156**(1.40)	0.199** (1.57)
C_fuel	-0.0210(-0.63)	--	0.0110(0.81)	-0.0244* (-1.06)
Food	-18.86(-0.00)	--	-2.175(-1.03)	-18.74(-0.01)
_cons	2.652(0.59)	--	0.190(0.06)	8.803*** (1.76)
N		21		
Log likelihood		-17.05		
LR chi2(4)		20.13		
Prob > chi2		0.0647		
Pseudo R2		0.3711		

t statistics in parentheses.
* $p < 0.30$, ** $p < 0.20$, *** $p < 0.10$

Longer tour duration is associated with a higher likelihood of using I-95, and lower likelihood of others, especially I-495. Apparently, trucks taking I-95 tend to make fewer stops while trucks using I-495 make more stops. Trucks using I-495 have lower fuel costs. Considering the higher fuel price along I-495 compared to other routes, this factor probably reflects the fact that delivery tours on I-495 tend to be shorter.

3.3.3 Dwell time

Dwell time here refers to the total time that a truck needs to make a delivery or pickup at a stop, an indicator of freight delivery efficiency and externalities. While dwelling, trucks take up limited road resources. If the truck is kept idling, it also adds to the problems of fuel consumption and emissions. Figure 3 presents the distribution of dwell time collected from this survey. In most cases, dwell time is between 10 minutes to 30 minutes. Very few have dwell time longer than 30 minutes.

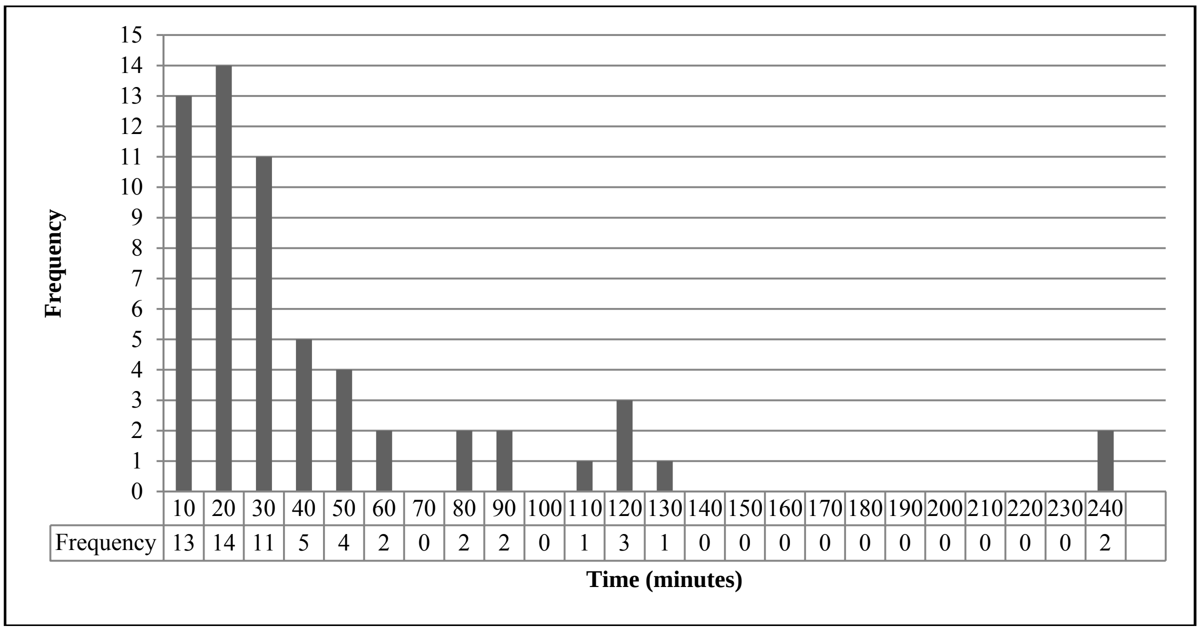


Figure 3 Dwell time distribution

Dwell time is analyzed with the hazard-based duration models, a type widely seen in biostatistics studies (Kalbfleisch and Prentice, 1980; Fleming and Harrington, 1991). Duration models are also used to study unemployment length and business cycle (Kiefer, 1988). The model’s application in transportation is relatively limited with a few exceptions. Bhat (1996) investigated potential factors affecting shopping activity duration using a duration model from grouped (interval-level) data. It was found that parametric baseline forms may result in biased estimates of duration dependence. Nam and Mannering (2000) applied hazard-based duration models to study highway incident duration based on the data provided by Washington State’s incident response program. Results indicated that detection, response and clearance time all affected incident time.

The dwell time is analyzed using a cox proportional hazard duration model and the estimation results are shown below:

Table 4 Estimation results of the dwell time model

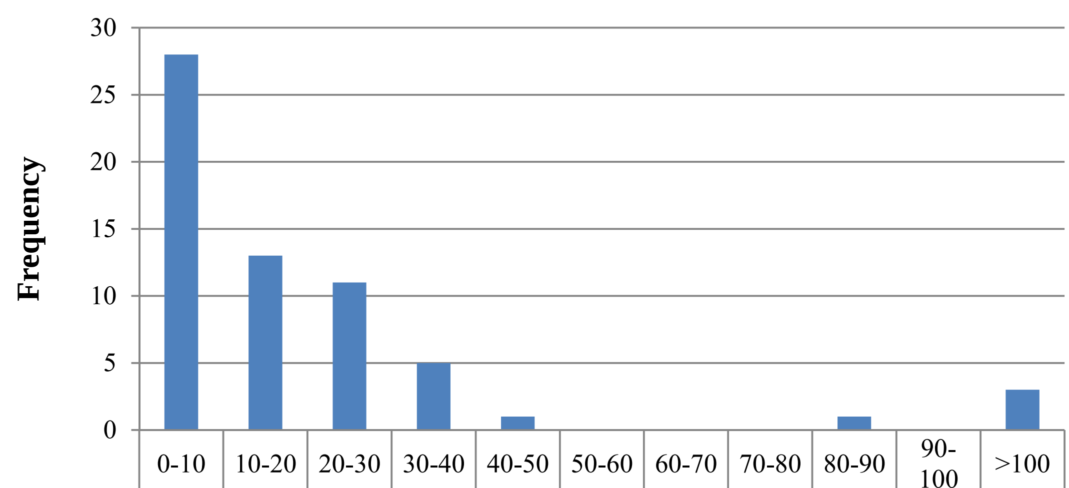
	dwelltime (minute)
N_stop	1.162*** (2.24)
C_fine	1.020** (1.63)
Fleet size	0.0296(-1.04)
Drink	0.4994(-0.41)
Mileage	1.022** *(1.84)
N	19
Log likelihood	-19.51
LR chi2(4)	19.19
Prob > chi2	0.0018

t statistics in parentheses. Coefficients are hazardous ratios in duration model.
* $p < 0.30$, ** $p < 0.20$, *** $p < 0.10$

The total number of stops is positively related to the dependent variable, indicating that trucks making frequent stops tend to have higher chance to end the duration. In other words, they are associated with short dwell time. High fine costs and long distance tours are also related to short dwell time.

3.3.4 Total number of stops

The total number of stops is another important indicator of truck tours. It is often a consequence of fleet operation and type of goods delivered. Therefore, variables characterizing the fleet, the delivery tour, and commodity type are controlled as explanatory variables. Figure 4 shows the distribution of total number of stops reported in the survey. Most trucks make less than 30 stops, but a few outliers stop very frequently.



	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	>100
frequency	28	13	11	5	1	0	0	0	1	0	3

Figure 4 Distribution of total number of stops

As the numbers of stops are mostly small integers, a count data model is used for its analysis. Count data are defined as those with non-negative integer values such as 0, 1, 2, 3, etc. In transportation, many variables, such as queue length, number of vehicles owned by a household, and number of accidents at a road segment, can be represented by count data. For example, Hellström (2006) developed a bivariate count data model to study household tourism demand. Ulfarsson and Shankar (2003) adopted a negative multinomial model to predict traffic accident frequency. Results showed that the negative multinomial model performed better than other models such as negative binomial and random-effects negative binomial.

This study uses a Poisson model to analyze the total number of stops, and the results are summarized in Table 5.

Table 5 Estimation results of the total number of stops model

	N_stop
LF_first	-0.4890*** (-1.99)
Dwell	-0.0073*** (-4.85)
Mileage	-0.0057*** (-2.82)
Drink	0.8997*** (4.24)
Fleet size	-0.2364* (-1.11)
_cons	3.1127***(16.80)
N	18
Log likelihood	-74.38
LR chi2(4)	85.76
Prob > chi2	0.0000
Pseudo R2	0.3657

t statistics in parentheses.
* $p < 0.30$, ** $p < 0.20$, *** $p < 0.10$

High load factor is estimated to be related to fewer stops. This may be because high load factor is often associated with bulk goods with intense needs from limited number of stops. The coefficient -0.4890 suggests if the load factor increases by 1%, the total stops would decrease by about 0.5%. Similarly, longer dwell time and longer tour mileage are related to fewer stops. Regarding the commodity type, “drink” shows a strong positive relation with the dependent variable, indicating that trucks delivering drinks tend to make frequent stops. Fleet size shows a negative relation with the dependent variable, suggesting that trucks belonging to a large fleet tend to make fewer stops.

3.3.5 Load factor

Load factor refers to percentage of carrying capacity used when the delivery vehicle departs from depot. It measures the extent of utilization of a delivery vehicle; therefore, higher load factor normally means higher delivery efficiency. Vehicle configuration, commodity type and the pattern of delivery tour may all influence load factor. Figure 5 shows the distribution of load factor in this survey. Most (40 out of 83 responses) trucks are fully loaded when leaving depot. And only a small portion (16 out of 83) have load factor lower than 60%.

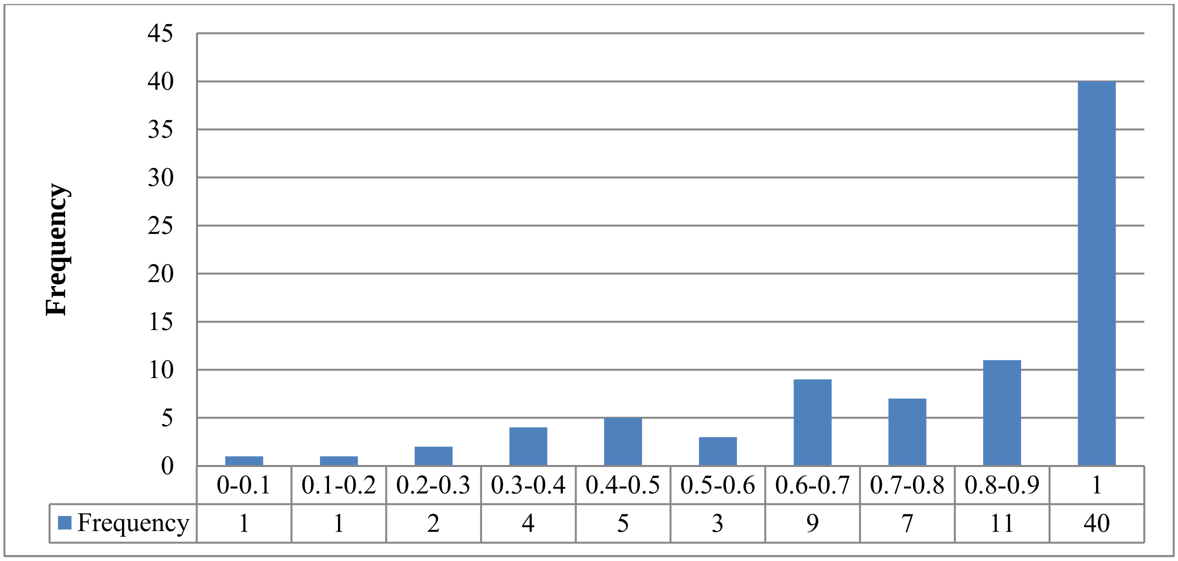


Figure 5 Distribution of load factor at first stop

A Tobit (censored linear) model is used to investigate the load factor as its value is limited between 0 and 1. As discussed above, explanatory variables include truck configuration, commodity type, and delivery tour pattern which is indicated by number of stops. Table 6 shows the estimation results of the load factor model.

Table 6 Estimation results of the load factor model

	load
Trailer	-0.791*** (-1.81)
SU	-0.0175(-0.16)
Axles	0.0100(0.88)
Tires	0.0708*** (1.92)
N_stop	-0.0000947(-0.29)
Food	0.187*** (2.59)
Drink	-0.158*** (-1.75)
_cons	0.348** (1.51)
Sigma	0.225***(10.45)
Summary	1 left-censored, 56 uncensored, 4 right-censored
N	61
Log likelihood	-0.621
LR chi2(4)	15.68
Prob > chi2	0.0282
Pseudo R2	0.9266

t statistics in parentheses.
* $p < 0.30$, ** $p < 0.20$, *** $p < 0.10$

Compared to delivery vans (the base case), combination trucks (trailers) are estimated to have a lower load factor. However, among the same type of delivery vehicles, large ones, indicated by the number of tires, tend to have a higher load factor. Trucks delivering food seem to have high load factor while trucks delivering drinks tend to have a low load factor, possibly due to the weight constraint.

3.3.6 Start time

The time that a delivery vehicle leaves a depot is an important indicator describing temporal distribution of truck volume. Like passenger vehicles, most delivery vehicles depart in the morning and return in the evening. In order to use the road facility in a more balanced manner, off-hour delivery has been proposed and is currently being implemented in New York City to foster deliveries made in off-hours. To be consistent with the definition of "off-hours" (Holguín-Veras, 2008), this study groups the start time into three intervals: 7 pm to 6 am (indexed as 0), 6 am to noon (indexed as 1), and noon to 7 pm (indexed as 2). Figure 6 summarizes the distribution of the start time. Apparently, most delivery vehicles start their tours during off hours or in the morning; very few start their tours in the afternoon.

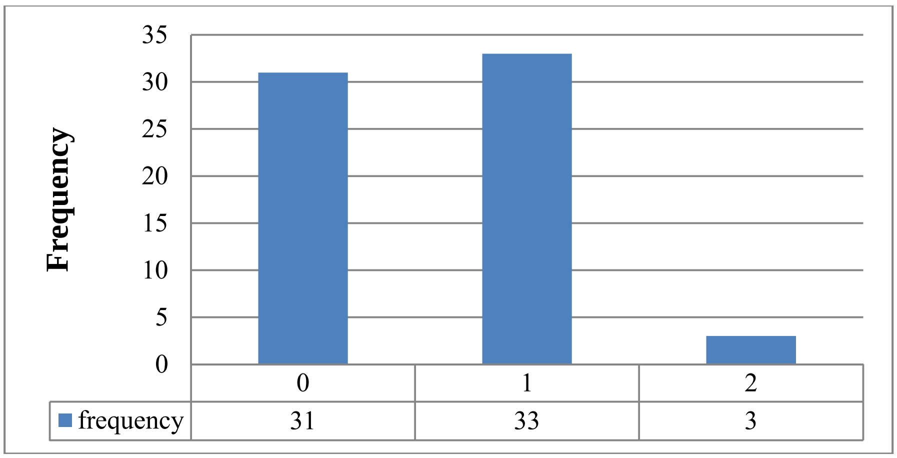


Figure 6 Distribution of starting time

The MNL model is used to analyze the start time choice. Similarly, factors representing truck configurations, delivery tour pattern and commodity type are used as explanatory variables. The estimation results are summarized in Table 7.

Table 7 Estimation results of the start time model

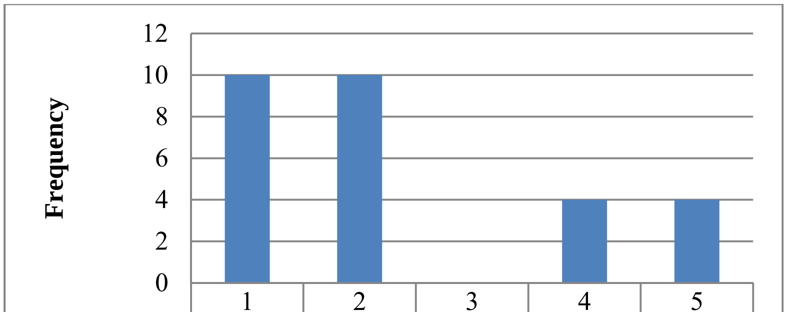
Start time	0(Base case)	1	2
Tires		-0.608^{*} (-1.25)	0.615(0.00)
N_stop		0.00563^{*} (1.07)	-2.868(-0.01)
Food		-0.762^{*} (-1.23)	25.49(0.00)
_cons		3.725^{*} (1.28)	-25.91(-0.00)
N		62	
Log likelihood		-38.81	
LR chi2(4)		17.16	
Prob > chi2		0.0087	
Pseudo R2		0.1810	

t statistics in parentheses.
* $p < 0.30$, ** $p < 0.20$, *** $p < 0.10$

Because of the small number of observations in group 2, the model cannot distinguish behavior of trucks leaving between 7pm and 6pm and those leaving in the afternoon. However, the model finds that large vehicles (indicated by number of tires), those delivering food and those making fewer stops are less likely to depart in the morning (between 6am and noon).

3.3.7 Willingness to participate in a FCC

Assessing truck drivers' willingness to participate in a FCC is an important step for FCC implementation. Identifying factors influencing their willingness level could help policy makers design strategies or incentives to foster participation. According to previous research on FCC, factors influencing the willingness level include carriers' characteristics and the types of goods they carry. Zhou and Wang (2013) stated that FCC organization, location and carrier size have a direct impact on FCC decision making. Figure 7 summarizes the distribution of the willingness level reported by the truckers, with one indicating the no willingness and five indicating high willingness. Only 28 out of the 94 interviewees responded to this question, and their responses seem to be on the two extremes, with most of them unwilling to use FCC. It should be noted that while surveyors provided a definition for a FCC, driver understanding of the concept was likely extremely variable.



	1	2	3	4	5
frequency	10	10	0	4	4

Figure 7 Distribution of willingness level

An ordered logit discrete model is established to explain the willingness level and the effects of various influential factors. The results are summarized in Table 8.

Table 8 Willingness level model results

	willingness
Employee	-3.513*** (-1.75)
Fleet	2.122* (1.09)
C_fine	-0.00467(-0.55)
Food	-5.338***(-2.19)
Drink	-4.060***(-2.14)
cut1_cons	-4.216***(-2.60)
cut2_cons	-0.460(-0.51)
cut3_cons	0.0652(0.07)
N	18
Log likelihood	-14.41
LR chi2(4)	13.88
Prob > chi2	0.0164
Pseudo R2	0.3251

t statistics in parentheses.
* $p < 0.30$, ** $p < 0.20$, *** $p < 0.10$

It is estimated that companies with more employees are reluctant to use a FCC, probably because the change of operation requires more efforts and costs for these bigger companies. However, when employment size is held constant, having a large fleet size is associated with a higher willingness. Truck drivers paying high parking fines are less willing to use a FCC, a result that seems counterintuitive, but the effect is statistically insignificant. Trucks delivering food and drinks are less willing to use FCC, compared to those carrying other types of goods. This could be due to the concerns over safety and reliability related to the transshipment of perishable goods.

In summary, six models have been developed, each addressing one different aspect of the freight delivery pattern in New York City. These regression models provide interesting and insightful results, as summarized in Table 9.

Table 9 Summary of model results

Items	Sample size	Goodness of fit (Prob>chi2)	Conclusion
Truck route model (MNL)	21	0.0647	Truck tours using I-95 have longer duration and fewer stops.
Dwell time model (duration model)	19	0.0018	Lower mileage, less frequent stops, and lower fines are associated with longer dwell times
Total stops model (count data model)	18	0.0000	Higher load factor, longer dwell time, longer mileage, and delivering drinks are associated with fewer stops
Load factor model (censored linear model)	61	0.0282	Combination trucks, smaller capacity, and delivering drinks are associated with lower load factor
Start time model (MNL)	62	0.0087	Larger vehicles and those that deliver food tend to begin their tours before 6 am; trucks making frequent stops tend to depart between 6 am and noon.
Willingness model (ordered logit model)	18	0.0164	Companies with small employment size, large fleet size and those delivering goods other than food and drinks expressed greater willingness to use a FCC

3.4 Summary

This study employs six statistical models to investigate freight delivery patterns in New York City. The six models, which are developed based on variable characteristics measured through a field survey of truck drivers, identify independent variables related to the truck's route, dwell time, total number of stops, load factor, and start time, and to the truck drivers' perception of his company's willingness to use a FCC. While the strength of conclusions are limited, the results described demonstrate the utility of the models employed for identifying freight patterns and for understanding the feasibility of policy interventions. For example, the willingness model directly identifies characteristics to predict FCC participation. The results of the load factor model indicate that companies operating small combination trucks and carrying drinks may have unused capacity, an indicator of potential for FCC participation. Results of the start time model suggest that trucks making frequent stops tend to begin their tours between 6 am and noon; these tours are likely to be the most difficult to shift to off-hours, as such a shift would potentially require behavioral changes from many receivers.

This study can be further improved by a larger sample size and more variables, which may be achieved by better treatment of missing values and integration of other data sources. Besides, the selection of controlled variables and model specification need to be refined following a more rigorous model development process. Although the applicability of the models is limited by the small sample size, the findings from this preliminary study will provide important reference for future large-scale data collection and analysis, eventually facilitating the city's freight policy design.

4. DECISION-MAKING PROCESS FOR FCC DEVELOPMENT

4.1 Introduction

Despite the advantages that FCCs possess, the implementation of an FCC is often difficult, involving multiple stakeholders in the freight transport system. Based on several FCC case studies, Lindholm (2010) proposed a Sustainable Urban Transport Plan (SUTP) freight transport model to identify basic elements and potential factors that could influence the decisions involved in FCC development. Basic element of FCCs, including types of goods and vehicles, facilities, and infrastructure were identified. Influential external factors such as financial and institutional constraints, concerns over land use, noise and air pollution, were also listed. In reality, other external factors such as location and organization type were also found to influence FCC development. For example, a reasonable location could save travel time and distances, and enhance delivery efficiency while reducing externalities such as traffic congestion and pollution. Other locations could make the freight transport situation, in all of its ramifications, worse. As for the organization type, if the FCC is self-sustained with no government financial incentives, then government will have little impact on the FCC operation On the other hand, if the FCC gets financial support from the government, the interactions between involved stakeholders will be further complicated. This study investigates the ways in which these various factors can affect FCC development and stakeholders' utilities.

Existing FCC studies focus primarily on specific case studies and logistics supply chain analyses. A thorough literature review of FCC examples and preliminary evaluation by Browne (Browne, et al, 2005) suggests that an FCC has great potential if it meets these criteria: availability of funding, strong public involvement and limited congestion and pollution. Panero, et al (2011) provided detailed FCC case studies in Europe, and discussed their transferability to the U.S. Major FCC case studies such as La Petite Reine in France, Heathrow Airport in the U.K. and Tenjin Joint Distribution System in Japan have been carefully studied in terms of operation, financial profile, social benefits and costs; these analyses have provided important references for this study.

In terms of studies in logistics and supply chain, Kayikci (2010) developed a conceptual model for the FCC location decision, applying a combination of the fuzzy-analytical hierarchy process (AHP) and the artificial neural network (ANN) method. Based on the data, the most influential factor among multi criteria was chosen, and the most appropriate location was selected. Moon, et al (2011) developed a joint replenishment and consolidation freight model. Based on mathematical models and four algorithms, results indicated that a quasi-stationary policy led to lower total costs compared to a stationary policy.

4.2 Method

Unlike traditional methods, this study studies the FCC development problem using experimental economics. Experimental economics is a subarea of economics that studies human behavior in a laboratory context. It allows researchers to control the decision setting to mimic decision-making processes (Riedl, 2009). Some researchers question the validity of the approach as a laboratory context is different from a real decision context, and players in the experiment cannot fully represent the whole population (Duflo, 2006). However, the experimental economics approach has two important advantages: replicability and control (Davis and Holt, 1993). Replicability allows other researchers to reproduce the experiment and validate the results. In addition, researchers can control the experiment context to investigate major factors in the decision process. FCC research requires various kinds of data that are not always available. In the absence of data, the experimental economics approach becomes increasingly important to generate synthetic data and analyze decision results.

The applicability of experimental economics has already been proven by several applications in freight transportation. Holguin-Veras and Thorson (2003) used experimental economics to study the urban freight transportation market. Participants acted as competing truck companies to earn as much profit as possible. Cost functions for truck companies were defined to measure the profit and relation between players. The estimated number of stops, load factors and time durations were well aligned with theoretical ones. As with the studies discussed above, this study will apply experimental economics to the FCC decision problem. A profit function is derived from empirical data for each type of stakeholder: carrier, operator, government and resident. As in the real collaboration process, four players, representing these four types of stakeholders, try to derive the most benefit from the FCC development. In the experiment, such "benefit" is mimicked by a bonus allocated to the players. In order to get the highest possible bonus, each player has to bid wisely so that he/she can maximize his/her own profit, while making necessary compromises to achieve group consensus. Eight scenarios are tested to determine the effects of organizational type, location, and carrier size on stakeholders, and eventually on the FCC development decision. Results from this study will help identify potential factors in the FCC development decision process, and provide guidance for future studies.

Besides, in some FCC schemes, receivers make direct payments to FCC service. but in most cases they do not, which gives rise to the benefits and cost distribution issue among stakeholders. In this study, it is assumed that FCC operator charges rent from carriers only, and that receivers are not involved.

In addition, the experiment only focuses on actors in local area. Multiple layers of players such as local, state, multi-jurisdictional and nation government may exist and affect each other. To simplify the problem, we only consider carriers, operators, government and residents from local area.

4.3 Experiment Design

The goal of the experiment is to assess how different FCC conditions affect stakeholders' decisions. The experiment results are expected to provide insights into the decision-making process of FCC development in practice. Four players representing carriers, operators, government and residents participate in the experiment. The experiment runs for 8 sessions, each representing a FCC proposal with specific organization type, location and carrier size conditions. Each session contains 10 rounds of bidding. If no agreement is reached in 10 rounds, the session is considered an undesirable FCC proposal.

Each participant receives $20 base payment for participation. Their total payments, however, are mainly determined by the bonus(es) they earn during the game. In each round, the participant may get a bonus based on his/her performance maximizing profit and achieving consensus. When the player's bid maximizes his/her profit, a $1.00 bonus is earned. If a player's bid is profitable but not maximally, the bonus will be proportional to the ratio of actual profit earned and maximum profit possible. For example, if according to the profit function, the maximum possible profit of the "operator" is $1000, and the player of "operator" earns $800 in one round, he/she might be given $0.80 as a bonus. However, the player will only get the bonus if consensus from all stakeholders is achieved. Otherwise, the player gets no bonus at all. Such an incentive mechanism is designed to mimic what happens in reality: stakeholders care most about their own benefit, and would only accept a FCC proposal if it is beneficial to them. However, if no consensus is achieved (i.e., the FCC proposal is not approved), nobody gets anything.

In order to characterize the interactive relations between stakeholders, profit function is defined for each stakeholder. As a starting point, most parameter values of these functions come from the La Petite Reine (LPR) freight consolidation center case study in France (Panero, et al, 2011). Started in 2001, this FCC has grown to be one of the largest urban distribution systems in Europe, distributing nearly one quarter of a million parcels per year. It uses small cargo cycles to transship goods from trucks to local receivers within 15 miles distance of the FCC, thus increasing efficiency and reducing congestion and pollution. It runs with minimal government support and charges relatively low rent. Additional revenue comes from advertising space on its cargo cycles. In general, it is a representative FCC that operates successfully and provides reasonable empirical parameter values.

4.3.1 Carriers

In this study, carriers are considered as an aggregate identity with one delivery route; this homogeneous assumption is implied for all involved carriers. Adapted from Arnott, et al. (1993), the profit function for carriers consists of cost savings in delivery distance and time, deducted by total rent paid to the FCC. It is also assumed that a truck would have to circle around the city to make all of its deliveries if the FCC is not present. The route is thus a circle, with a radius equal to the average FCC delivery distance. Therefore the profit function for carriers could be expressed as:

$$P_c = N(2\pi\lambda\Delta D + 2\pi\alpha\Delta T) - Vr_c \quad (1)$$

Where

P_c = total profit for carrier ($)
N = number of deliveries per year
ΔD = reduced distance traveled per delivery (km)
ΔT = reduced travel time per delivery (hour)
r_c = rent for carrier ($/parcel)
V = freight volume (parcel)
α = value of time ($/hour)
λ = unit cost related to delivery distance, including fuel cost, insurance and maintenance ($/km)

The estimated parameter values are presented in Table 10, below.

Table 10 Parameter Values for Carriers' Profit Function

Parameters	Values	
	Original value	Value in 2012
α	5 $/hour (Arnott et al., 1993)	5*1.59*55/24=18.22 $/hour (BLS, 2012 and Holguín-Veras, 2010)
λ	0.49 $/mile (Holguín-Veras and Polimeni, 2006)	0.56 $/mile (BLS, 2012)
ΔD	15km (Panero, et al, 2011)	
ΔT	15km/(25km/h)=0.6h (Panero, et al, 2011)	
N	180 deliveries per week * 52 weeks=9360 deliveries per year (Panero, et al, 2011)	
V	250000 (Panero, et al, 2011)	
r_c*	Variable	

Note: The original values are converted into current values by multiplying inflation factor (BLS, 2012). For α, commuter's value of time is converted to trucker's value of time by multiplying 55/24 (Holguín-Veras, 2010). ΔD is the distance traveled by cargo cycles from FCC and ΔT is the time it takes. To keep consistency, major parameters are from La Petite Reine (LPR) freight consolidation center case study in France (Panero, et al, 2011). r_c* indicates that rent is set as the variable for carrier in the experiment.

4.3.2 Operator

The operator's revenue comes primarily from the rent (Panero, et al, 2011). In case of strong public involvement, financial incentive(s) from government may be a part of the operator's revenue. The operation cost of the FCC is calculated by the FCC labor cost, and its percentage in total costs. When there is only one operator, the profit function for the operator could be expressed as:

$$P_o = Vr_o + f_o - nw_o h / l \quad (2)$$

where

P_o = operator profit ($)

f_o = financial incentive for operator ($)

l = labor cost percentage in the total operation cost

n = number of employees

w_o = wage rate for operator ($/hour)

h = working hour per year (hour)

r_o = rent for operator ($/parcel)

V = freight volume (parcel)

The estimated parameter values are presented in Table 11, below.

Table 11 Parameter Values for Operator Profit Function

Parameters	Values
n	10 (Panero, et al, 2011)
h	13h/day*6 days/week*50 weeks=3900 hours/year (Panero, et al, 2011)
l	0.83 (Panero, et al, 2011)
f_o^*	Variable
w_o^*	Variable
r_o^*	Variable

Note: To keep consistency, major parameters are from La Petite Reine (LPR) freight consolidation center case study in France (Panero, et al, 2011). f_o^*, r_o^* and w_o^* indicate that financial incentive, rent and wage rate are set as variables for the operator in the experiment.

4.3.3 Government

Government in this study refers to the aggregate of public agencies that work for the benefit of the entire region potentially impacted by the FCC. The profit of government thus consists of reduced externalities of pollution and congestion (Panero, et al, 2011). Externalities of major pollutants such as carbon dioxide and nitrogen oxide are converted into monetary values using their emission prices. As for the quantification of congestion externalities, besides congestion pricing, toll revenue redistribution is also considered as a reasonable alternative (Mirabel and Reymond, 2011). It is thus assumed that congestion caused by truck deliveries is equivalent to the amount of tolls paid by trucks. The profit function for government could be expressed as:

$$P_g = a\Delta CO_2 + b\Delta NO_x + tN - f_g \quad (3)$$

where

P_g = government profit ($)
t = toll price ($)
$\Delta CO2$=reduced carbon dioxide (ton)
ΔNOx=reduced nitrogen oxide (ton)
a = CO2 price ($/ton)
b = NOx price ($/ton)
N = number of deliveries per year
f_g = financial incentive for the government ($)

The estimated parameter values are presented in Table 12 below.

Table 12 Parameter Values for Government Profit Function

Parameters	Values
t	$30+$150=$180 (Holguin-Veras and Polimeni, 2006)
ΔCO_2	22 ton (Panero, et al, 2011)
ΔNO_x	200 kg=0.2 ton (Panero, et al, 2011)
a	20 $/ton (Johnson, L. *et al*., 2011)
b	300 $/ton (FERC, 2012)
f_g^*	Variable

Note: It is assumed that 5-axles trucks are used make peak hour deliveries, which correspond to $30 toll price and $150 parking fine (Holguin-Veras and Polimeni, 2006). To keep consistency, major parameters are from La Petite Reine (LPR) freight consolidation center case study in France (Panero, et al, 2011). f_g^* indicates that financial incentive is set as the variable for the government in the experiment.

4.3.4 Residents

Many FCC case studies indicate that residents living close to a FCC are often the major opponents of FCC development for a number of rational concerns. On one hand, FCC creates employment opportunities for local residents, which may be accounted for using wage rate. On the other hand, the concentrated freight transportation involved may negatively impact the local community in terms of increased noise, reduced community vibrancy and safety. In an open market, it is also reasonable to assume that these externalities will be reflected in land price changes. Lin and Ben (2009) used an improved hedonic price model to study the impact of industrial land agglomeration (such as FCC construction) on land price. Residents care about their own land value, which directly affects residents' profit. Profit function for local residents consists of wage income and land price change, which could thus be expressed as follows:

$$P_r = nw_r h + A\left(\frac{P_0 \mu A_c}{A}\right) = nw_r h + P_0 \mu A_c \tag{4}$$

where

P_r = residents profit ($)

μ = land price elasticity ($/percentage change in industrial land)

A_c = FCC size (m^2)

A =community area (m^2)

P_0 =original land price ($/m^2)

n = number of employees

w_r = wage rate ($/hour)

h = working hour per year (hour)

The estimated parameter values are presented in Table 13, below.

Table 13 Parameter values for residents profit function

Parameters	Values
μ	-0.257 (Lin, S.-W., & Ben, T.-M., 2009)
A_c	600 m^2 (Panero, et al, 2011)
P_0	44.2€/m^2*1.2287=$54.3/m^2 (Abelairas-Etxebarria, P., & Astorkiza, I., 2012 and Google Finance, 2012)
w_r^*	Variable

Note: Land area value comes from La Petite Reine (LPR) freight consolidation center case study in France (Panero, et al, 2011). w_r^* indicates wage rate is set as the variable for residents in the experiment.

The interactions between four players are illustrated in Figure 8. For example, a carrier interacts with the operator through rent bids. The carrier bids r_c* and the operator bids r_o*. The final rent bids would affect both carriers' profit and operator's profit, which is noted with the double arrow. It The interactions between operator and other players are similar. For simplicity, it is assumed that carriers, government and residents do not have direct interactions between them.

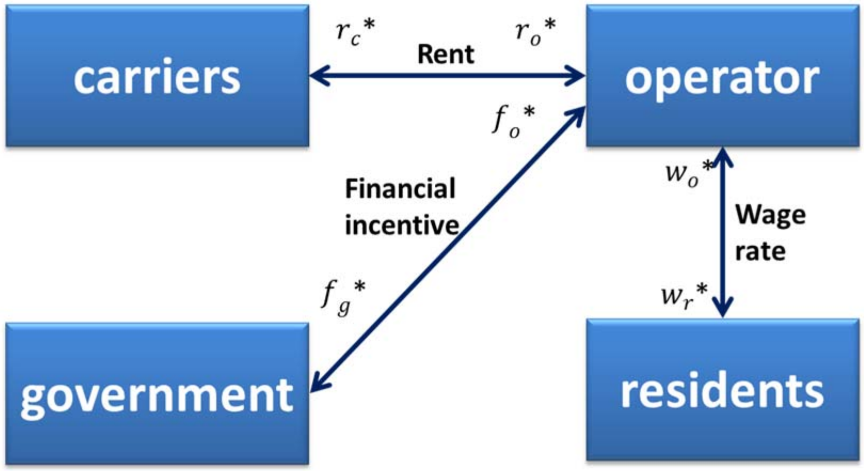


Figure 8 Interactions between Freight Agents

4.4 Experiment Implementation

Four graduate students are recruited to perform the experiment. They are randomly assigned characters of carrier, operator, government and resident. In each scenario, each player chooses his/her own values of variables within given ranges to maximize his/her profit, with the understanding that their potential bonus will be proportional to the achieved profit, and can only be earned when consensus is achieved. A total of three variables are used in the experiment: rent ( ) charged by operator and paid by carriers; financial incentive ( ) provided by government and received by operator; and wage rate ( ) decided by operator and resident. Group consensus is reached if the bids' differences for all three variables are within 5%. During each round the players are allowed up to 2 minutes to discuss, reconsider, and revise their bids. If no group consensus is reached within 10 rounds, the scenario is considered an undesirable situation for building a FCC.

Eight scenarios are created to test different organizational types, location choices and carrier sizes. Organization type defines the partnerships and relevant financial incentives between operator and government. Major organization types include private (no financial incentive), public (full financial incentive), and public-private-partnership, PPP, (partial financial incentive) (Panero, et al, 2011). Since PPP is a more recent and effective organization, this study tries to compare private and PPP organization types. Location is directly related to service area provided by the FCC. For example, location in the urban area has smaller delivery distances while the congestion and pollution problems may be more significant. Instead, suburban location saves more delivery distance for carriers, and causes less externality. In this study, outskirt location (suggesting longer travel distance saved) and center location (suggesting shorter last-leg travel distance) are compared. "Carrier size," indicated by the number of truck deliveries handled by the FCC, is relatively straightforward. To a certain extent, this factor represents the carriers' acceptance and utilization rate of the FCC. Two values are assumed here: small size with

250,000 parcels and 9,360 deliveries, or large size with 750,000 parcels and 28,080 deliveries (Panero, et al, 2011). The complete scenario information is summarized in Table 14.

Table 14 Summary of Scenarios

Scenarios	Parameter values			Variable range ($)
	Organization	Location	Carrier size	
1	Private ($f = 0$)	Outskirt ($\Delta D = 15\ mile$, $\Delta T = 0.6h$)	Small ($V = 250000$, $N = 9360$)	$r = 0 \sim 10$ $f = 0$ $w = 7.25 \sim 50$
2	Public-Private ($f <$ $2,000,000)	Outskirt ($\Delta D = 15\ mile$, $\Delta T = 0.6h$)	Small ($V = 250000$, $N = 9360$)	$r = 0 \sim 10$ $f = 500{,}000 \sim 2{,}000{,}000$ $w = 7.25 \sim 50$
3	Private ($f = 0$)	Center ($\Delta D = 5\ mile$, $\Delta T = 0.2h$)	Small ($V = 250000$, $N = 9360$)	$r = 0 \sim 10$ $f = 0$ $w = 7.25 \sim 50$
4	Public-Private ($f <$ $2,000,000)	Center ($\Delta D = 5\ mile$, $\Delta T = 0.2h$)	Small ($V = 250000$, $N = 9360$)	$r = 0 \sim 10$ $f = 500{,}000 \sim 2{,}000{,}000$ $w = 7.25 \sim 50$
5	Private ($f = 0$)	Outskirt ($\Delta D = 15\ mile$, $\Delta T = 0.6h$)	Large ($V = 750000$, $N = 28080$)	$r = 0 \sim 10$ $f = 0$ $w = 7.25 \sim 50$
6	Public-Private ($f <$ $2,000,000)	Outskirt ($\Delta D = 15\ mile$, $\Delta T = 0.6h$)	Large ($V = 750000$, $N = 28080$)	$r = 0 \sim 10$ $f = 500{,}000 \sim 2{,}000{,}000$ $w = 7.25 \sim 50$
7	Private ($f = 0$)	Center ($\Delta D = 5\ mile$, $\Delta T = 0.2h$)	Large ($V = 750000$, $N = 28080$)	$r = 0 \sim 10$ $f = 0$ $w = 7.25 \sim 50$
8	Public-Private ($f <$ $2,000,000)	Center ($\Delta D = 5\ mile$, $\Delta T = 0.2h$)	Large ($V = 750000$, $N = 28080$)	$r = 0 \sim 10$ $f = 500{,}000 \sim 2{,}000{,}000$ $w = 7.25 \sim 50$

Note: Variable range is different to ensure nonnegative profit. Rent range is given based on rent level of different case studies (Panero, et al, 2011). The estimated freight volume and number of deliveries for large carrier are based on the study of Nemoto (1997). Wage rate is defined according to minimum wage level (Department of Labor, 2012) and an employee with high annual income of $100,000 and working 40 hours per week.

4.5 Results

The experiment was carried out successfully, with four players. The bidding values and group consensus results are summarized in Table 15.

Table 15 Bidding Values and Group Consensus Results

Scenarios / Rounds	1	2	3	4	5	6	7	8
	(r_c, r_o)(\$/parcel) (f_g, f_o)(million \$) (w_r, w_o)(\$/hour)							
1	(2,2.5) (0,0) (29,29) *	(3,3.5) (0.75,1.5) (29,25)	(0.5,5) (0,0) (25,15)	(0.5,2) (0.6,0.7) (15,13)	(3,3.5) (0,0) (15,15) *	(3.5,8) (0.5,1.5) (20,15)	(1,5) (0,0) (19.7,17)	(0.5,2) (0.5,1) (18,12)
2	(2,3) (0,0) (28,27.5)	(4,3.5) (0.9,1) (25.9,27)	(0.5,3) (0,0) (24,16)	(0.5,1.5) (0.61,0.69) (14,12)	(2.8,3.6) (0,0) (15,13)	(3.5,5) (0.6,1) (19,17)	(0.5,3) (0,0) (50,17.7)	(0.5,1) (0.6,1) (10.5,12)
3	(1.5,3) (0,0) (28,27.5)	(3.5,3.7) (0.95,0.98) (26.5,27) *	(0.5,5) (0,0) (23,13)	(0.5,1) (0.625,0.69) (13,11) *	(3,3.5) (0,0) (16,13)	(3.5,4) (0.65,0.9) (19,17)	(0.5,2) (0,0) (30,15)	(0.5,1) (0.63,1) (20.5,11)
4	(3.5,3) (0,0) (28,27.1) *	(3.5,4.0) (0.94,0.98) (27,26.5) *	(0.5,1) (0,0) (22,7.25)	(0.4,1) (0.625,0.7) (12,10)	(3,3.5) (0,0) (15.5,14) *	(3.5,4.5) (0.675,0.8) (19,17)	(1,2) (0,0) (32,15)	(0.5,1) (0.65,0.9) (18.5,12)
5	(3,3.5) (0,0) (27,26.5) *	(3.7,4.5) (0.94,0.99) (26.5,26.5)	(0.5,3) (0,0) (21,8)	(0.4,0.9) (0.63,0.7) (12.5,10)	(3,3.5) (0,0) (16,13.5)	(3.6,4.1) (0.675,0.75) (19,17) *	(1,1.5) (0,0) (7.25,10)	(0.5,1) (0.67,0.8) (17,11)
6	(3,3.4) (0,0) (26.9,26.8) *	(4,4.2) (0.93,0.99) (26.5,26.5) *	(0.7,2.5) (0,0) (20,10)	(0.4,0.9) (0.63,0.7) (12.8,10.5)	(3,3.5) (0,0) (16.5,14.5) *	(3.6,4.3) (0.7,0.8) (19.2,16.8)	(1.2,1.7) (0,0) (10,9) *	(0.5,1) (0.69,0.79) (17,15)
7	(3.1,3.5) (0,0) (26.5,26.0) *	(4,4.2) (0.93,1) (26.5,26.5) *	(1,2) (0,0) (19,11)	(0.4,0.9) (0.63,0.7) (13,11) *	(3,3.5) (0,0) (17,14)	(3.1,4.1) (0.7,0.76) (19.3,17.2)	(1.2,2) (0,0) (12.2,10)	(0.5,1) (0.72,0.79) (17.1,15) *
8	(3.1,3.6) (0,0) (26.0,25.9) *	(3.9,4.5) (0.93,1.1) (26.3,26.0)	(1,2.5) (0,0) (18,10)	(0.3,0.9) (0.62,0.71) (13.5,11)	(3,3.5) (0,0) (17,15) *	(3.2,3.9) (0.69,0.76) (19.4,17.3)	(1.2,1.7) (0,0) (12.3,11) *	(0.4,1) (0.71,0.83) (20,14)
9	(3.1,8) (0,0) (25.5,25.5)	(4,4.4) (0.95,1.01) (26,25.0) *	(1.2,2.5) (0,0) (17,10)	(0.4,0.9) (0.63,0.7) (14,12) *	(3,3.5) (0,0) (17.5,14.5)	(3.3,3.9) (0.68,0.76) (19.5,17.4)	(1.1,1.7) (0,0) (15,10)	(0.4,0.9) (0.74,0.83) (21,19)
10	(3,8) (0,0) (25.5,25.0)	(4,4.5) (0.94,1.01) (25,24.0) *	(1.2,2) (0,0) (16,11)	(0.4,0.9) (0.63,0.7) (14,11.9) *	(3,3.5) (0,0) (18,15)	(3.4,3.9) (0.68,0.75) (19.6,17.6) *	(1.2,1.7) (0,0) (16,14) *	(0.4,0.9) (0.75,0.82) (22,20) *
Number of group consensus achieved	6	6	0	4	4	2	3	2

Note: The "*" indicates group consensus is reached.

Table 15 indicates that in all but the third scenario, consensus was achieved multiple times. However, the different number of group consensus achieved seemed not to have been caused by the different FCC conditions, but rather, by player experience. Players were very conservative in the first two scenarios, and became too drastic in scenario 3, and eventually grew more experienced and rational in the last several scenarios.

However, FCC factors such as organizational type, location choice and carrier size may have direct impacts on bidding prices and the profit earned by each player, which is analyzed by comparing different scenarios with control factors. The bidding and profit results in different scenarios are compared in Table 17.

Table 16 Impacts of Different Factors on Bidding and Profits

Factors	Scenarios compared	Average bidding prices (r: \$/parcel, f: million \$, w: \$/hour)	Average profits (million \$)	Analysis
Organization (private vs public-private)	1 vs 2 (outskirt, small carrier size)	r: 3.10 vs 4.00 f: 0.00 vs 0.97 w: 27.06 vs 26.08	P_c:0.42 vs 0.20 P_g:1.80 vs 0.86 P_o:-0.45 vs 0.82 P_r:1.05 vs 1.02	P_g decreases P_o increases
	3 vs 4 (center, small carrier size)	r: NA vs 0.68 f: NA vs 0.66 w: NA vs 12.49	P_c:NA vs 0.28 P_g:NA vs 1.18 P_o:NA vs 0.39 P_r:NA vs 0.52	NA
	5 vs 6 (outskirt, large carrier size)	r: 3.25 vs 3.75 f: 0.00 vs 0.71 w: 15.31 vs 18.30	P_c:1.23 vs 0.85 P_g:5.40 vs 4.72 P_o:1.94 vs 2.94 P_r:0.62 vs 0.74	P_g decreases P_o increases
	7 vs 8 (center, large carrier size)	r: 1.45 vs 0.70 f: 0.00 vs 0.77 w: 12.05 vs 18.53	P_c:0.26 vs 0.82 P_g:5.40 vs 4.67 P_o:0.74 vs 0.70 P_r:0.49 vs 0.75	P_g decreases P_o slightly decreases
Location (outskirt vs center)	1 vs 3 (private, small carrier size)	r: 3.10 vs NA f: 0 vs NA w: 27.06 vs NA	P_c:0.42 vs NA P_g:1.80 vs NA P_o:-0.45 vs NA P_r:1.05 vs NA	NA
	2 vs 4 (public-private, small	r: 4.00 vs 0.68 f: 0.97 vs 0.66 w: 26.08 vs 12.49	P_c:0.20 vs 0.28 P_g:0.86 vs 1.18 P_o:0.82 vs 0.39 P_r:1.02 vs 0.52	Lower r Lower w Lower P_o Lower P_r

	carrier size)			
	5 vs 7 (private, large carrier size)	r: 3.25 vs 1.45 f: 0.00 vs 0.00 w: 15.31 vs 12.05	P_c:1.23 vs 0.26 P_g:5.40 vs 5.40 P_o:1.94 vs 0.74 P_r:0.62 vs 0.49	Lower P_c Lower r Lower w Lower P_o Lower P_r
	6 vs 8 (public-private, large carrier size)	r: 3.75 vs 0.70 f: 0.71 vs 0.77 w: 18.30 vs 18.53	P_c:0.85 vs 0.82 P_g:4.72 vs 4.67 P_o:2.94 vs 0.70 P_r:0.74 vs 0.75	Lower P_c Lower r Lower P_o
Carrier size (small vs large)	1 vs 5 (private, outskirt)	r: 3.10 vs 3.25 f: 0.00 vs 0.00 w: 27.06 vs 15.31	P_c:0.42 vs 1.23 P_g:1.80 vs 5.40 P_o:-0.45 vs 1.94 P_r:1.05 vs 0.62	Higher P_c Higher P_g Higher P_o
	2 vs 6 (public-private, outskirt)	r: 4.00 vs 3.75 f: 0.97 vs 0.71 w: 26.08 vs 18.30	P_c:0.20 vs 0.85 P_g:0.86 vs 4.72 P_o:0.82 vs 2.94 P_r:1.02 vs 0.74	Higher P_c Higher P_g Higher P_o
	3 vs 7 (private, center)	r: NA vs 1.45 f: NA vs 0.00 w: NA vs 12.05	P_c:NA vs 0.26 P_g:NA vs5.40 P_o:NA vs 0.74 P_r:NA vs 0.49	NA
	4vs 8 (public-private, center)	r: 0.68 vs 0.70 f: 0.66 vs 0.77 w: 12.49 vs 18.53	P_c:0.28 vs 0.82 P_g:1.18 vs 4.67 P_o:0.39 vs 0.70 P_r:0.52 vs 0.75	Higher P_c Higher P_g Higher P_o

Note: The "NA" indicates data is unavailable.

According to Table 17, compared to purely private organizations, the private-public-partnership (PPP) decreases the government's profit. For example, government profit decreases by 12.6% from 5.40 million dollars to 4.72 million dollars when the organizational type changes, the FCC remains to be located in outskirt and carrier size remains small (scenarios 5 vs 6). The extreme case occurs in scenarios 1 vs 2 (when only organizational type changes while the FCC keeps to be in outskirt and carrier size remains large), whereby the government's profit decreases by 52.2%, from 1.80 million dollars to 0.86 million dollars. This result is in keeping with the negative relation between financial incentive and government profit indicated in equation (3).

Besides, the operator profit increases when the organizational type is private-public partnership, except for scenarios 7 vs 8 (which have a big increase in wage). The operator's profit increase ranges from 51.5% (scenarios 5 vs 6) to around 282% (scenarios 1 vs 2), which is consistent with the positive relation suggested in equation (2). One interesting finding is that local residents also seem to benefit from the private-public-partnership, as indicated by the higher wages. It seems that the financial incentive received by the operator is partially used to cover labor costs, which leads to the increase in wages (scenario 5 vs 6 and 7 vs 8). In general, the experiment suggests that the involvement of the public sector in FCC organization helps redistribute the benefits, and make the FCC more attractive for both the operator and local residents. However, an increase in operator profit does not necessarily mean lower rent. Rent increases from 15.4% (scenarios 5 vs 6) to 29.0% (scenarios 1 vs 2). From the perspective of policy design, using financial incentives does not seem to effectively lower rent for carriers.

In terms of the effect of FCC location, it is found that a FCC located in city outskirts is more attractive to carriers, as it translates into higher savings in travel distance and time (scenarios 5 vs 7 and 6 vs 8). The exception in scenarios 2 vs 4 is mainly the result of extremely low rent, which substantially lowers rental costs for carriers. Therefore, in order to attract carriers, operators tends to lower rent when a FCC is located in a central location, which consequently decreases the operator's profit (scenarios 2 vs 4, 5 vs 7 and 6 vs 8) and leads to lower wages (scenarios 2 vs 4 and 5 vs 7) and lower resident profits (scenarios 2 vs 4 and 5 vs 7). Outskirt location saves carriers' travel distance. Trucks do not need to enter cities to deliver goods. Besides, outskirt FCC tends to charge lower rent and has less impact on local residents. But this does not mean all FCCs need to be located in suburban areas. Some cities may establish FCC within cities through reusing brownfields and promoting utilization of short line railroads. Again, the experiment is simplified and results may vary from city to city under different conditions. In short, the experiment suggests that a central location is less attractive than an outskirt location for almost all stakeholders.

The analysis of carrier size indicates that carrier size (which can be considered as a proxy of FCC utilization rate) is positively correlated with total carrier profit and government profit. Larger carrier size increases both carrier cost savings and government profit. Of course, an operator's profit increases with carrier size too: higher FCC utilization rates means higher revenue for an operator. However, carrier size has no significant direct impact on rent and financial incentives. Rent remains fairly steady (scenarios 1 vs 5, 2 vs 6,and 4 vs 8) regardless of the carrier size increase. Financial incentive decreases by 26.8% in scenario 2 vs 6 and increases by 16.7% in scenarios 4 vs 8. Apparently, while every stakeholder benefits more or less from higher utilization rates, the operator is the biggest winner, as the high utilization rate allows the operator to have more negotiation power with other players.

The impacts of organizational type, location choice and carrier size on bid prices and profits are summarized in Table 17. Clearly, the most appropriate conditions for FCC development are public-private-partnership, outskirt location and larger carrier size.

Table 17 Qualitative Factor Impacts

Items	Group consensus	Carriers' Profit	Government's Profit	Operator's Profit	Residents' Profit	Rent	Wage
Organization (Change from private to private-public)	NI	+	−	+	+	NI	+
Location (Change from central to outskirt)	NI	+	NI	+	+	+	+
Carrier size (Increase)	NI	+	+	+	NI	NI	NI

Note: "+" means positive impact, "−" negative impact and "NI" no significant impact.

4.6 Summary

This study uses experimental economics to investigate the potential factors and their impacts on stakeholders' profit in freight consolidation center development decisions. Four players representing carriers, operators, government and residents bid on rent, financial incentives and wages under different scenarios, always aiming to maximize their own profit and achieve consensus. Profit function and relevant parameter values are defined for each player based on previous findings. Results indicate that organizational type, location and carrier size do not have a significant impact on reaching group consensus, primarily due to player inexperience. However, these factors do directly influence different player's profits. Outskirt location and larger carrier size lead to higher profits for both carriers and operators. An outskirt location also increases residents' profits, rent and wages. This study develops an insightful framework to investigate FCC development, and the relative effects of various factors. Of course, along with the innovations of this study, some limitations exist. In order to utilize findings from previous studies, profit functions are simplified. Estimated parameter values also rely heavily on the LPR case study. Experiment results may be sensitive to parameter value changes. For example, the freight volume and the number of deliveries per year may vary according to the size of FCC and/or FCC's geographic locations, leading to different profit structures and different results. Besides, some subtle interactions between players could not be captured fully. For example, there is no direct link between local residents (who reside closely to the FCC) and government (which represents the interest of the entire involved region). In other words, local residents' opinions are not conveyed directly to, or considered influential by the government. The monitoring of the experimental process also suggests that the results, to a certain extent, are influenced by the players' experience. The players did not fully understand the cost structure and its influence on their bonuses until after a few iterations. Several test iterations could be run in the future experiment.

Future work in this type of study will include the identification and development of more theoretically grounded cost functions, and more robust parameter values from empirical studies. Player training and the selection of "burnt" samples (i.e., discarded experiment results due to players' misunderstanding of the problem) are also necessary. Moreover, future work could benefit from the incorporation of more factors and more players, as FCC development decisions are affected by many other factors, such as local economy and transportation conditions. There could also be multiple carriers with heterogeneous features, and different groups of residents.

The analysis prototype developed here allows for a preliminary investigation of the FCC development decision process. Findings in this study will help practitioners gain a better understanding of the interactions between stakeholders involved in the decision process. With some refinement, this insightful framework can be expected to effectively improve FCC planning and decision-making, and contribute to the development of more sustainable freight transportation systems.

5. CONCLUSIONS

The report investigates the cooperative multicarrier delivery initiatives and assess its impacts on a disaggregate level from two parts. The first part examines current freight delivery patterns in New York City. A survey is designed and conducted to collect detailed delivery information including truck configuration, delivery route information, truck load factor, operation costs, as well as truckers' willingness to use FCC. A set of statistical models are developed to investigate the relationship between these factors, especially the factors influencing dwell time, load factor, departure time and total number of stops, which are key indicators determining efficiency and feasibility of FCC implementation. Results from this study will provide important insights into freight delivery patterns in New York City and eventually serve as key reference for the city's freight policy design.

Future work for the first part includes collecting more detailed data. The current dataset has a very limited sample size and freight delivery information, and a number of partial responses. In addition, other models could be tested and current models could be refined to provide more comprehensive results.

The second part uses experimental economics to investigate the potential factors and their impacts on stakeholders' profit in freight consolidation center development decisions. Profit functions are defined for involved stakeholders, and based on those profit functions, four players--representing carriers, operators, government and residents--bid on rent, financial incentives and wages in order to maximize their own profits. Eight scenarios are analyzed and compared to determine potential influential factors and appropriate conditions for FCC decision-making. Results show that public-private-partnership lowers rent and increases wage rate, which leads to higher carriers, operator's and residents' profits. Central location lowers rent, wages, financial incentive and all stakeholders' profits. Larger carrier size benefits all stakeholders. In conclusion, the appropriate conditions for FCC development would be public-private-partnership, outskirt location and larger carrier size.

Future work for the second part includes improving profit functions for all players. Current profit functions are simplified. More variables could be incorporated. In addition, multiple carriers with heterogeneous features, and different groups of residents could also be considered in future games.

6. REFERENCES

Abelairas-Etxebarria, P., & Astorkiza, I. (2012). "Farmland prices and land-use changes in periurban protected natural areas." *Land Use Policy*, 29(3), 674-683.

Arnott, R., Palma, A. d., & Lindsey, R. (1993). "A Structural Model of Peak-Period Congestion: A Traffic Bottleneck with Elastic Demand." *The American Economic Review*, 83(1), 161-179.

Bhat, C. R. (1996). "A hazard-based duration model of shopping activity with nonparametric baseline specification and nonparametric control for unobserved heterogeneity." *Transportation Research Part B: Methodological*, 30(3), 189-207.

Best Urban Freight Solutions (BESTUFS). (2007). "Best practice update 2007 Part I. Road pricing and urban freight transport."
<http://www.bestufs.net/download/BESTUFS_I/clustering_reports/BESTUFS_I_Results_clustering_report.pdf> (July 5, 2012)

Browne, M., Sweet, M., Woodburn, A., Allen, J. (2005). "Urban Freight Consolidation Centres. Final Report". *Department of Transport*, UK.

Bureau of Labor Statistics (BLS). (2012). "CPI Inflation Calculator" <http://www.bls.gov/data/inflation_calculator.htm> (July 10, 2012).

Chow, J. J., Yang, C., & Regan, A. (2010). "State-of-the art of freight forecast modeling: lessons learned and the road ahead." *Transportation*, 37(6), 1011-1030.

Davis, D.D. and Holt, C.A. (1993). *Experimental Economics*. P.U. Press, New Jersey.

Duflo, E. (2006). *Field Experiments in Development Economics*. MIT.

van Duin, J. H. R., Quak, H., & Muñuzuri, J. (2010). :New challenges for urban consolidation centres: A case study in The Hague.: *Procedia - Social and Behavioral Sciences*, 2(3), 6177-6188.

Yen to Dollar. (2012). "Exchange rate average." < http://www.x-rates.com/average/?from=JPY&to=USD&amount=180&year=2012> (April 24, 2013)

Federal Energy Regulatory Commission (FERC). (2012). "SO2 Allowance Spot Prices and NOx Allowance Spot Prices." <http://www.ferc.gov/market-oversight/othr-mkts/emiss-allow/othr-emns-no-so-pr.pdf > (July 11, 2012)

Fleming, T. & Harrington, D.P. (1991). *Counting processes and survival analysis*. John Wiley & Sons, New York.

Garrido, R. A., & Mahmassani, H. S. (2000). "Forecasting freight transportation demand with the space–time multinomial probit model." *Transportation Research Part B: Methodological*, 34(5), 403-418.

Google Finance. (2012). "Euro to US Dollar." < https://www.google.com/finance?hl=en&biw=1298&bih=793&q=CURRENCY:EURUSD&sa=X&ei=1RIIUJPiIYWo8QT6iY2-BA&sqi=2&ved=0CH0Q5QYwAA> (July 19, 2012)

Hellström, J. (2006). "A bivariate count data model for household tourism demand." *Journal of Applied Econometrics*, 21(2), 213-226.

Holguín-Veras, J., Sánchez, I., González-Calderón, C., Sarmiento, I., & Thorson, E. (2011). "Time-Dependent Effects on Parameters of Freight Demand Models." *Transportation Research Record*, 2224, 42-50.

Holguín-Veras, J. *et al*. (2010). "Integrative Freight Demand Management in the New York City Metropolitan Area." Rensselaer Polytechnic Institute, Troy, NY, Final Report.

Holguín-Veras, J., M. Silas and J. Polimeni (2008). "An Investigation on the Attitudinal Factors Determining Participation in Cooperative Multi-Carrier Delivery Systems." *Innovations in City Logistics IV*. E. Taniguchi and R. Thomson, Nova Science Publishers: 55-68.

Holguín-Veras, J. (2008). "Necessary conditions for off-hour deliveries and the effectiveness of urban freight road pricing and alternative financial policies in competitive markets." *Transportation Research Part A: Policy and Practice*, 42(2), 392-413.

Holguín-Veras, J. and Polimeni, J. (2006). "Potential for Off-Peak Freight Deliveries to Congested Urban Areas." Rensselaer Polytechnic Institute, Troy, NY, Final Report.

Holguin-Veras, J. and E. Thorson. (2003). "The Role of Experimental Economics in Freight Transportation Research: Preliminary Results of Experiment." Proceedings of the Association for European Transport's Annual Conference, Strasbourg.

Holguin-Veras, J., List, G.F., Meyburg, A.H., Ozbay, K., Teng, Hg. and Yahalom, S. (2001). "An assessment of methodological alternatives for a regional freight model in the New York Metropolitan Transportation Council (NYMTC) region." Project report of University.

Holguin-Veras, J. & Thorson, E. (2000). ''An investigation of the relationships between the trip length distributions in commodity-based and trip-based freight demand modeling.'' *Transportation Research Record*, 1707, 37–48.

Transportation Research Center (UTRC) and Federal Highway Administration (FHWA). (http://www.utrc2.org/sites/default/files/pubs/regional-freight-final_0.pdf)

Kalbfleisch, H. & Prentice, R.L. (1980). *The statistical analysis of failure time data*. John Wiley & Sons, New York.

Kayikci, Y. (2010). "A conceptual model for intermodal freight logistics centre location decisions." *Procedia - Social and Behavioral Sciences*, 2(3), 6297-6311.

Kiefer, N.M. (1988), "Economic duration data and hazard functions." *Journal of Economic Literature*, 26, 646−679.

Johnson, L. *et al*. (2011). "2011 Carbon Dioxide Price Forecast." Synapse Energy Economics, Inc., 13-14.

Lewis, A., M. Fell, Palmer, D. (2010). "Freight Consolidation Centre Study*." Department for Transport in association with Transport and Travel Research Ltd*. <http://www.dft.gov.uk/publications/freight-consolidation-centre-study> (July 5, 2012)

Lin, S.-W., & Ben, T.-M. (2009). "Impact of government and industrial agglomeration on industrial land prices: A Taiwanese case study." *Habitat International*, 33(4), 412-418.

Lindholm, M. (2010). "A sustainable perspective on urban freight transport: Factors affecting local authorities in the planning procedures." *Procedia - Social and Behavioral Sciences*, 2(3), 6205-6216.

Moon, I. K., Cha, B. C., & Lee, C. U. (2011). "The joint replenishment and freight consolidation of a warehouse in a supply chain." *International Journal of Production Economics*, 133(1), 344-350.

Nam, D., & Mannering, F. (2000). "An exploratory hazard-based analysis of highway incident duration." *Transportation Research Part A: Policy and Practice*, 34(2), 85-102.

National Cooperative Highway Research Program Report (NCFRP) 606. (2008). Forecasting Statewide Freight Toolkits. Transportation Research Board, Washington D.C.

Nemoto, T. (1997). “Area-wide inter-carrier consolidation of freight in urban areas”. *Transport Logistics*, 1(2), 87-101.

Olsson, J., & Woxenius, J. (2012). “Location of Freight Consolidation Centres Serving the City and Its Surroundings”. *Procedia - Social and Behavioral Sciences*, 39(0), 293-306.

Panero, M.A., Shin, H.-S. and Lopez, D.P. (2011). “Urban Distribution Centers – A Means to Reducing Freight Vehicle Miles Traveled.” New York State Energy Research and Development Authority (NYSERDA). <https://www.dot.ny.gov/divisions/engineering/technical-services/trans-r-and-d-repository/C-08-23_0.pdf?nd=nysdot> (July 5, 2012)

de Palma, A., & Lindsey, R. (2011). “Traffic congestion pricing methodologies and technologies.” *Transportation Research Part C: Emerging Technologies*, 19(6), 1377-1399.

Rich, J., Holmblad, P. M., & Hansen, C. O. (2009). “A weighted logit freight mode-choice model.” *Transportation Research Part E: Logistics and Transportation Review*, 45(6), 1006-1019.

Riedl, A. (2009). “Behavioral and Experimental Economics Can Inform Public Policy: Some Thoughts.” Cesifo Working Paper.

Tamagawa, D., Taniguchi, E., & Yamada, T. (2010). Evaluating city logistics measures using a multi-agent model. Procedia - Social and Behavioral Sciences, 2(3), 6002-6012.

Thompson, R. G., & Hassall, K. (2005). “A methodology for evaluating urban freight projects.” *Proceeding of the 2005 Institute of City Logistics Conference*, Langkawi, Malaysia.

Tsekeris, T., & Vob, S. (2009). “Design and evaluation of road pricing: state-of-the-art and methodological advances.” *Netnomics : Economic Research and Electronic Networking*, 10(1), 5-52.

Turnquist, M.A. & Jordan, W.C. (1986). “Fleet sizing under production cycles and uncertain travel times.” *Transportation Science*, 20 (4), 227-236.

U.S. Department of Labor. (2012). "Minimum Wage " <http://www.dol.gov/dol/topic/wages/> (July 16, 2012).

Ulfarsson, G., & Shankar, V. (2003). “Accident Count Model Based on Multiyear Cross-Sectional Roadway Data with Serial Correlation.” *Transportation Research Record*, 1840, 193-197.

Yamada, T., Russ, B. F., Castro, J., & Taniguchi, E. (2009). “Designing Multimodal Freight Transport Networks: A Heuristic Approach and Applications.” *Transportation Science*, 43(2), 129-143.

Yang, H., & Huang, H.-J. (1998). “Principle of marginal-cost pricing: how does it work in a general road network?” *Transportation Research Part A: Policy and Practice*, 32(1), 45-54.

Zhou, Y., Wang, X. (2013). “The Decision-Making Process for Developing Urban Freight Consolidation Centers: An Analysis with Experimental Economics”. *Journal of Transportation Engineering*. DOI: 10.1061/(ASCE)TE.1943-5436.0000632.

7. APPENDIX: SURVEY FORMS

Information to be observed visually:

Location of the vehicle	Time of survey	Surveyor

1. Number of axles: ______________________ ; Number of tires:
2. Vehicle Configuration: ______________________ ; (Samples provided van, single unit, tractor-trailer)
3. Estimated load factor: ______________________ % of capacity filled with cargo;
4. Name of the company: ______________________ ; Zip Code:
5. Commodity Type: ______________________ ;
6. Parking Time: Arrived: ______________ Departed: _______________.

Note:
If possible to be done discreetly, take a picture of the vehicle.

Survey Questions for Driver

Part 1: Delivery related

I. Load Status:

Full Load in First stop?	Load Varies Every time?	Reload or not?
☐ Yes: 100%-95% ☐ No, how full: o 95%-80% o 80%-50% o 50%-30% o Less than 30%	☐ Yes ☐ No	☐ Yes ☐ No If yes, how often: ________

II. Times:

Leave depot	First Stop	Final stop
Exact Time: ____________________ **Or:** ☐ Midnight-6 A.M ☐ Morning(6 A.M-12 A.M) ☐ Afternoon(12 P.M-6 P.M) ☐ Evening(6 P.M-Midnight)	Exact Time: ____________________ **Or:** ☐ Midnight-6 A.M ☐ Morning(6 A.M-12 A.M) ☐ Afternoon(12 P.M-6 P.M) ☐ Evening(6 P.M-Midnight)	Exact Time: ____________________ **Or:** ☐ Midnight-6 A.M ☐ Morning(6 A.M-12 A.M) ☐ Afternoon(12 P.M-6 P.M) ☐ Evening(6 P.M-Midnight)

III. How many stops:

Already completed	Yet to be completed	Varies daily or not?
Number : ___________;	Number : ___________;	☐ Yes Average Number of stops : ; ☐ No

IV. Only delivery in Manhattan?

- ☐ Yes
- ☐ No, other place:
  - o Brooklyn
  - o Bronx
  - o Queens
  - o Long Island
  - o Staten Island
  - o Other:________;

V. Can you estimate the **average distance** you traveled:_________Miles/day

VI. Route Traveled

Origin	Major Roads Used
What is your origin:	o I 78 o I 95 o I 278 o I 495 o Other:________

Crossing		
Tunnel o Queens Midtown o Lincoln o Holland o Brooklyn Battery	**or**	Bridge o George Washington o Third Avenue o Willis Avenue o Triborough o Queensborough o Williamsburgh o Manhattan o Brooklyn

Part 2: Company related

I. Company: **<u>if unobservable</u>**

Name of your company	Type of goods

II. Can you estimate:

Employees of your company	Vehicle fleet
Exact No. ______________ **Or:** ☐ **≤ 5** ☐ 5-24 ☐ 25-49 ☐ **≥ 50**	Exact No. ______________ **Or:** ☐ 1 ☐ **≤ 5** ☐ **≤ 10** ☐ **≤ 20** ☐ Above 20

Part 3: Cost related

I. Parking

Parking Cost in Manhattan	Parking fine	Double Park
How much: ☐ Daily: $; ☐ Weekly : $; ☐ Monthly: $ ________;	How often did you receive : ☐ Daily: times ☐ Weekly: times ☐ Monthly: times	How often you have to double park: ☐ Never ☐ 1-5 times/day ☐ 5-10 times/day ☐ Always ☐ Other: times

II. Fuel

Can you estimate your **daily fuel cost**: $ ___________;

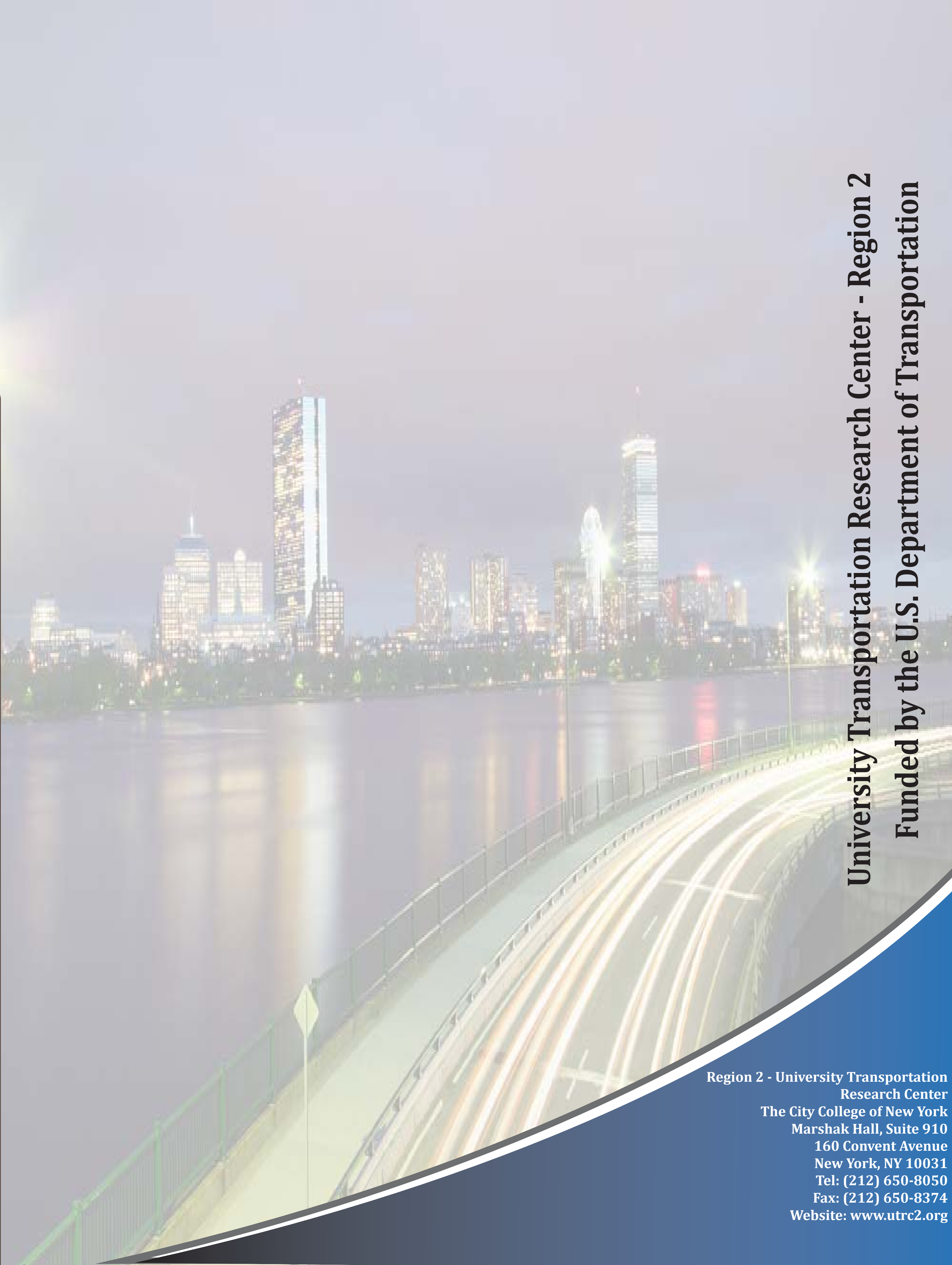
III. Joint distribution

How likely do you think your company will use joint distribution if necessary facilities provided?

Please rate:

1 Definitely not
2 Unlikely
3 Neither likely nor unlikely
4 Possible
5 Likely

Total: 21 questions



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