A BEHAVIORAL MICRO-SIMULATION FORMULATION FOR THE DESIGN OF OFF-PEAK DELIVERIES POLICIES IN NEW YORK CITY

A Final Report Submitted By:
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1. INTRODUCTION

Urban vehicle traffic congestion is a serious economic problem in the New York City area. In addition to making traveling conditions difficult and more time consuming, traffic congestion makes business operations more costly, and it decreases environmental conditions. Examples of increased costs includes longer traveling times for employees hired to make deliveries, and higher operating costs from facility operations; while decreasing environmental factors includes poor air quality and increased pollution levels from vehicle emissions. This decrease in business and environmental conditions subsequently makes metropolitan areas like Manhattan less attractive for conducting business and living. Traffic congestion has also caused many citizens, politicians, and urban planners to be concerned about urban congestion, which has subsequently created the formations of many public and private sector collaborations to discuss ways to mitigate the problem. In general, in most congested areas in the world, local business, corporate and government officials have expressed concerns about this problem, which is being brought about by population and economic expansion. As a by product of these discussions, there have been many attempts to improve travel conditions. Some of these efforts included: the implementation of toll roads, the expansion of public transportation systems, and the increase of the number of urban roadways and interstate highways. All of these solutions, while showing the promise to alleviate traffic congestion in the short term, need the assistance of other initiatives in order to reduce this problem.

Another method in reducing traffic congestion in New York City, on the business and corporate levels of operations, is to control the delivery times, in particular, the actions of accepting and shipping of goods in Manhattan. This is because the delivery activities taking place during regular-weekday business hours (i.e. Monday through Friday, between the hours of 6AM and 6PM) have a lot of influence on traffic congestion *(1)*. More specifically, it has been proposed to have carriers (i.e., trucking companies, third party logistics companies, and other carriers of goods with delivery trucks) shift part of their shipping operations to the *off-peak* hours of the day (between the hours of 6PM and 6AM). This solution has the promise to reduce traffic congestion and parking demand levels, since for example, the length of one semi-trailer truck, with an attached fifty-three foot trailer, occupying about 70 feet, occupies about 3 automobile lengths of highway space. This is a major problem when dealing with high traffic levels during the peak hours, which is a time when commuters heavily occupy metropolitan streets and highways with automobiles, and truckers are continuously circling around the vicinity of their delivery stops looking for space to park and load or unload their shipments. This truck traffic in urban areas also leads to a higher demand for parking spaces *(2)*. Moreover, the shifting of delivery times has the potential to reduce traffic congestion, and to also improve air equality, by reducing human exposure to pollutants, and thus minimizing the number medical cases of: chronic bronchitis, asthma, respiratory infections, and even cancer (3).

Receiving and shipping of goods outside of regular business hours, during the time period between of 6PM and 6AM is referred to as *off-peak deliveries (OPD)*. While the practice of OPD is not the complete answer in solving the urban traffic congestion problem, it can make significant contribution to reducing peak-hour traffic. Policies to promote OPD have been adopted in Europe and Asia, where its practices has shown a noticeable difference in travel conditions. Furthermore, this shift in delivery times needs two stakeholders, *receivers* and *carriers*, to agree to participate in off-peak delivery operations, since both entities solely control delivery scheduling. *Receivers*, who act as the customers in this business transaction, would accept goods and services from *carriers* during non traditional business hours of the day, and in turn, *carriers* can increase their productivity by traveling at faster speeds and moving more goods and services to receivers, the customers, in less time. In return for receivers and carriers participating in off-peak deliveries operations, government officials would give various economic incentives (i.e., tax deductions, shipping discounts, toll discounts, and traveling rewards), with the projected result being that peak-period traffic congestion would become reduced in major urban regions, because there would be less truck traffic on the network. Moreover, in order to gather a better understanding of policies for off-peak deliveries programs, policy analysis techniques are needed to understand how to increase the participation in off-peak deliveries by receivers and carriers.

The fundamental purpose of this paper is to gain a better understanding of how to increase the participation in off-peak deliveries, through the use of behavioral simulation and economic incentives. Secondary goals of this paper are to understand how different characteristics and market segments of receivers and carriers influence the participation of off-peak deliveries. Lastly, this form of policy and economic analyses in this paper will be used to understand how receivers and carriers interact when agreeing on the scheduling of deliveries in congested urban areas.

This document contains six sections including this introduction. The next section is a literature review of publications on off-peak deliveries. The third section discusses the scope of work and objectives pertaining to this behavioral micro-simulation formulation. Section four describes the behavioral simulation formulation, particularly the policy incentives used, and the micro-simulation of receivers and carriers on the decision to participate in off-peak deliveries. Section five presents some key findings from the proposed behavioral simulation formulation, and the last section discusses some conclusions gathered from this formulation towards urban freight transportation policy and delivery scheduling.

2. LITERATURE REVIEW

This literature review gives brief accounts from previous findings and studies on off-peak deliveries.

2.1 Literature on Off-Peak Deliveries

The first historical account of off-peak deliveries on record stems from Julius Caesar’s implementation of a law that prohibited commercial deliveries during the daytime in Ancient Rome, which was called the Lex Julia Municipalis or “The Julian Law of Municipalities” (circa 48 B.C.). The Lex Julia Municipalis also caused Roman commoners to complain about noise pollution and the increase in evening traffic congestion in the metropolitan areas of Rome *(4)*.

There have been other notable studies conducted throughout the world on the implications of shifting freight deliveries to the off-peak hours in urban areas. However, the most recent and pertinent of these off-peak deliveries studies occurred in the New

York City area, particularly focusing on the Manhattan area *(5)*. The goal of this study was to understand how policies targeting receivers located in Manhattan, and carriers making deliveries to this area would affect the shift in delivery operations to the off-peak hours of the day; this was done with the intent of reducing truck traffic in the Manhattan area during normal business hours of the day *(5)*.

The first element of the preliminary findings focused on outreach efforts targeting private sector receivers and carriers, which came in the form of: focus groups, in-depth interviews, and internet surveys *(6)*. From the focus group discussions, it was found that: (a) participants were unsure about the effectiveness of toll differentials or other incentives that might increase off-peak deliveries; b) truckers indicated that receivers are more concerned with accepting goods in a timely fashion than how many hours the truckers drive; and (c) receivers would only accept off-peak deliveries when given incentives to do so *(6)*. The in-depth interviews indicated that restaurants are good targets for off-peak deliveries because of their extended hours of operations, and the receivers controlled the participation in off-peak activities because they control the delivery schedules for the carriers *(6)*. The final component of the outreach efforts, the internet surveys, upheld the conclusions acquired from the focus group discussions and in-depth interviews, and suggested that avoiding parking fines, increased productivity, and tax incentives are elements that could make off-peak deliveries attractive to both receivers and carriers. The analyses done from the in-depth interviews also suggested that increased operation costs and lack involvement by receivers can prevent the participation in off-peak deliveries for both receivers and carriers *(6)*.

The second element of the preliminary findings of the study focused on receivers, particularly those establishments that were classified as restaurants and drinking places, which amounts to more than 6,500 establishments. It was found from this analysis that: (a) 40% of the establishments have control over their delivery times, and 38% of the companies collaborate with their distributors in determining the delivery times of their shipments; (b) restaurants accept more than 6 deliveries per day; (c) the number of deliveries that these receivers generated was a function of the company location, number of employees, and number of customers; (d) restaurants were in favor of accepting off-peak deliveries in exchange for tax deductions (55.4% approval rate) and government subsidies (57.8% approval rate), but were less in favor of accepting off-peak deliveries for tax cuts (46.3% acceptance rate) and lower shipping charges (33.3% acceptance rate); and (e) receivers in commercial areas are more receptive to accepting larger and more time consuming deliveries during the off-hours *(5)*.

Separate analyses of receivers and carriers were lastly conducted to understand the other factors that influenced their individual choices to participate in off-peak deliveries *(1) (7)*. For receivers, it was found that they displayed increased levels of willingness to participate in off-peak deliveries operations when given certain higher levels of economic incentives (e.g. tax deductions and shipping discounts); and receivers of: food, alcohol, wood/lumber, metal, paper products, and medical supplies are considered good market targets for fostering the implementation of an off-peak deliveries program in Manhattan *(1)*. Carriers displayed the higher levels of willingness to participate in off-peak deliveries when given higher toll discounts and financial rewards for off-peak travel; and as the percentage of customers requesting off-peak deliveries increased so did the number of carriers likely to participate in these OPD *(7)*. Also, carriers of food, wood/lumber, metal, computers/electronics, textiles/clothing, and furniture are also considered good market targets for doing off-peak deliveries *(7)*. It was also concluded that large traffic generators in Manhattan (i.e. Grand Central Terminal and Penn Station) are good target areas for an off-peak deliveries program *(1) (7)*.

A product of this research project was to develop an outline of the receiver-carrier interactions that determine the decision to participate in off-peak delivery an activity, which was first presented Holguín-Veras, et, al, and is displayed in Figure 1 *(1)*. This figure shows that the receivers have the leading influence on the decision to do off-peak deliveries; this is because they are considered the customers in this situation *(1) (7)*. It also displays that factors like the off-peak deliveries incentives, operational decisions, and other price signals have influences on receivers' decision on delivery times, as well as the joint decision to participate in this activity made by receivers and carriers.

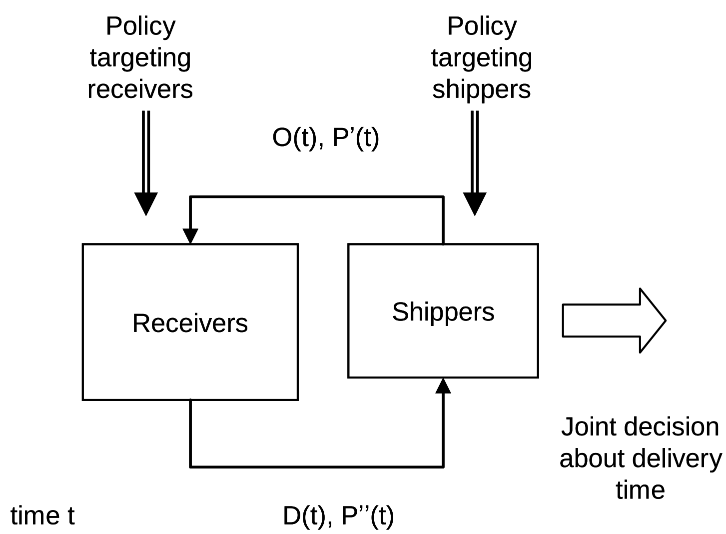

Figure 1: Modeling schematic for understanding the receptiveness of off-peak deliveries (1).

The proposed outline was simplified by assuming a systematic process to enable the use of two sets of discrete choice models representing receivers' and carriers' decisions pertaining to off-peak deliveries. However, little has been done in this formulation in accounting for the geographic locations of receivers and carriers, carrier costs, in exploring the bargaining influences on the off-peak deliveries' market, and the cost and capacity constraints experienced by carriers. The overall uncertainty about the effectiveness of off-peak deliveries is still prevalent because there is a need for a more detailed analysis of receivers' and carriers' receptiveness to economic incentives, using more thorough policy analysis techniques, and the previously mentioned factors.

Other findings were found from the primary study efforts on the effectiveness of off-peak deliveries in New York City, which resulted from the analyses of larger and more diverse populations of receivers and carriers. The analyses done recognized that the willingness of carriers to participate in off-peak deliveries is dependent upon the participation of the receivers *(1)*. This means that the higher the rate of participation in off-peak deliveries by receivers, the more likely the carriers would be to shift their delivery schedules to the off-hours of the day. Moreover, it was shown that the receivers' receptiveness to accept off-peak deliveries is a function of the economic incentive scenarios proposed, meaning that the higher the proposed incentive the more likely the receivers are to participate in such a program *(1)*. Other key findings from this analysis highlighted the descriptive statistics and behavioral modeling of receivers' and carriers' receptiveness to policies that might increase the number of off-peak deliveries, using the discrete choice models derived from this work. These analyses revealed that: (a) 4.09% of the goods accepted by receivers in Manhattan are during off-peak hours, while 11.76% of the goods delivered by the carriers are during the off-peak hours of the day; (b) receivers were most likely to accept off-peak deliveries when given tax deductions for one employee assigned to accept off-peak deliveries; and, (c) carriers were likely to participate in OPD when given toll discounts for off-peak deliveries and financial rewards for making off-peak deliveries *(1) (7)*.

3. SCOPE OF THE PAPER

As discussed in the sections of the *Literature Review* section of this paper, the previous research done mainly uses discrete choice model analyses to estimate market shares and to measure the effectiveness on the choice to participate in off-peak deliveries. These methods have significant limitations in what they could consider as impacting the decisions to participate in off-peak deliveries. First, discrete choice models cannot truly account for geographic factors such as: (a) carrier delivery route distances in reference to the locations of their receivers; (b) receiver and carrier costs accumulated from accepting and making deliveries during this period of the day. Generally speaking, the consideration of the geographic location is very important because it dictates logistic operations and delivery routes for carriers. Also for receivers and carriers, the costs for participating in off-peak deliveries is a driving factor in making a final decision about delivery scheduling.

Furthermore, the consideration of other real-world conditions should be added to the analyses, since their impact on off-peak deliveries is also unclear. These factors includes the consideration of: (a) budget and working constraints imposed on receivers and carriers; (b) delivery routes selection; (c) productivity levels (e.g., travel time, and traveling speed estimations during regular and off-peak hours); and (d) other government regulations and policies that interact with and limit off-peak hour delivery activities. In conclusion, to understand the effectiveness of off-peak delivery operations, there is a need to simultaneously consider as many of these factors as possible. This can be done through the use of a simulation-optimization model, which will assist in developing a clearer picture on how this shift in delivery scheduling affects regional freight transportation and other transportation conditions.

In addition to fulfilling a need of gaining an understanding of the interaction between receivers and carriers, there is also a need to better understand how economic incentives gives to both receivers and carriers. The purpose of the research in this paper is to assist in developing the framework on how to incorporate economic incentives which would foster a shift in off-peak delivery activities.

4. METHODOLOGY

Before getting into the details of the simulation model, it is important to acknowledge the origin of the data used in this research. The data originates from a project funded by the New York State Department of Transportation. Two hundred receivers located in Manhattan and two hundred carriers making deliveries to receivers in Manhattan were interviewed in 2005; both stakeholders gave information about their: (a) receiving and shipping patterns, (b) operations and flexibility, (c) receptiveness to OPD when given economic incentives, and (d) company characteristics.

The basic outline of this simulation approach is an expansion of Figure 1, and is shown in Figure 2. Figure 2 aims to consider the full range of interactions shown in the figure, and would overcome the limitations of previous approaches by Holguín-Veras et al. that had to assume a sequential decision making process for participating in off-peak deliveries *(7)*. The key components in this figure are the *receiver incentive used for simulation*, the *carrier-receiver selection process*, the *behavioral simulation for receivers and carriers*, and the *updating of* receivers' and carriers' policies to understand how to jointly participate in off-peak deliveries. In this schematic, the receivers' decision to accept off-peak deliveries is solely influenced by the given policy incentive. In Figure 2, it should also be recognized that the decision for carriers to do off-peak deliveries is directly influenced by the receivers' decisions of whether or not to accept off-peak deliveries (denoted Π_r), and the delivery costs that carriers must consider. Finally, Figure 2 is concluded with an updating process. The overall goal of this simulation is to understand how the economic incentives given to receivers and other factors influences carrier participation in off-peak deliveries. This complete micro-simulation formulation is methodically and mathematically sound under the conditions outlined for conducting Monte Carlo (i.e. random number generation) simulations *(8)*.

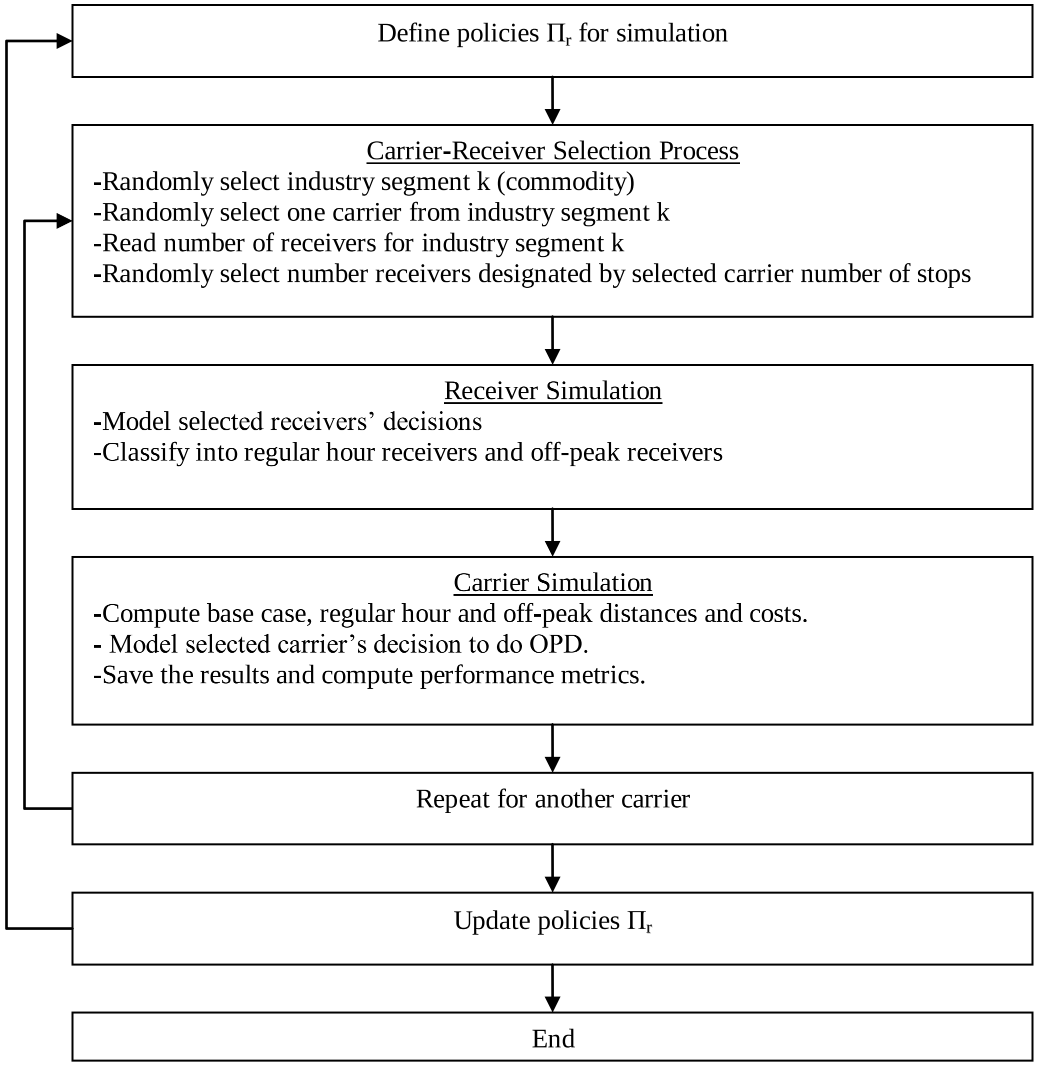

Figure 2: New modeling schematic for understanding the receptiveness to off-peak deliveries

In more detail, receivers and carriers make systematic decisions on whether or not to participate in off-peak deliveries is based on their receptiveness to particular incentives, and the costs incurred from shifting their delivery schedules. The simulation of the decision of whether or not do off-peak deliveries is discussed for both the receivers and the carriers. Then the optimization component, which will be used to improve the amount of participation in off-peak deliveries, will be analyzed. The following sections discuss in detail the *policy incentives*, the *carrier-receivers selection process*, the *behavioral simulation of receivers*, the *behavioral simulation of carriers*.

The incentive provided to receivers is denoted by Π_r, and is a tax deduction given for one worker to accept deliveries during the off-peak hours, ranging from one thousand to fifty-thousand dollars. This incentive was used for this micro-simulation formulation because they were previously found as the most efficient in fostering off-peak deliveries *(1) (7)*. The tax deduction was also used in this formulation to understand how the participation in off-peak deliveries by carriers changes when receivers were encouraged to change the receiving schedules.

The carrier-receivers selection process is simple to follow. The objective here is to use a synthetic population of carriers to understand how the delivery scheduling of commodities are influenced. For this reason, the industry segments listed in Table 1 generate the most truck traffic of goods transported into the Manhattan area, and was used for this simulation process *(10)*. The exact process starts in this manner; first, a random number is generated between 0 and 1, and depending on where the number lies within the cumulative distribution of truck traffic displayed in Table 1, an industry segment is selected. Next, a random carrier is randomly selected from the industry segment's population. Lastly, using the selected carrier's number of stops, that number of receivers is selected from the corresponding industry segment's population. This is the set of customers that the behavioral simulation of receivers will be used for. The carrier will then use the decisions of this of receivers to estimate delivery costs during regular and off-peak hours, and make a decision on the participation of off-peak activities.

Table 1: Empirical and Cumulative distributions of truck traffic by industry segment into New York City (10)

Industry Segment	Empirical Percentage	Cumulative Percentage
Plastics	0.57%	0.57%
Jewelry/Art	1.16%	1.73%
Chemicals	1.70%	3.43%
Wood/Lumber	2.08%	5.51%
Medical Supplies	2.31%	7.82%
Non Alcoholic Beverages	2.56%	10.38%
Alcoholic Beverages	2.56%	12.94%
Petroleum/Coal	3.40%	16.34%
Stone/Concrete	4.17%	20.51%
Paper	4.92%	25.43%
Printed Material	4.92%	30.35%
Computers/Electronics	5.31%	35.66%
Office Supplies	5.31%	40.97%
Textiles/Clothing	6.13%	47.10%
Metal	6.48%	53.58%
Furniture	6.60%	60.18%
Household Goods	7.08%	67.26%
Machinery	8.10%	75.36%
Food	17.90%	93.26%

4.1 Receiver Behavioral Simulation

The micro-simulation of receiver behavior is also driven by the tax deduction behavioral model estimated in Holguín-Veras, et al. *(10)*. The discrete choice model used for this formulation is discussed in Holguín-Veras et al., *(10)*, and is displayed in Table 2. The model was found using information given from receivers being asked about their willingness to accept OPD when given a tax deduction as an incentive. The model is a function of the tax deduction variable (TDEDUCT), reasons for not accepting OPD, and interaction terms between the policy variable and the commodity types: wood/lumber, alcohol, paper, medical supplies, food, printed material, and metal *(10)*.

Table 2: Binary logit model for receiver tax deduction scenario (10)

Variable	Name	Coefficient	t-value
Utility of off-peak deliveries:	C1CHOICE		
A tax deduction for an employee assigned to OPD	TDEDUCT	8.392E-05	1.410
Reasons for not receiving OPD			
No access to building/freight entrance after hours	REASON1	-1.234	-1.571
Additional costs to the business if accepting more OPD	COST	-0.888	-3.232
Interferes with normal business	REASON2	-0.591	-1.208
Policy interaction terms			
Tax deduction for receivers of Wood/lumber	TDCOM8	6.968E-04	2.219
Tax deduction for receivers of Alcohol	TDCOM4	4.356E-04	2.209
Tax deduction for receivers of Paper	TDCOM9	2.627E-04	2.988
Tax deduction for receivers of Medical supplies	TDCOM22	2.598E-04	3.188
Tax deduction for receivers of Food	TDCOM2	1.875E-04	3.973
Tax deduction for receivers of Printed Material	TDCOM21	1.652E-04	1.802
Tax deduction for receivers of Metal	TDCOM13	1.415E-04	1.410
Other interaction terms			
Number of employees in a branch facility	BRANEMP	9.867E-03	1.612
Utility of no off-peak deliveries:			
Alternative specific constant	CONSTANT	1.599	4.151
R^2	0.172		
Adjusted R^2	0.140		

For the receivers, the behavioral simulation of their decision making process pertaining to OPD is initialized. First, each receiver is given a particular incentive and level, e.g., receivers could be given the option to accept off-peak deliveries when given a tax deduction. Then that receiver's utility for accepting this incentive is estimated, using the discrete choice models in Table 2. Then the following two calculations are made: (a) the receiver's probability of accepting off-peak deliveries for this incentive, $P(OPD) = \frac{e^{U(OPD)}}{e^{U(OPD)} + e^{U(C)}}$ (C is the constant value in Table 2), and, (b) the probability that the receiver will not accept the incentive, $P(NoOPD)$ *(11)*. Once those calculations are made, a random number between 0 and 1 is generated, and if $P(OPD)$ is greater than the random number, then that particular receiver will accept OPD for that incentive. This process is continued for the entire set of selected receivers, and for various levels of incentives.

4.2 Carrier Behavioral Simulation

The third component of this simulation is the carrier behavioral simulation. After the receivers have made their decisions on accepting off-peak deliveries when given an incentive, the carriers will then use that information to make their own decisions. It is assumed that the carriers' decision will be modeled on the basis of the profits generated. As with the receivers, the carriers are initially given a particular incentive and level. For the carriers, the incentives considered are toll discounts for doing off-peak deliveries, and on financial rewards based on mileage traveled during the off-peak hours. From here, a set of receivers is randomly selected for each carrier based on that carrier's industry segment, and the number of receivers in this set is designated by the selected carrier's number of stops. Once the set of receivers is established, the shortest tour distance is calculated using the receivers' choices to accept off-peak deliveries. For example, if the selected carrier makes five stops, then a set of five receivers is randomly selected; and if three receivers are accepting off-peak deliveries and two receivers are not, then optimal routes for off-peak delivery routes and regular hour deliveries should be estimated. Next, the transportation costs for regular-hour $(RHDCosts)$ and off-peak deliveries $(OPDCosts)$ are calculated by putting the calculated tour distances into transportation cost functions that includes the incentives. Lastly, the individual carrier agrees to do off-peak deliveries if the total network transportation cost $(RHDCosts + OPDCosts)$ are less than the "Base Case Costs" (i.e. the transportation cost for having all of the receivers in the network only accept regular hour deliveries).

The key component of the simulation of the carrier decisions requires the identification of optimal routes taken for the base case, the regular hours and off-peak hours of the day, since the locations of the receivers and carriers are known. This is needed to estimate travel costs, and is done in a two-step process. Since the latitude and longitude are known for all receivers and carriers, the methodology used for the simulation of carrier behavior is driven by solving vehicle routing problems. In this paper, the determination of optimal routes was done by using the *Radial Sweep Heuristic (13)*. This method first requires that latitude and longitude locations of the receivers and carried be placed on a two-dimensional Euclidean space, where the latitude coordinates are plotted as x-coordinates, and the longitudes are the y-coordinates. This is shown in Figure 3. Then the *Radial Sweep Heuristic* uses the Euclidian locations of the delivery points (the receiver locations), which means that the traveling space is also treated like a geometric space, and each delivery point is assigned a polar location. Then, using these assigned locations, calculations of radian angles are made from a given starting location or home base *(13)*. Once all of the network angles are computed, the entire *Radial Sweep* is performed in a two step process: the *forward-sweep* and the *backward-sweep*. The *forward-sweep method* reorders the network angles from smallest to largest, and then the smallest Euclidian distance is computed based on that order. The *backward-sweep* of this algorithm does the same procedure as the *forward-sweep*, but "in reverse order," and the minimum computed distance estimated by the *forward-sweep* and *backward-sweep* is considered the optimal path of travel amongst the set of locations. The *Radial Sweep* method is a technique used in determining optimal paths for travel within minimal distances, because it accounts for geographic distances, which is given by the calculation of the radian angles, and using longitude and latitude locations as substitutes for polar coordinates. The originators of this heuristic highlight the *Radial Sweep*'s computational speed with the use of this method as a benchmark to find solutions, through the means of standard computer technology and correct mathematical implementations *(9)*. This complete process is done, as illustrated in Figure 3, for the base case (BC), the regular-hour (RH), and the off-peak hour (OP).

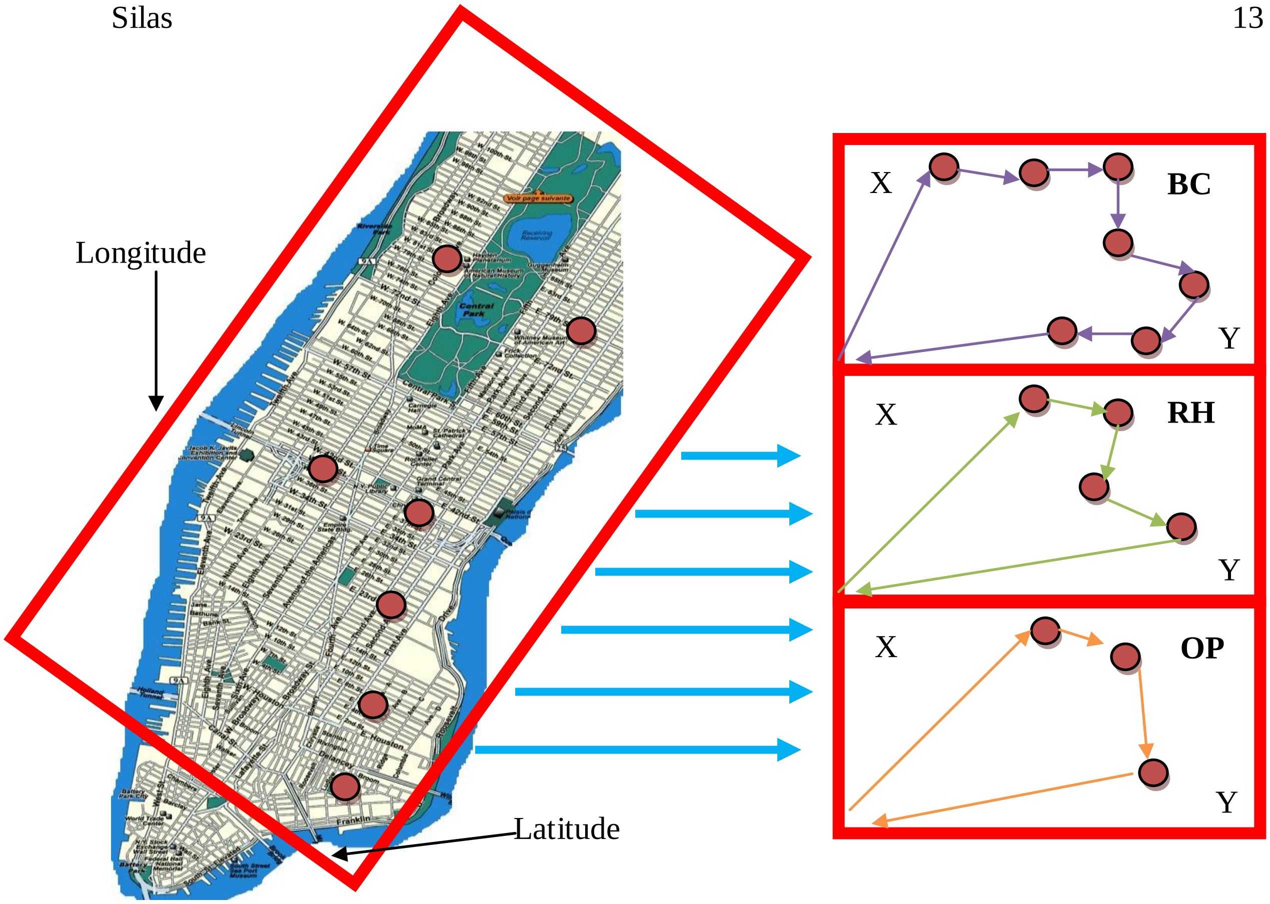

Figure 3: Vehicle routing diagram for carrier delivery routes in Manhattan

5. KEY FINDINGS

In order to understand the implications of this behavioral micro-simulation system on off-peak delivery operations in the New York City region, several sensitivity analyses were conducted. The section will discuss in some details the findings of these analyses.

5.1 How the overall populations of receivers and carriers are influenced by off-peak deliveries

First, since it is known that receivers are important in driving the participation in off-peak deliveries for carriers, it is essential to understand how economic incentives given to receivers dictate the participation of both receivers and carriers. For that reason, the overall participation of receivers and carriers was analyzed and shown in Figure 4. In this figure it can be seen how the participation in off-peak deliveries by both stakeholders increases and changes as the tax deduction increases, and further confirms the usefulness of this economic incentive. Also, this graph of both stakeholder market shares shows that receivers are more receptive to the tax deduction incentive than the carriers, which is because the carriers have more elements to overcome (i.e. costs and delivery route distances) to participate in off-peak delivery operations in the simulation.

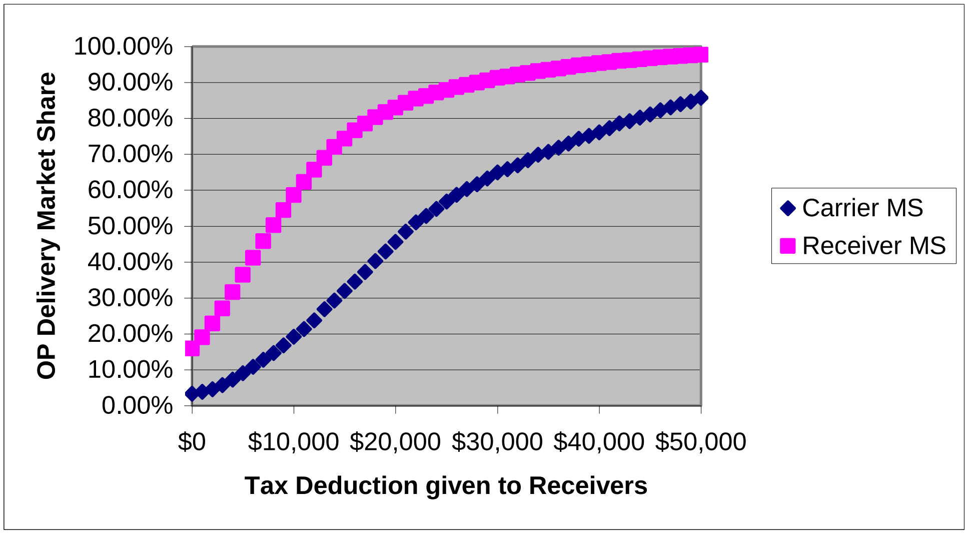

Figure 4: Receiver and carrier market shares as a function of the tax deduction given to receivers

Additionally, Figure 5 shows the carriers participation as function of the tax deduction and broken down by industry segment. In this figure, the same increasing behavior occurs as the tax deduction increases amongst the industry segments, but the main difference is that some industry segments are more receptive and sensitive to the tax deduction incentives than others. The industry segments most receptive and sensitive to these incentives are: *Food, Non-Alcoholic Beverages, Alcoholic Beverages, Printed Material, Paper, Medical Supplies, Metal, and Wood/Lumber*. This analysis of the market shares of the individual industry segments might be helpful in identifying good targets for the implementation of an off-peak deliveries program. This figure was only plotted for the $0 to $10,000 tax deductions because the higher incentives displayed a convergence to 100% participation in off-peak deliveries.

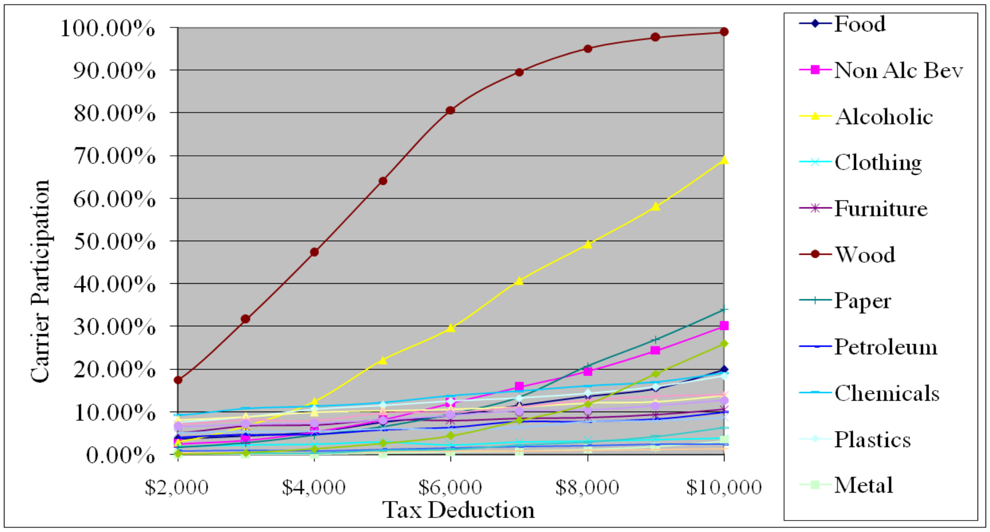

Figure 5: Industry segment market shares as a function of the tax deduction given to receivers

5.2 The influence of transportation costs on carriers' participation in off-peak deliveries

Secondly, in addition to being influenced by the receivers, the carriers' decisions to participate in off-peak deliveries are also influenced by the costs of transporting goods to their customers. For this reason, an analysis was done using this behavioral simulation structure to understand how carriers would stand to benefit from these delivery operations, as both a function of customer requests for off-peak deliveries, and the traveling distance to the first delivery stop, which is shown in Figure 6. In this figure, it should be noted that the carriers stand to make profits when they have higher requests for off-peak deliveries from the customers, while also traveling at shorter distances to their first delivery stops. This is indicative by the negative trends in the lines, which represents the different tested first stop delivery distances. These findings point toward the idea that carriers in close proximity to the Manhattan area (i.e. other boroughs in New York City, Northern New Jersey, and Southern Connecticut) might be good targets for off-peak delivery operations because of their decreased transportation costs, and frequent trips to this highly congested urban area.

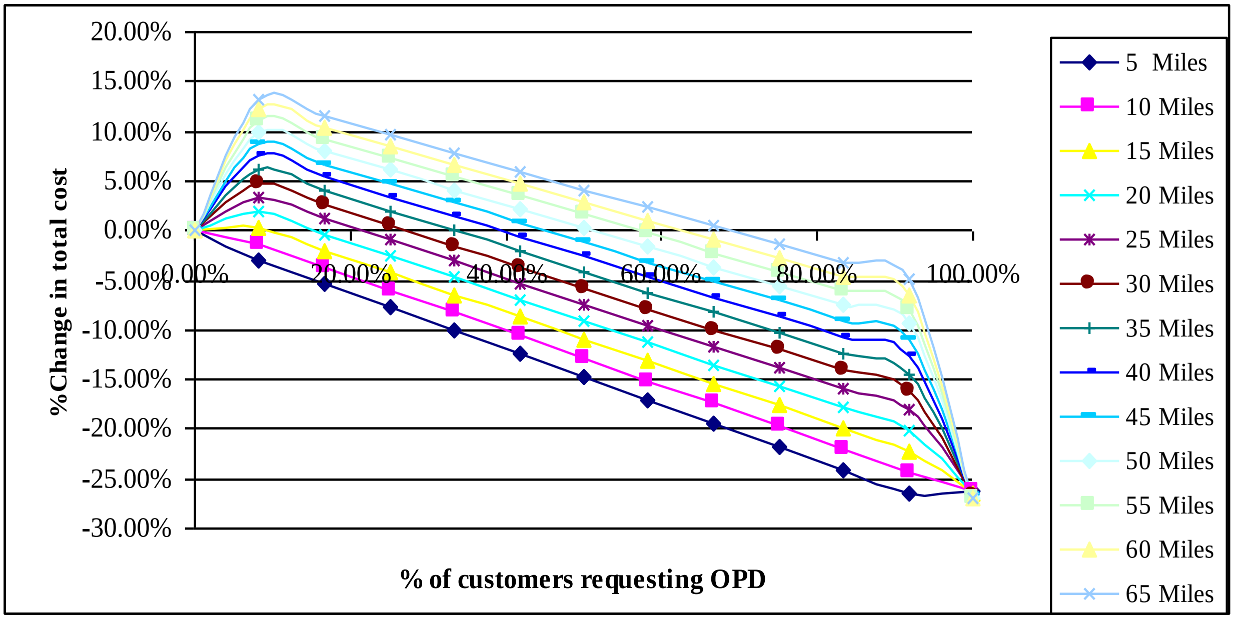

Figure 6: Transportation costs as a function of customer requests and the distance to the first delivery stop

5.3 The influence of route choice on off-peak delivery operations on carrier participation

Lastly, since it is known that carriers do not always make logical route choice selections when making deliveries, which is sometimes due to scheduling and load demands, traffic congestion, and human tendencies, the analyses of logical delivery route choice selections (i.e. using systematic methodologies like the radial sweep heuristic) versus illogical or randomly chosen route selections (shown in Figure 7 and Figure **8**) was deemed necessary to understand how realistic driving conditions influences off-peak delivery participation.

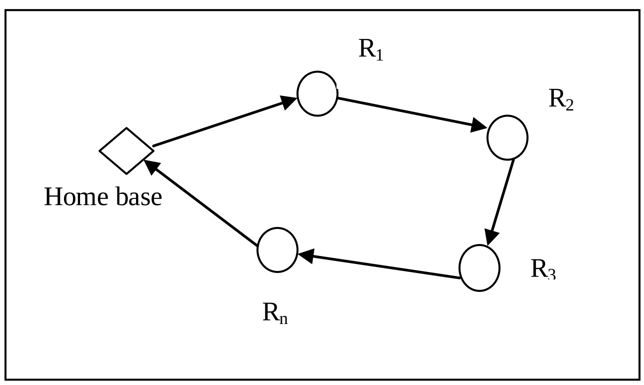

Figure 7: Carrier logical delivery route choice delivery selection

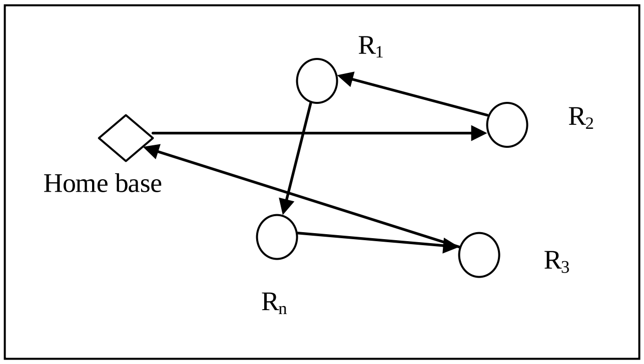

Figure 8: Example of a carrier's illogical or randomly chosen delivery route selection

From the analysis shown in Figure 9, it can be seen that delivery route choice selections by carriers is noticeably significant on the influence of the amount of participants in off-peak deliveries. Secondarily, there are major differences in off-peak delivery participation as the tax deduction increases. On average, there is between a 2.3% and 20% differences in the participation as the incentive increases between the route choice methods. This analysis might be helpful in understanding how random or realistic travel patterns displayed by carriers might influence delivery operations during the off-peak hours.

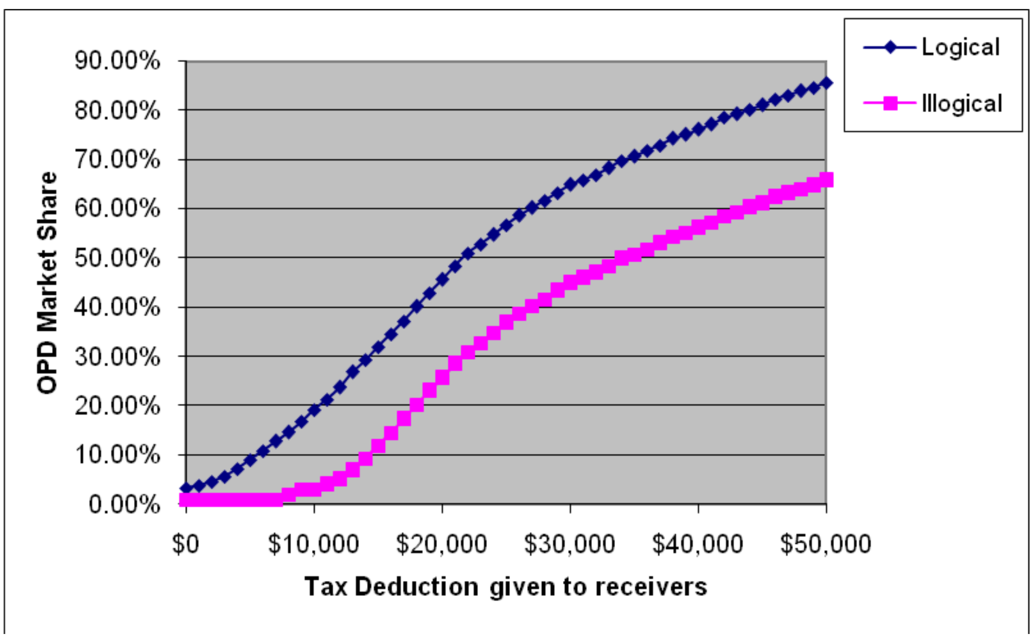

Figure 9: Carrier market shares as a function of the tax deduction given to receivers, and in terms of logical and illogical route choice delivery selections

6. CONCLUSIONS

This report has further assisted in establishing the benefits of implementing an off-peak deliveries program in order to help in reducing the traffic congestion problem in New York City, which can also be used in conjunction with other freight transportation policies. Furthermore, this behavioral micro-simulation structure is also a policy analysis tool that can demonstrate the effectiveness of off-peak deliveries and its impact on the transportation market in urban areas, while also assisting in targeting industry and market segments of receivers and carriers that might receptive to these policies. The main benefit is that this framework can be as detailed as necessary, and can be tailored to understand how receptive any region is to off-peak delivery policies, while further extending the research done on understanding the interactions between receivers and carriers.

In terms of the behavioral micro-simulation framework detailed in this report, several lessons were learned. First, OPD operations are dependent upon the company characteristics of the participating receivers; this means that larger companies with branch locations, and companies receiving: wood/lumber, alcohol, paper, medical supplies, food, printed material, and metal are receptive to these operations. Secondly, it was found that off-peak delivery operations are also dependent upon the operational costs that receivers stand to acquire from increased hours of business functions (e.g. electricity, security, management and employee wages, etc.), which influences their overall budget constraints. Regrettably, these other costs were only used indirectly in the discrete choice model to simulate the receivers' behaviors. From the carriers' perspective, OPD participation is reliant on customer demands, traveling distances to urban areas, delivery route choice, and transportation costs. More specifically, carriers located in and relatively close to the New York City area (i.e. Brooklyn, Northern New Jersey, and Southern Connecticut) would be good targets for participating in off-peak deliveries, because of their lower transportation costs and easier access to this region as a whole.

In conclusion, the use of off-peak deliveries in New York City has many needs, beyond the practical academic research displayed in this report, before it can be accepted as a common practice in this region. In general, these needs include the political, financial and social backing of major stakeholders affiliated with the transportation of goods into the New York City region. Specifically, other actions are needed to gain a full picture for implementing off-peak deliveries into the New York City region, including the gathering of more behavioral and characteristics data from receivers and carriers, and pilot testing of off-peak delivery policies on smaller scales to better understand the advantages and disadvantages of this practice.

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