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Integrative Freight Demand Management in the New York City Metropolitan Area:

IMPLEMENTATION PHASE

COOPERATIVE AGREEMENT NO. RITARS-11-H-RPI

FINAL REPORT

SUBMITTED TO THE UNITED STATES DEPARTMENT OF TRANSPORTATION

Rensselaer Polytechnic Institute

New York City Department of Transportation

Rutgers University

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José Holguín-Veras, Jeffrey Wojtowicz, Xiaokun (Cara) Wang, Miguel Jaller, Xuegang (Jeff) Ban, Felipe Aros, Shama Campbell, Xia Yang, Iván Sanchez, Johanna Amaya, Carlos Gonzalez-Calderon, Robyn Marquis
Rensselaer Polytechnic Institute

Stacey Hodge, Thomas Maguire, Michael Marsico, Shane Zhang, Sandra Rothbard
New York City Department of Transportation

Kaan Ozbay*, Ender Faruk Morgul*, Shri Iyer, Kun Xie*, Eren Erman Ozguven
Rutgers University
(* now at New York University)

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José Holguín-Veras		Stacey D. Hodge		Kaan Ozbay

EXECUTIVE SUMMARY

Background

Urban freight transportation is crucial to the quality of modern life, though at the same time it produces significant negative externalities. Despite the relatively small proportion of freight with respect to all traffic, urban freight movements are increasingly recognized as significant forces of influence on urban transportation systems and urban economic vitality. A range of freight system management strategies have been tried and implemented with various degrees of success throughout the world. Some of these strategies are carrier-centered, such as the use of cooperative delivery systems, which change the logistical aspects of carrier operations, but do not affect the actual underlying demand. As a result, their influence tends not to extend beyond carriers, to other aspects of urban transportation systems. At the other end of the spectrum, receiver-centered traffic demand management (TDM) measures attempt to change the nature of the actual demand for the cargo. These policies take advantage of the fact that receivers—by virtue of being the carriers' customers—have a great deal of power over when and how deliveries are made. Carriers must respect receivers' wishes if they want to stay in business.

The Off-Hour Delivery (OHD) project is an innovative example of receiver-centered freight TDM. This initiative relies on incentives (financial or otherwise) to induce receivers to accept deliveries in the off-hours (7PM to 6AM). Since the incentives remove the opposition of the receivers, and the carriers are generally in favor, entire supply chains can switch to the off-hours, and the effect of these shifts reverberate through entire supply chains. The NYC OHD project has been implemented in stages. After a successful pilot phase that concluded in 2010, the Research and Innovative Technology (RITA) sponsored implementation phase (Integrative Freight Demand Management in the New York City Metropolitan Area: Implementation Phase) was launched in June 2011. Although this is technically the implementation phase, it should be noted that the term 'launch phase' may be more appropriate. The reason for this is that for a proper and successful implementation of an off-hour delivery program a sustained effort over a long period of time is required. After all, the program aims at transforming supply chains, which requires profound modifications of business practices. This report documents the key aspects and findings, impacts and influence of the OHD project, through the implementation phase which concluded in September 2013.

Key Project Aspects/Findings

There are two modalities by which off-hour deliveries can be received: (1) staffed, meaning that someone who works for the receiving business is present to inspect and sign off on the deliveries; and (2) unassisted, or unstaffed, indicating that the goods are left at the establishment without the need for someone present. Both modalities were implemented during the pilot phase of this project, and unassisted off-hour deliveries (UOHD) proved quite favorable. In the previous phase, the economic implications of staffed OHD and UOHD were derived, and it was confirmed that UOHD performs better than staffed OHD, and that pursuing UOHD would be more beneficial. *Therefore, this project focuses on the implementation of UOHD.*

One of the key findings of the pilot phase was the extent to which receiver reluctance or opposition to the program was based on the perceived risk associated with vendors having unaccompanied access to their premises while making off-hour deliveries. With this central focus, the project investigates the *implementation setup of unassisted OHD* considering three levels of defense: (1) access surveillance; (2) access control; and (3) internal surveillance; as well as carrier-supplied insurance coverage in case of a negative outcome. *Public sector policies* that could foster unassisted OHD are then examined, including financial incentives in exchange for participation, financial incentives to be used towards security equipment, public recognition and other non-monetary incentives, and complementary policies and programs. The project team, with assistance from the Industry Advisory Group (IAG), also engaged other businesses and groups to expand off-hour deliveries in New York City. In addition to financial rewards, other incentives such as tax incentives, EPA credits, LEED program credit, parking ticket discounts, road toll subsidies, BID-Led Competitions, Inspiration Tools, and a Delivery Personnel Accreditation program were investigated.

Another concern regarding off-hours deliveries (OHD) identified during the pilot phase was the possible effects on the community of noise emissions from delivery operations taking place at night. Based on a comprehensive review of noise control technologies, policies and programs, this project proposes *a three-stage approach to addressing the noise issue associated with off-hour deliveries*. The first stage is educating project participants on proactive noise mitigation measures. The training will cover driver behavior, low-cost noise control measures such as noise-absorbing materials, and finally low noise trucks and equipment. The second stage requires participants to commit to proactively addressing the noise issue. Participants must agree to a code of conduct that includes taking steps to avoid and/or mitigate noise issues that may occur during off-hour deliveries. The third stage is to direct stakeholders, or anyone with noise questions or concerns, to the assigned point of contact at New York City Department of Transportation (NYCDOT) for further assistance.

The *project area* was selected as Midtown and Lower Manhattan, from river to river. This area houses several key Business Improvement Districts and business centers, including the Javits Center, Madison Square Garden, Grand Central Terminal, and Times Square. In addition, the NYCDOT has abundant traffic data for this area that can be leveraged for the project, such as taxi GPS data and data from the Midtown in Motion project.

Based on a stated preference survey of representative receivers, the project then *analyzes the impact of different structures of incentives to foster OHD* using Behavioral Micro-Simulation, which recognizes the joint decision process of carriers and receivers in determining delivery times. The results show the superiority of geographically-focused incentives, which require between 71% and 75% fewer expenditures than incentives spread over Manhattan. In terms of whether incentives for participation in unassisted OHD could become a self-supported freight demand management (SS-FDM) system, the analyses show that in order to have a sizeable impact, the one-time-incentive should be larger than $4,000 per establishment. Incentive values below that amount would not attract a significant number of receivers. The analyses also revealed that a SS-FDM that is solely supported by a toll surcharge on freight vehicles could only foster the program in a limited, though still meaningful, fashion. It is estimated that a toll surcharge of $1/axle could increase participation in UOHD to 6.3% (from a base case share of 3.9%); while a $2/axle surcharge would increase participation to 7.1% during the implementation period of three years. In contrast, applying a small surcharge of $1 to all passenger cars that travel in the regular hours would significantly increase toll revenues, and the incentive budget. The potential effects of this level of increase are notable; they could produce a deep transformation in urban delivery patterns. The estimates are that a $1 toll surcharge to passenger cars that use the bridges and tunnels in the NYC area, combined with a toll surcharge in the range of $1-2/axle to freight vehicles, could fund incentives sufficient to switching in excess of 13% of the city's total truck traffic to the off-hours. These findings have significant policy implications, clarifying: *(1) the benefits of targeting receivers in the most congested part of the* *cities, and (2) that a combination of small toll increases, combined with targeted incentives, could have a dramatic effect on urban congestion.*

The *outreach* efforts undertaken during this project—by RPI, NYCDOT and by the members of the IAG--were enormous. The IAG represented a diverse group of businesses from across the Manhattan target area, that were instrumental in promoting this project and interesting private sector businesses in participating. An important lesson learned was the importance of identifying a 'champion' at each business—whether carrier or receiver--with whom the team could interact, and who would advocate for the concept/program internally. When there was no such internal champion, the operational switch to the off-hours was often difficult to achieve, despite interest. The many factors and issues of day-to-day business operations can overshadow a new idea, despite its economic and/or environmental appeal. The exigencies of the NYC employment market further complicated this process. Often, especially in the restaurant and retail industry, the team would find a champion only to have them change employers, and typically the team would then have to 'resell' off-hour deliveries from scratch. The ultimate lesson learned was the importance of moving expeditiously once a business expresses interest in the program. It is also worth noting that many businesses (both carriers and receivers) are against changing their operations in the busiest, fourth quarter of the year (October through December) when they are gearing up for the holiday period. Multiple shippers said that they would consider offering shipping discounts to businesses willing to receive goods in the off-hours. However, the shippers would have to significantly increase the number of off-hour delivery routes they made in order to make such an offer feasible. In the future, a discount model could conceivably replace the need for incentives. It may also be possible for larger companies to offer an incentive to their sales team to promote off-hour deliveries. Since the shipper would have lower operating costs when making OHD, they may be able to provide a higher sales commission for items delivered in the off-hours. This would have to be investigated on a case-by-case basis, but it is a potential mechanism for shippers to increase the amount of off-hour deliveries.

The report also summarizes the *design and implementation of the evaluation plan* that quantifies the key impacts of OHD on a wide range of stakeholders. This plan includes the estimation of impacts on road users and communities, carriers, receivers, and the public sector. The report documents the impact assessment matrix that covers each of the pre-identified impacts, the corresponding metrics, anticipated assessment processes, and data collection mechanism. A technique worth specific discussion is the use of GPS data provided by carriers. GPS trajectories are direct reflections of traffic states, which can be further processed and exploited to acquire more information. The focus in this project is on using GPS data for performance evaluation of urban freight activities, including mobility, fuel consumption, and emissions. The mobility measures are primarily useful in evaluating the efficiency of urban freight movements, e.g., the travel time of a delivery tour, number of delivery stops, and service times at delivery stops. Fuel consumption and emissions are used to quantify the expenses and the environmental externalities of urban freight activities. Project impact findings based on surveys and interviews, GPS data analysis, and traffic modeling are summarized next.

Project Impacts

It is estimated that in excess of 400 businesses in Manhattan shifted some of their deliveries to the off-hours. The businesses are predominantly located in Midtown and Lower Manhattan. This estimate includes businesses of various sizes that shifted after the pilot phase and through the implementation phase. It also includes businesses that did and did not receive financial incentives from the project team. Some of these businesses receive multiple deliveries per week in the off-hours, while others receive more limited overnight deliveries, such as once per week. For this program, a financial incentive of $2,000 was made available to Manhattan businesses that could demonstrate a shift to the off-hours. It was a requirement that the company had to have multiple deliveries per week shifted to the off-hours, and they had to participate for a minimum of six months. Many of the smaller companies were receptive to the financial incentive to help offset any additional costs, but for larger companies a financial incentive was not always needed. All of the companies that received the incentive for this phase continued accepting off-hour deliveries even after the required length of participation (six months) had passed. These businesses also indicated to the project team that they were working with their other vendors to shift additional deliveries to the off-hours.

Impacts on Carriers

The participants, including Sysco, Wakefern, Duane Reade Pharmacies, National DCP (Dunkin Donuts), and The Beverage Works (supplier of Red Bull in the NYC area), have all reported positive experiences shifting to OHD. As reported by Sysco,

> *"Sysco Metro New York was very pleased with the results of the Off Peak Delivery Project. ... From the company perspective, our drivers are dealing with light traffic at those hours, parking is easier at the customers locations, resulting in less fuel consumption because we are not sitting in traffic, overtime for our delivery associates is less because they are not tied up in traffic, and we are not receiving parking tickets like we are during the morning hours or 8am on… If we continue to decrease our ticket expense as a result of deliveries at night, I am sure this would result in more aggressive pricing for our customers ..."* ----Bobby Heim, Vice President of Operations,
> Sysco Metro New York

For confidentiality and competition reasons, the participating carriers would not provide estimates of the project's financial impacts. However, the research reported in Holguín-Veras et al. (2011b) and interviews with drivers indicate that switching a delivery route from regular to off-hours saves on average 2.5 hours. Assuming a value of time of $85/hour, which is consistent with the estimate produced by the American Transportation Research Institute (Short et al., 2010), one could estimate that for every delivery tour that switched from regular to off-hours the carriers save, on average, $212.50 per day or $42,500/year/OHD-tour (assuming 200 days/year).

The parking fines in New York City average about $750/truck-month. Since it is easier for the truckers to find legal parking spaces near their delivery locations during the off-hours, every OHD route that replaces a regular-hour route saves about $9,000/year/OHD-tour in parking fines. Essentially, the total savings to carriers amounts to about $51,500/year/OHD-tour. It is estimated that approximately 40-50 daily delivery tours in Manhattan have been switched to the off-hours, which corresponds to a total savings to all participating carriers of over $2,250,000 per year.

Impacts on Receivers

Participating receivers, including Waldorf Astoria, Whole Foods Market, CVS Pharmacies, and Just Salads also provided positive feedback about their experiences shifting to OHD.

"Whole Foods Market Union Square has enjoyed the ability to take deliveries in overnight, serve our customers better and enhance our commitment to the environment through more efficient trucking operations." ----Mary Snow Thurber, Director of Receiving, Whole Foods Market Northeast Region

"Our locations will continue to receive "night drops" even though this program has ended, as our managers now favor the dependability of night drops vs late day time deliveries. Thanks again for the program." and "The Off-Hours Delivery Program… [is] a win-win as business owners and citizens will both realize real immediate benefits." -- Nick Kenner, Managing Partner Just Salad, LLC

The information collected from in-depth interviews with receivers indicates that the use of OHD has enabled them to reduce their safety inventory from 1.5 days to 1 day. Essentially, due to the unreliability of regular-hour deliveries, receivers were forced to stockpile 1.5 days of inventory; with OHD they only purchase what they need during the day.

Pollution savings accrued by trucks making OHD

Using the GPS data collected from the participating companies, the team computed fuel consumption and emissions using the Comprehensive Modal Emission Model (CMEM; see Barth et al., 1996 and An et al., 1997). The analyses focus on three key segments of the network that that were used in both regular and off-hour deliveries. Given the second-by-second speed profiles, the fuel consumption rate and emissions rates (in terms of CO2, CO, HC, NOX) are estimated by CMEM. The average fuel consumption rate and total emission rate during off-hours were found to be significantly lower than those during regular hours for the same segment. The differences are generally larger than 20% for highway and toll road segments, and larger than 50% for urban arterial road segments because: (i) traffic is generally much smoother during off-hours, leading to reduced fuel consumption and emissions; and (ii) for toll roads and urban arterials, such a smoothing effect is more significant (e.g., vehicles stop less frequently at toll booths or signals), leading to even more dramatic reductions of fuel consumption and emissions. The results confirm that OHD help reduce fuel consumption and emissions during urban freight activities.

Congestion and pollution savings accrued by all regular-hour travelers

The congestion and pollution savings for regular-hour road users are significant. If 20.9% of the deliveries in Manhattan were shifted to the off-hours, each receiver would be responsible for an annual reduction of about 551 vehicles miles traveled (VMT), 195 vehicle hours traveled (VHT), CO of 12 kg, HC of 1.9 kg, NOx of 0.7 kg and PM10 0.004kg. This translates to a total reduction of 202.7 tons of CO, 40 tons of HC, 11.8 tons of NOx and 70 kg of PM10 per year.

Overall, program benefits to carriers and roadway users—reduced congestion, travel times, and pollution levels—steadily increase with increased receiver participation in OHD. The optimal amount of incentive to stimulate participation seems to be in the range $6,000- $7,000/year per participant; beyond this amount participation levels did not rise accordingly.

Coordinated demand management policies targeting both passenger cars and trucks are critical. As economic theory suggests, induced passenger car demand can be generated to take advantage of the road capacity made available by trucks switching to the off-hours. The analysis of such phenomena is beyond the scope of this project, however, a comprehensive cost/benefit analysis of OHD and other large-scale projects clearly should include these more complex, system-wide analyses for a fuller quantification of the actual benefits.

Project Influence

Institutional Commitment from NYCDOT

The OHD project has transformed NYCDOT's relations with the freight industry and the private sector. The OHD project has clarified the potential that exists for paradigmatic change when public and private sector and academic partners work collaboratively to find solutions to freight issues. The institutional support for, and commitment to, the OHD program--now branded "NYC deliverEASE--is made clear by these and other factors: 1) the adoption of OHD as part of NYC's Sustainability Plan (PlaNYC); 2) the Award ceremony organized by NYCDOT to honor the project participants; 3) the creation of an Industry Advisory Group that provides ongoing input to the city on freight matters; and 4) by conservative estimate, the NYCDOT investment of more than $700,000 of staff time and actual expenses in support of the program.

In March 2012, the NYCDOT Commissioner sent letters to other public agencies seeking their support for OHD. Agencies with the ability to offer incentives, both financial and other, were briefed about the public benefits of expanding their incentive programs in support of OHD. In July 2013, NYCDOT met with NYC Economic Development Corporation to discuss options for tax subsidies or other financial incentives that could be developed to incentivize receivers to shift some of their deliveries to the off-hours. Also, in July 2013, $500,000 was obligated by NYCDOT to support the expansion of OHD. NYCDOT will use these funds to help participants shift to the off-hours, and to fund a quiet truck demonstration project with private sector participation. NYCDOT also submitted a proposal to the New York State Energy Research and Development Authority (NYSERDA) to advance work related to reducing the noise associated with OHD. NYSERDA provided $112,500 in funding to NYCDOT, offering partial assistance to help purchase and evaluate noise reduction equipment to be used in OHD.

National and International Impacts

The Off-Hour Deliveries (OHD) program has been profoundly influential and impactful, domestically and internationally. The OHD program:

1) has been officially adopted by the City of New York as a feature of its sustainability plan; the first research project incorporated into NYC transportation policy.
2) led to the creation of a grant program, jointly funded by the Federal Highway Administration and the Environmental Protection Agency, to foster OHD programs in other cities. Orlando, Florida and Washington, DC were selected as the first recipients, and are actively developing their own versions of OHD programs.
3) caught the attention of both public and private sector representatives from multiple US cities, including Boston, Atlanta, Chicago, and Seattle.
4) is being advanced internationally.

   London: The City of London is collaborating with RPI and NYCDOT to promote OHD there.

   Sao Paulo, Brazil: After the RPI team made a presentation in July, 2013 about the NYC OHD program, business groups organized a follow-up meeting—attended by over 200 companies—to urge the government to create an OHD program.

   Toronto and Montreal, Canada: Public and private sector representatives from these cities have asked RPI to provide them with additional information about the NYC OHD project.

The Off-Hour Delivery (OHD) project has clarified the potential that exists for paradigmatic change when public and private sector and academic partners work collaboratively to find solutions to freight issues. The research conducted by the team previous to the implementation phase clearly outlined fundamental project concepts (that ran contrary to prevailing wisdom), confirming the importance of receivers in influencing how and when deliveries are made. This research also determined the magnitude of the incentives that should be offered, identified the target industry segments, and outlined a path for implementation. The program's power, confirmed in its implementation phase, is the identification of this receiver-instigated fulcrum that allows for lasting, sustainable economic shifts through entire supply chains. The OHD program also confirms the viability and potential of the emerging field of freight demand management by demonstrating that changing receivers' behavior leads directly to changes in carriers' operations, while policies that target carriers do not necessarily result in broader changes, in the supply chain, the urban freight system, or the environment.

Widely considered one of the most impactful and business-friendly public sector freight initiatives to date, the OHD program has the potential to influence large numbers of urban deliveries (up to 20-40% of truck traffic). Since urban deliveries dwarf all other truck trips, the resultant potential economic impacts are enormous; savings in NYC estimated at $100-$200 million/year. The findings also confirm dramatic reductions in both the congestion and associated pollution produced by regular-hour traffic, and the pollution produced by the off-hour delivery trucks. Implementation experience shows that economic and operational benefits for receivers and carriers drive their continued participation; initial incentives may become less necessary as word about the program, and participant experience spreads. Financially sustainable, the OHD program is also socially and politically sustainable; if properly implemented, its impacts are positive for all involved--carriers, receivers, and urban communities--enhancing urban quality of life, economic development, and environmental sustainability.

CHAPTER 1 - INTRODUCTION

Increased urban congestion puts pressure on transportation agencies to find solutions that are also responsive to citizens' desires for vibrant urban economies, enhanced livability, and high quality of life. To reduce congestion and attain sustainability goals, decision makers employ a wide array of Transportation Demand Management (TDM) programs, including among others fostering carpool and transit use, and promoting flexible work schedules. Since the bulk of urban traffic is passenger-related, TDM measures have primarily focused on passenger vehicles, while the potential of TDM in urban freight demand has been overlooked. However, unique opportunities exist to reduce congestion and improve economic competitiveness by developing and implementing freight-related TDM programs. A vital component of achieving this goal is insight into the behavioral underpinnings of the urban freight system, and how best to influence the system to minimize its negative externalities, without limiting its numerous contributions to the economy and quality of life.

A number of freight TDM measures have been tried and implemented throughout the world, with various degrees of success. Some of these measures are carrier-centered, such as the use of cooperative delivery systems—in conjunction with urban consolidation centers—whereby a neutral carrier does the last leg of deliveries on behalf of other carriers. Such measures limit the multiple independent trips that the other carriers would have been forced to make with low load factors (Nemoto, 2004; Holguín-Veras et al., 2008a). Another carrier-centered measure is the provision of real-time traffic information so that truck drivers have accurate information about traffic conditions. These systems reduce congestion and pollution by lowering the number of truck-trips that take place during peak hours. However, the actual demand (the number of deliveries, and the amount of cargo consumed by the receivers) is unaffected; only the logistical aspects are changed.

At the other end of the spectrum are receiver-centered TDM measures, which attempt to change the nature of the actual demand for the cargo. These policies take advantage of the fact that the receivers—by virtue of being the customers—have a great deal of power over how and when they receive their deliveries. Vendors and carriers, must respect receiver wishes if they want to stay in business. Examples of receiver-centered measures include encouraging receivers to consolidate their deliveries, and retiming deliveries so that they take place outside peak hours, among others. The Off-Hour Deliveries (OHD) project is a leading example of receiver-centered freight demand management. The OHD program relies on incentives (financial or otherwise) to induce receivers to accept deliveries in the off-hours (7PM to 6AM). Since the incentives remove the receivers' opposition, and the carriers are generally in favor, entire supply chains could switch to the off-hours. The program's power is the identification of this receiver-instigated fulcrum that allows for lasting, sustainable shifts throughout the supply chain, with tremendous potential for sustainability advances throughout the urban freight system.

In the first phase of the RITA Integrative Freight Demand Management in the New York City Metropolitan Area project, a pilot test of OHD was conducted in NYC with great success (Brom et al., 2011; Holguín-Veras et al., 2011b). Two different modalities of OHD were used in the pilot: half of the establishments relied on staffed off-hour deliveries (OHD; with staff from the receiving establishment present for deliveries), while the other half used unassisted off-hour deliveries (UOHD; without staff from the receiving establishment present). In addition to confirming the chief findings of the research that was conducted before the pilot (Holguín-Veras et al., 2007; Holguín-Veras, 2008; Holguín-Veras et al., 2008b; Holguín-Veras, 2009), the pilot produced important new findings, including: that unassisted off-hour deliveries could play a key role in a TDM strategy; off-hour deliveries could be conducted with minimal disturbance to local communities (no noise complaints were received during the pilot); off-hour deliveries are more reliable than regular-hour deliveries; and can be safely performed without putting drivers or the establishment at risk. The pilot also revealed that, if delivery errors are made as part of UOHD, those errors can be remedied early in the day with minimal interruptions in receiver operations. In contrast, if an error is found in a delivery that takes place at 10AM, replacements may be received later in the afternoon, which could produce significant disruption in the business and may require businesses to retain a larger safety stock.

The success of the pilot, widely reported in the press (Journal of Commerce, 2009; 2010; Wall Street Journal, 2010), led the United States Department of Transportation's Research and Innovative Technology Administration and the New York City Department of Transportation to fund a "launch" phase. This report details the start of full implementation in NYC. Also in response to the project success, the Federal Highway Administration and the Environmental Protection Agency created a program to foster OHD in mid-size cities (Federal Highway Administration, 2012) across America. Orlando, FL and Washington, DC were selected as the first recipients of these grants, with an expectation that new grants will be made available in the near future to other cities interested in implementing OHD.

The pilot test experience concerning UOHD and staffed OHD deserves further mention because of its implications for implementation efforts. These two modalities exemplify the classic tradeoff between risk and reward. Participants in staffed OHD minimized the risk of "something bad" happening at the establishment, by using the financial incentive to pay for the off-hour staff's work. The incentive thus generated only a small profit to the receiver, because the bulk of it went to pay the employees. In contrast, participants in UOHD took the risk and allowed their vendors to enter their establishments unsupervised. Trusting their vendors, they calculated that if nothing went wrong the incentive would become a profit. Not surprisingly, at the end of the pilot test, the receivers that used staffed OHD generally reverted to regular hour deliveries as, without incentives, they could not afford the OHD staff costs. In contrast, the vast majority of the receivers doing UOHD opted to stay in the program to the great delight of their vendors. When asked why, the managers indicated that the convenience and reliability of UOHD made it worthwhile for them to continue. Instead of uncertain delivery times because of congestion—which forced them to maintain a safety stock of supplies—UOHD guaranteed that supplies would be in place when the business opens. Once receivers tried UOHD, and "nothing bad" happened, they were able to benefit from: superior reliability, fresher products, reduced inventories, and a more efficient use of their staff.

This report provides a comprehensive account of the work conducted by the team as part of the second phase of the RITA Integrative Freight Demand Management in the New York City Metropolitan Area: Implementation Phase Project. In addition to this introduction there are six chapters: Chapter 2 describes the design of the implementation phase including a review of operational concepts and policies, noise control and the identification of the project area; Chapter 3 discusses the institutional coordination and outreach efforts completed during this project; Chapter 4 presents the assessment on market potential including an assessment of the effectiveness of proposed policies and programs and the behavioral micro-simulation developed in this phase; Chapter 5 presents the collection and analysis of urban freight performance evaluation using global positioning system data; Chapter 6 presents an assessment of the impacts as a result of this phase of the project; and Chapter 7 presents concluding remarks.

CHAPTER 2 - DESIGN OF THE LAUNCH PHASE

This chapter details the team's process in designing the project's launch phase, as well as the findings that would provide the building blocks for the rest of the project. The chapter is broken into three main segments. The first identifies operational concepts and policies that can be used by the public sector to foster off-hour deliveries (OHD). The findings presented are the result of a comprehensive research and evaluation of a wide range of possible concepts and policies that could be used. The strategies include technologies that receivers and carriers can use during the delivery process to ensure security of the business and to mitigate noise pollution, incentives, as well as other strategies that will help ensure that OHD takes place with full consideration of all stakeholders. The second segment expounds on noise, which is a major concern for night deliveries. Some of the policies in place relating to noise are discussed, and the section concludes with the formulation of a code of conduct that all participant of the launch phase were required to agree to. The chapter's third segment identifies a set of alternative corridors, sections of the city, and potential large traffic generators (LTGs), where OHD can be implemented. The following are considered when identifying these areas: community impacts and concerns; potential for noticeable impact on traffic and congestion; and possible interaction--synergistic or conflicting with other ongoing projects.

Review of Operational Concepts and Policies

Off-hours deliveries (OHD) or nighttime deliveries, describe goods that are brought to the recipient's business during nighttime hours, or between 7 pm and 6 am, as defined by this project. There are two modalities by which these deliveries can be received: (1) staffed, meaning that someone who works for the business is present to inspect and sign off on the deliveries; and (2) unassisted, or unstaffed, indicating that the goods are somehow left at the establishment without the need for someone present. Both of these delivery types were implemented during the project's pilot phase, and unassisted off-hours deliveries (UOHD) proved preferable to the receivers, prompting the need for further consideration of these systems.

Those businesses that used staff cited the additional personnel cost as a major drawback of the program; these costs were shown to range from $20 to $150 an hour (Holguín-Veras, 2006b). However, economic analyses indicate that annual benefits from a full-scale implementation of OHD in the borough of Manhattan in New York City could be in the range of $100-$200 million (Holguín-Veras et al., 2010b). It follows that, if UOHD are used, the attendant benefits could be on the higher end of that range, given reduced costs. The fundamental tradeoff for businesses lies between these benefits and the possibility of a negative outcome, or the risk that something bad could happen, particularly without receiving staff. This can be represented using a Pareto frontier with cost on the vertical axis, and risk in the horizontal, as shown in Figure 1.

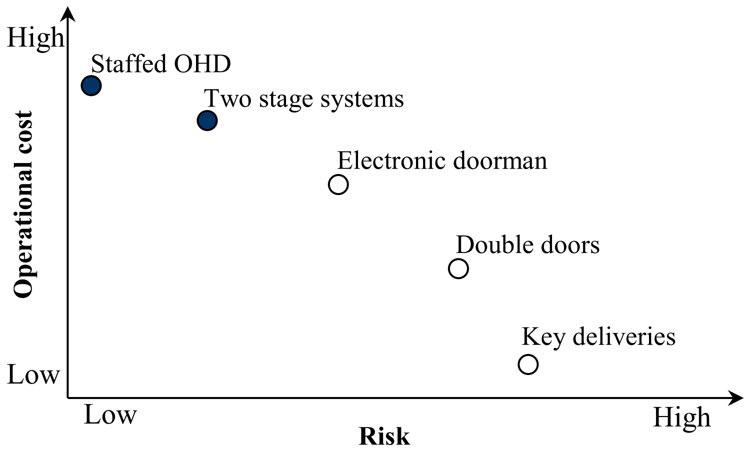


Figure 1: Cost versus Risk

This section addresses operational concepts and policies concerning the stakeholders involved and identify the most promising alternatives to foster a large-scale implementation. This include strategies and technologies for receivers to encourage unassisted off-hours deliveries (UOHD), public sector policies to promote switching deliveries to the off-hours, and strategies and technologies that may be used by the carriers to execute low noise deliveries.

Unassisted Off-hours Delivery (UOHD) Programs

The economic analyses in the previous section show the importance of clearly identifying the costs and risks of UOHDs to receivers, and developing programs that address, and reduce or eliminate these issues. This section is structured to reflect the multi-layered nature of this type of delivery operation. A *program* here refers to a packaged implementation setup that considers three levels of defense: (1) access surveillance; (2) access control; and (3) internal surveillance; as well as carrier-supplied insurance coverage in case of a negative outcome. This is summarized graphically in Figure 2.

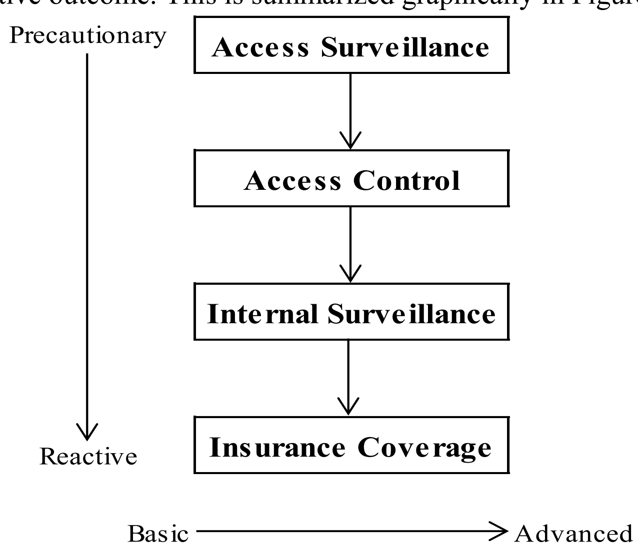


Figure 2: Layers within an UOHD program

These layers of security range from basic to more advanced systems, and from precautionary to reactive measures. The sections below cover each of these layers in more detail.

Surveillance: Access and Internal

Electronic security cameras, which are used to monitor a chosen location, are a common feature in both commercial and residential applications; examples include cameras focusing on doorways or cash registers. It is important to distinguish the two types of surveillance that factor into UOHD: (1) access surveillance, where the doorway or other entry barrier is monitored; and (2) internal surveillance, where the interior of the storage area and/or business is monitored. These will be compared, particularly with regard to their respective risks and benefits, within this section.

The first level of defense for a business is access surveillance, which is useful to have in place regardless of the time of day and current activities. Whether or not deliveries are scheduled to be received, companies can use external security cameras to watch access points at all times. Realistically, there may be situations in which the business or delivery area is accessed through either an internal or external building door; the focus here is on the latter. In this case, security cameras must be mounted outside, so weather-resistant and tamper-resistant devices may be necessary.

After access is gained to the delivery receptacle or main establishment, internal surveillance is the next step in risk mitigation. Cameras can be used in two ways in the interior: (1) to monitor the predetermined delivery location, such as a separate storage area or walk-in refrigeration unit; and (2) to monitor the main establishment. The first application can assist in delivery verification, and in ensuring that subsequent carriers do not remove goods that were already deposited. The second, similar to access surveillance, is not limited to times in which deliveries are received. Here, the camera helps protect the merchandise or other materials already present.

Both types of camera surveillance require the use of multi-component setups to achieve the full security effect. The camera itself is an integral part of the system, useful in deterring crime through its presence alone, as someone may see the camera and decide not to act, though these cases are rare. More commonly, the camera's video feed allows for digital video recording (DVR), and the saved footage can be reviewed in the event of an incident. Businesses that opt for heightened security, such as high-end retail, may also choose real-time monitoring (RTM).

The costs for the different setups vary significantly depending on factors including but not limited to: the camera's placement, desired picture clarity, viewpoint range, and networking capabilities. The individual cameras can cost anywhere from \$100 to over \$10,000. To capture the video feed, a DVR device must also be used. The price range for DVR cameras is similar to that of stationary cameras, and is primarily based on the number of inputs, and whether or not there is a hard drive. Optional RTM does not necessarily require additional components. Most standard DVR boxes allow the feed to be viewed remotely over the internet, and on some Smartphone models, so there are additional costs associated with paying the person monitoring the feed (B&H Photo and Electronics Corp., 2011). Some businesses may require the more costly, advanced devices, which they are likely to already have been installed; however, for the purposes of these UOHD programs, equipment on the lower end of the price scale is generally sufficient.

Access Control

To accept deliveries without the assistance of staff, businesses have several operational options that can be implemented to best fit their needs. The access control options presented below are divided into two main categories: (1) systems in which the need for building access is eliminated or restricted; and (2) systems in which full access to the establishment is granted. This distinction is important, as the level of access is directly associated with the amount of risk assumed by each business.

Restricted Access

This section discusses the ways in which UOHD could be implemented without the need for full access to the establishment. The driver and the newly-delivered goods are separated from the materials inside, and in some cases, entirely from the interior of the business.

- Delivery Lockers

Delivery lockers, or parcel boxes, can be used to receive, or even send, smaller deliveries without permitting any level of access to the inside of the establishment. Individual units and modular designs are available, so that each anticipated delivery could be given its own designated space; however, these are subject to dimensional constraints, which may be a challenge for businesses that receive deliveries by pallets or larger. Each locker can be equipped with its own access control, or the entire delivery station can be controlled through a central system.

There are different models currently available, which differ primarily by how access to the locker is achieved. A common approach is to include a subscriber identity module (SIM) card directly into the lock, which allows the driver to call its associated number and gain access after entering a numerical code. More complex commercial installations use barcode reader access to open the locker door, and to instantaneously update inventory systems once the goods are deposited. Each person making a delivery would be required to have an identification card with a unique barcode. The costs for this setup depend on whether there is a single unit, or a cluster design with several receptacles, and whether or not the lockers are wall-mounted or free-standing, as well as the construction materials.

- Double Doors

With a double-door setup, sometimes referred to as a vestibule, the driver is provided with a key to an external door, which leads to a designated storage area. This area is separated from the rest of the business by a second, locked door; whether separate infrastructure or a caged zone. Based on information available regarding commercial installations, a typical double-door system could cost anywhere from $20,000-$60,000 (Guardian Security Entrance, 2011). These installation costs are substantial, and may be an entry barrier for new businesses; however, this system could be the best option for establishments that already have double doors in place. Given that real estate is very expensive in Manhattan, this system has the value of the designated space itself. However, a storage area detached from the main business is not likely to have refrigeration capabilities, so the types of deliveries that double-door systems can receive is limited.

Another restricted access setup that allows for more freedom with installation is the virtual cage. The virtual cage only requires sufficient floor space for the delivery to be placed by the carrier. In other words, this technology does not require a specific storage room or delivery area, only a floor area in the store which, once the staff has unpacked the deliveries before the start of business, will be clear for normal use. The virtual cage operates using motion sensors—typically four—connected to the establishment's security system, to form a "cage" that segregates a section of the floor for the delivery to be placed. The driver is given a code that allows access to the space, and he/she then reactivates the cage after the delivery has been completed. This technology provides additional risk mitigation, as security alerts are triggered when someone goes beyond the confines of this cage into other sections of the establishment, as well as if something is removed from the cage. The virtual cage is well-suited for UOHD in large traffic generators (LTGs), such as skyscrapers, as it allows for deliveries to be placed in a section of the lobby area without allowing access to other floors, or to the operating spaces of establishments within the building.

As discussed, if a receiver has more than one supplier providing nighttime deliveries, each subsequent driver has access to the goods that have already been deposited. Additional security measures, such as cameras, should be used to ensure that drivers do not remove items from the delivery area. Access control technologies, described in the following section titled "Full Access," are also applicable here, as entry into the storage area needs to be controlled. If keyless (electronic) locks are used, the system records each new access attempt, information that could be useful in the event of a negative outcome.

- Two-stage Deliveries in Large Traffic Generators (LTGs)

Large traffic generators (LTGs) refer to single buildings that have a unique ZIP code, as warranted by the number of deliveries they receive, or to a conglomeration of numerous individual establishments, which collectively receive a high volume of goods. It is important to note that while not all large buildings are LTGs, this target group is responsible for roughly 4-8% of all daily deliveries in Manhattan (Holguín-Veras et al., 2010b).

The LTG delivery room receives/sends the UOHD initially. From there, the deliveries to the actual consignees take place during regular hours. In LTGs that already have central delivery areas, there would be little to no additional costs associated with UOHDs. Depending on the current delivery room operations, new security devices may be required if the area is traditionally staffed when in use. If the building does not have such an area, there would be costs associated with converting space. Also, there may need to be more than one central delivery area, depending on the size of the LTG, and the volume of deliveries associated with that location. In these cases, the issues involved are similar to those covered by the electronic doorman service in the following section; notably, it is more difficult to control access to upper floors. The building owner may also not be willing to use ground level space for a central delivery area. For a detailed discussion of off-hour deliveries and centralized receiving stations at LTGs, the reader is referred to (Jaller et al., 2013b).

Full Access

When the delivery person has full access to the establishment, goods can be left in any predetermined location, without the need for separate infrastructure. This is particularly useful for perishable goods that must be deposited into walk-in refrigeration units. Also, if cameras are used for internal surveillance, there is an added level of security. As discussed, though, increasing the amount of access increases the risks associated with someone—whether authorized or not—being inside the business premises unattended. The goods already present and accessible are not protected.

- Key Deliveries

Key deliveries are those in which the use of a physical door key is necessary. If the external door has a traditional deadbolt or other key lock, a copy of the key can either be given to the driver, or can be accessed from a key box, typically using an electronic code. This system requires the least amount of technology, and can be easily implemented. If a business wants to use a key box to store the drivers' copy, the associated costs can be as low as $50-$100 for surface-mounted devices, depending on the storage capacity and number of labels included (Assured Lock Tool and Supply, 2011).

There are drawbacks, however, to providing drivers with a key or access to a copy. When there is driver turnover—if a driver is fired, for example—then the business must be able to update the access list. For those drivers with door keys, this becomes a more pressing issue, as it may be difficult to manage key returns in unfavorable conditions. The business may need to replace the locks, which is not only an added cost, but also an added effort, involving distributing new keys to authorized individuals. There is also the risk that authorized individuals could give copies of the key to unauthorized individuals.

- Keyless Entry

Similar to key deliveries, keyless entry devices allow access into an establishment through a main door. Instead of having a physical door key, however, entry is controlled by an electronic lock that requires a pin code, access card, or more advanced recognition. Commercial grade keyless door locks can range from $300-$1,500 depending on the durability of the lock itself, ease of installation, and complexity of the access requirements. Pin code locks are the most basic form of keyless entry, and are typically the least expensive; though the prices do vary depending on how many access codes must be stored. The more advanced locks, such as biometric fingerprint scanners, are on the higher end of that cost range, given the multi-layer technology involved. These locks can store both fingerprints and pin codes, and also have an emergency override key. In the event of a power outage, or if the override key is lost, backup batteries keep the system online (BrickHouse Security, 2011a).

Although there are companies that both sell and install the locks, there are others that sell devices that can be easily installed by the business owner. The locks are manufactured to allow for easy installation on any existing door using only a few screws, eliminating installation costs. These are typically battery operated, so they do not require hardwiring into the building's electrical system. While there is a variety of keyless door locks available, which makes it easier to find an applicable system at a reasonable price, some of the more advanced models appear to be discontinued, particularly the fingerprint scanners (BrickHouse Security, 2011b). It is unclear why these locks are no longer on the market—whether it is a function of the devices, or that employees were uncomfortable having their fingerprints stored in a database.

- Electronic Doorman Service

These systems involve a remote operator, assisted by security cameras and radio/phone, who grants access to the authorized vendors by opening the doors electronically. The systems require thorough identification checks to ensure that only authorized individuals are allowed access. There is typically one company that oversees the system as a whole and its customer service, while the actual monitoring is contracted out to a third party. There is a server at each location that can be updated remotely by the business owner, and camera footage that is recorded by a digital video recorder (DVR). The cameras are also monitored on a real-time basis, so in the event of a theft, the company can take a more proactive approach to recover the losses. Also of note, the equipment is proprietary, so that once a company pays for the installation, it permanently owns the devices (Fischetti, 2011).

There are both upfront and running costs associated with this service, and the costs can vary drastically depending on the layout of the establishment, and the number of remote access requests. The third party monitoring company charges the primary doorman service each time access is requested (remote access requests), and this cost is passed on to the client. In other words, there is a fee associated with each use, so companies that receive 10 nighttime deliveries will have higher costs than those expecting only one. The installation costs can vary from $9,000 to $30,000, based on the complexity of the system. If an establishment is on the ground floor, with a door that directly accesses the interior, then the system is simpler, and requires only a couple of cameras to monitor the premises. If, however, the business is on an upper floor, or is difficult to access externally, then cameras and remote access points need to be installed to guide the drivers from the front door to the delivery location. The overall costs vary, and are determined on a case-by-case basis by examining the floor plans (Fischetti, 2011).

Insurance Coverage

It is assumed that the carriers and receivers involved in UOHDs already have their own respective insurance policies to protect against damages. Under an UOHD program, the receivers are being asked to assume a higher perceived risk in order for the carriers to benefit, so it makes sense that the carriers would assume additional coverage. These policies would be used to mitigate receivers' concerns, and to protect receivers from any accidental damage that occurs during UOHD. This coverage could be administered by the insurance sector, in combination with one of the motor truck associations in the New York and New Jersey area. It must also be noted that the other layers—access surveillance, access control, and internal surveillance— in an UOHD program, shown in Figure 2, can be used to verify which carrier is responsible for a negative outcome experienced during a multi-delivery period.

Public Sector Policies

After identifying the various ways to conduct unassisted off-hour deliveries (UOHD), policies should be outlined to foster their use. From the pilot phase of the Integrative Freight Demand Management in the New York City Metropolitan Area project, it was shown that these policies can play a crucial role in overcoming receivers' reluctance to participate (Holguín-Veras et al., 2010b). Receivers that are not already accepting UOHD must be convinced that it is beneficial for them to do so before they will change their operations. The success of an UOHD implementation depends on how well the UOHD operational concepts meet the needs and constraints of the participants, and how effective the policies are in inducing the desired change in delivery practices.

Although the carriers prefer off-hours deliveries because of the reduced costs and increased productivity, it is clear that receivers, who generally prefer daytime deliveries, are the key decision makers. When considering the classic "Battle of the Sexes" game (Rasmusen, 2001), there are two equilibrium solutions, and in this case the receivers impose the less favorable solution on the carriers. To change this outcome to the social optimum--participation in UOHD--there must be an incentive given to the receivers either by the carriers, or through the public sector.

While there are savings to carriers who use OHD, and by extension UOHD, it has been shown that these values in savings are typically smaller than the incremental costs to the receivers. This insight is crucial in understanding why there has not been a large shift to the off-hours. The carriers cannot pass on their savings to compensate the receivers, while still benefiting themselves. Therefore, public sector intervention is necessary to reduce the costs to receivers, and thus to reduce the costs that carriers would otherwise have to cover. By lowering this differential, the carriers can compensate the rest of the receivers' needs while still benefiting themselves; in which case adopting an UOHD program becomes "win-win," or optimal. This section identifies a set of potential policies to support a switch to OHD.

Financial Incentives in Exchange for Participation

A one-time monetary incentive in the form of a tax deduction, or any other modality, is provided to the receivers of UOHD. During the pilot test, this approach proved to be the most effective method of increasing the number of night deliveries. While one carrier in particular offered to install key boxes at its own cost; most receivers only agreed to accept OHD after a financial incentive was provided. This highlighted the receivers' need to perceive a tangible benefit before changing their operations.

Financial Incentives in Exchange for Security Equipment

Receivers are provided with a financial incentive to pay for, or offset, the cost of security devices or enabling equipment (like walk-in refrigerators). As previously discussed, the incentive approach may not be as effective as other monetary approaches if the receiver cannot quantify the full benefit of this equipment.

Public Recognition

Branding is being carefully considered to increase the validity of the UOHD implementation, and to recognize participants. There are a large number of environmental programs with seals, logos, or other graphics that are used to signify that a product or company has met the criteria for certification or inclusion. Taking a cue from these, and from branding done in Europe for the quiet trucks technologies, a public recognition or accreditation program will be used to help consumers identify which companies are proactively reducing negative impacts from deliveries. This may also induce a company (or their competitors) to participate.

Other Non-monetary Incentives

There are other means by which receivers can be compensated for agreeing to participate in an UOHD program. Current initiatives and available resources can be leveraged to assist businesses with the transition in their operations, and other business matters. Preferential parking and other curbside management policies have been discussed; however, these could interfere with current plans in the city, and more importantly, could be perceived as biased toward one company over another, if manageable curb area is not available for all buildings. For these reasons, curbside policies are not further evaluated in this report.

Of particular interest, though, is the concept of providing exclusive business resources to small and emerging companies that participate. There are existing resources available to assist businesses with tax preparation, managing financial databases, and other important business tasks. An online database of these resources that provide business assistance could be easily compiled, and any additional information determined to be of value to the businesses could also be added. In order to use this as an incentive, access to the database would be restricted to participants only.

Complementary Policies and Programs

In addition to new policies that could help foster the use of UOHD, there are complementary policies and programs already in place that could be applied to this implementation. The potential for collaboration with other agencies and sectors has not been fully realized, however, preliminary research and discussion have shown that the U.S. Environmental Protection Agency (EPA) could be a good starting point. The EPA regulates vehicle emissions and has certification programs already in place to recognize sustainable activities, so it may be possible to integrate OHD into these existing accreditations.

Furthermore, the team developed a noise policy to minimize the sound levels produced by UOHD, which can be adhered to through driver training and quiet truck technologies. From the pilot phase and in other OHD trials in Europe, it is clear that noise is a major issue for city residents, so this is addressed in more detail later in this Chapter. Hybrid and alternatives fuel vehicles are becoming more popular, and in some cases mandated, which again points to the advantages of a possible partnership with EPA.

Industry Feedback

The research team conducted a series of phone calls to gain industry feedback on the menu of alternatives presented in the Economic Implications and Unassisted Off-Hours Delivery Programs sections. Some of the feedback has already been integrated into the information in those chapters; more detailed accounts of the conversations are found below. The four individuals interviewed were part of the Industry Advisory Group (IAG) for the pilot test, and have agreed to serve in the same capacity for the implementation phase. It is also of note that Whole Foods Market, Sysco, and Foot Locker/New Deal Logistics were the primary corporate participants in the pilot phase of the Integrative Freight Demand Management in the New York City Metropolitan Area project.

Robert Twyman, Whole Foods Market

Mr. Twyman is President for the Northern California region for Whole Foods Market (WFM); previously the Northeast regional vice president. Whole Foods Market (WFM) is a large food retailer that features natural and organic products, with locations all across the United States and beyond. WFM currently receives some UOHD, and since they are dealing with perishable products, keypads are commonly installed to allow access into the stores, and subsequently to the refrigeration units.

When asked about the potential for double doors, Mr. Twyman raised the following questions: "How many people have those keys, and how many people have access to it [the keys]? What level of security is there such that if I deliver something that is of high value, and then somebody else … [is] delivering and they see that, what's to prohibit them from taking some or all of that product out?" As discussed in Chapter 2, there is a risk when multiple vendors need to access the delivery area, though this risk is lessened through the use of security cameras.

With regard to the incentives, Mr. Twyman mentioned that insurance might not be a viable option for small businesses that operate on a day-to-day basis. When the cash profits from one day are needed to purchase goods for the next, any sort of incident—and in particular, a cash robbery—could be detrimental to continued operations. Although the funds would eventually be reimbursed through an insurance policy, the business may not be able to survive long enough to be fully recompensed. It was originally suggested by Mr. Twyman to offer exclusive business resources to these small companies, such as "financial management resources [and] how to build their business." This type of partnership "[helps] them to grow" without "just asking them [to participate, which] is going to be one more thing … to deal with."

Joseph Killeen, New Deal Logistics

Mr. Killeen is a Managing Partner, and Director of Operations for the Greater New York City area at New Deal Logistics (NDL). NDL is a retail carrier for companies ranging from Foot Locker (who participated in the pilot) to Saks Fifth Avenue. Mr. Killeen has been very proactive in pushing for more sustainable deliveries, and has purchased electric trucks for NDL's fleet.

During the discussion of key deliveries, Mr. Killeen concurred with other feedback that electronic keypads are preferable to key boxes. He mentioned that companies now prefer an even higher level of security that could include the card swipe system previously mentioned, and retinal scanners to gain entry. It seemed, though, that these advanced systems are primarily used at buildings that require heightened security, such as the United Nations, or at high-end retailers that have very valuable merchandise to protect. These advanced systems may not be necessary, or within the scope of this implementation stage.

Robert Heim, Sysco

Mr. Heim is the Vice President of Operations for the Metro New York area at Sysco, which is the largest food distribution service in North America. Sysco currently serves nighttime routes in NYC, with some using UOHD through key deliveries so that goods can be left in refrigerators. Mr. Heim was unsure about the potential for keypads specifically, noting that when codes are changed, "getting that information to [the driver] is paramount." He cited instances in which the business updated the codes for one reason or another, but failed to pass on necessary information, which resulted in the driver having to wait at the location for someone to grant access. There was a similar reaction to the electronic doorman service, as drivers themselves are subject to change, so the system would need to be able easily update rosters.

As for the incentives and other policies, Mr. Heim stressed that financial incentives were the "tipping point" during the pilot, so any other options might not seem as attractive. In order to gain feedback from the receivers, Mr. Heim agreed to distribute small questionnaires. Sysco sales staff spoke with its customers and gathered the requested information, which includes reactions to the menu of alternatives, as well as basic company information. This feedback was considered when designing the full sample survey discussed in Chapter 4.

Thomas Connery, New England Motor Freight

Mr. Connery is the Executive Vice President and Chief Operating Officer of New England Motor Freight (NEMF), a large and diverse carrier in the Northeast. NEMF is currently providing OHD—in some cases unassisted—primarily in smaller metropolitan areas, such as Boston.

Mr. Connery originally mentioned caged areas monitored by security cameras, similar to physical double doors, as a typical retail setup. It was stressed that "risk is probably the biggest [issue]" for the management, which "has to be convinced that the risk has been taken out." Though the risk is reduced, there is also the issue of whether or not the business can "afford to put up a cage that keeps the driver separated from the other merchandise."

Mr. Connery discussed the nighttime operations with one of NEMF's large retail customers, where UOHD are left in a storage area. The driver uses a handheld scanner to instantly update the inventory database, so that when the staff arrives to open the store, the merchandise can immediately go onto the shelves. This "was the biggest thing" that influenced the retailer's decision to accept OHDs, because it increased the "face time with the customer" for the sales personnel, instead of having to receive the deliveries manually.

With regard to possible incentives, Mr. Connery noted that business owners need to see the value of each option, so highlighting labor and inventory control savings would be more tangible than offering small business solutions. In order to help quantify these savings, the research team mentioned conducting a case study of the retailer's UOHD, and Mr. Connery has agreed to participate. He also stated that public recognition could be a successful strategy because the company would have something to promote.

Analysis of Unassisted Off-Hours Deliveries (UOHD) Programs

Taking into consideration the industry feedback in the previous section, the research team evaluated the system components introduced in the earlier section "Unassisted Off-Hours Delivery (UOHD) Programs," to identify the most promising unassisted off-hours delivery (UOHD) programs. To analyze which public sector policies would best foster the use of each program, the alternatives had to be narrowed. The four security levels, with their respective alternatives, are summarized in Figure 3.

The three programs outlined represent the most cost-effective, easiest to implement, and industry-preferred alternatives. During the team's analysis, and especially from the feedback received, it became quite clear that keyless entry systems, particularly those using PIN codes, should be considered as the top alternative for full access control. While the UOHD implementation is not limited to one industry sector, there is a large representation from restaurants and food services, and these businesses often receive perishable goods that require refrigeration. This was the case for many participants of the pilot phase, and keypads were used to control access. Some higher-end retailers that are concerned for the security of valuable store merchandise already use keypad entry systems. This program and the other two are discussed in more detail in the following section.

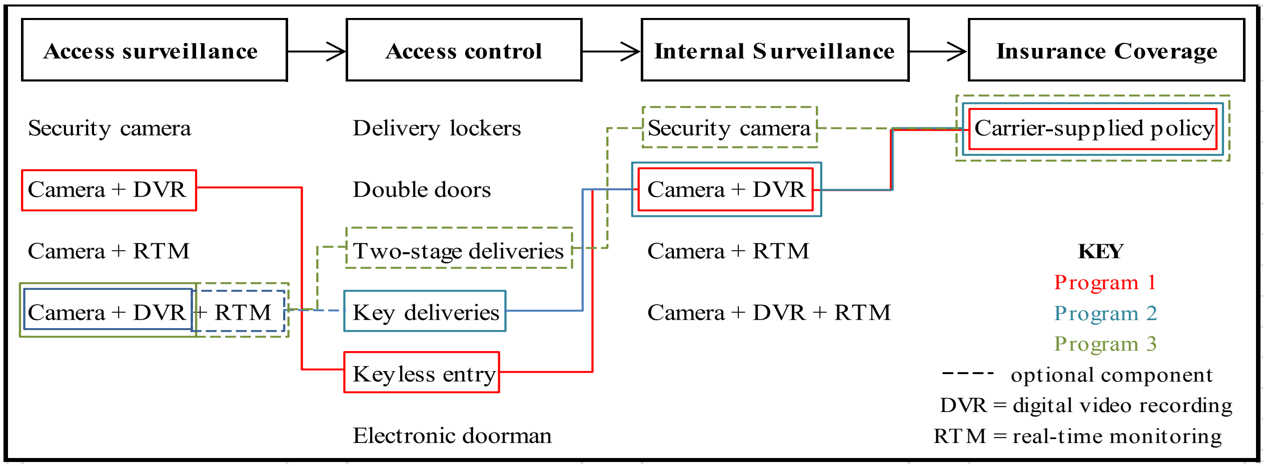


Figure 3: Overview of UOHD Program Alternatives

Preferred UOHD Programs

The first program in Figure 3 is comprised of a keyless entry system, security cameras with digital video recording (DVR) devices for both access and internal surveillance, and the insurance coverage provided by carriers. It can be seen that the other two programs include optional real-time monitoring (RTM) of the access surveillance camera, which is not explicitly considered here, but can still be offered in the menu of alternatives. The access control system itself provides additional security with the electronic lock, and more advanced devices like fingerprint scanners ensure that only authorized individuals can gain access; codes or swipe cards can be given away, while fingerprints cannot.

The second program includes a camera with DVR for both access and internal surveillance, and the carrier insurance coverage. The main difference between it and the first program is in terms of access control, as door keys are used instead of keyless entry components. The previous section on UOHD programs notes that there are several advantages to using electronic access instead of traditional keys; however, there may be cases in which a business cannot or does not want to install electronic devices. The keyless entry systems offer additional security by keeping a record of who gains entry and when, which is offset by the optional RTM of the access camera. A company could use RTM to verify that only authorized individuals have keys to access the business, though this could negate the savings realized from not installing a keypad.

The third program of note is targeted specifically to large traffic generators (LTGs), which are being given extra attention throughout this implementation phase. There are special considerations for the two-stage delivery setup, and these influence the required surveillance equipment. Some buildings already have staging areas available, which may or may not be under 24/7 surveillance, which would influence whether or not UOHD are allowed, and whether or not RTM is an option. Also, since access is not granted to the establishments themselves, the inclusion of internal surveillance is not required, except to monitor the delivery area.

Effectiveness of Public Sector Policies

After narrowing the potential program combinations to the three outlined above, public sector policies were evaluated against each program. Although the prior section entitled “Public Sector Policies” discusses monetary incentives for either general participation or for specific security equipment, it was decided that making this distinction is unnecessary, and that receivers should be able to apply the one-time payment as needed. Public recognition and small business resources are also considered. The results of this analysis can be found in Table 1. Each cell includes the pros and cons for each program-policy pairing, from the standpoint of the receivers. The most favorable combinations are discussed.

Table 1: Analysis of top UOHD programs

UOHD Programs	Public Sector Policies		
	One-time Financial Incentive	Public Recognition	Small Business Resources
Program 1	Successful in pilot (+)	Could increase customer draw to participating businesses (+)	Could help small business grow more rapidly (+)
Camera + DVR	If equipment is already installed, can use $ as desired (+)		
Keyless entry			
Camera + DVR		It is unclear how effective this will be in inducing a change (-)	Might not be effective for large or established companies (-)
Carrier Policy	Runnning costs not covered (-)		
Program 2	Same pros as Program 1 (+)	Could increase customer draw to participating businesses (+)	Same pros as Program 1 (+)
Camera + DVR + *RTM*	Lower setup costs, so incentive makes a larger impact (+)		Companies not using keyless entry may be more independent and need these resources (+)
Key deliveries			
Camera + DVR		It is unclear how effective this will be in inducing a change (-)	
Carrier Policy	Runnning costs not covered (-)		Same cons as Program 1 (-)
Program 3	May be effective in convincing individual businesses (+)	Participants stand out from large group of establishments (+)	Easy add-on to $ incentive (+)
Camera + DVR + *RTM*			
Two-stage deliveries			May not be as attractive to LTG businesses, which tend to be larger/more established (-)
Security camera	Does not consider building setup costs for stagin area (-)	It is unclear how the building itself could be recognized (-)	
Carrier Policy			

The information in Table 1 shows that a financial incentive may be the most effective means to solicit receiver participation. As noted, an incentive was used in the pilot, and was the tipping point for many companies. There is also precedent and subsequent information into this policy’s effectiveness; in other words, financial incentives have been proven to work. It is not quite as clear how effective the public recognition and business support approaches would be on their own; they may need to be presented as a pairing with the monetary incentive. However, based on industry feedback, it is clear that both should be investigated further.

The advantages of the one-time financial incentive have already been discussed. The negative attributes warrant further attention, as one-time payments do not consider or cover costs that will be incurred by businesses in the future. The use of security equipment or electronic locks comes with operation and maintenance costs, in addition to the upfront purchase and installation costs. Companies that already have some or all of this equipment would be able to apply the incentive toward these running costs, or as desired.

As for the other two policies, preliminary analysis has highlighted some advantages, or 'pros' that are worth mentioning. Recent trends in branding and corporate responsibility show that customers often do seek out businesses or products that meet certain criteria, so providing an accreditation or recognition to those businesses that participate may help them attract more customers. In addition, this may encourage other companies to join an UOHD program, to lessen their competitor's advantages. Within the context of an LTG, a certification would help customers more readily identify which stores to visit out of the potentially hundreds in that single building. This would also help distinguish those businesses and help them grow, as would exclusive resources for tax, financial, or other purposes. These business support resources are not as universally applicable however, especially not for large corporations.

Quiet Truck Technologies/Noise Policies

Off-hours deliveries (OHD) raise major concerns about the effects on communities of noise emissions from truck operations during the night. There is less ambient noise during off peak (night-time) hours, so truck noise is more noticeable, and could impact people in the area. The main effects of noise are sleep disturbance and health problems. A study done by the European Heart Journal showed that noise emitted by aircrafts cause significant damage to health. The study concluded that even while sleeping, the subjects' blood pressure increased as a result of the noise (Finlay, 2008). To effectively mitigate these negative effects, the implementation of suitable low-noise policies, and the use of low noise technology features for trucks, delivery equipment, and buildings could be used. These technologies and strategies are discussed in this section.

Noise Levels Involved in the Delivery Process

The standard diesel engine truck operates at 80 dB(A), but the engine is not the only source of noise associated with the delivery process (Wieman, 2010). Table 2 shows the measurement of some typical sounds that occur in the delivery process without the implementation of low-noise technologies, as measured from a distance of 7.5 meters (Goevaers, 2010a).

Table 2: Noise Measurements for Delivery Related Noise-makers (Goevaers, 2010a)

Action	Noise Measurement dB(A)
Slamming door	74
Driving up/away	67-83
Load hatch	65-92
Containers over load floor	74-85
Refrigeration kicking in	70-78
Removing onboard forklift	77-82
Shopping trolleys	53-77

The following sections discuss low noise technologies, most of which were developed under the PIEK Program in the Netherlands (discussed in the Consideration of Noise Pollution Control Section), as well as initiatives from other European countries, which address the delivery-related sounds mentioned in Table 2.

Low-Noise Truck Solutions

Natural Gas Trucks

The most identifiable noise culprit associated with night deliveries is the delivery truck. There are various technologies that have been developed to combat this noise source, including low-noise engines, refrigeration systems, tires and other truck accessories.

Investments that address the truck's engine are the most costly of the solutions, but low-noise truck types are also environmentally friendly, resulting in fewer emissions. Solutions for engine noise include trucks that use natural gas—whether compressed natural gas (CNG) or Liquefied Natural Gas (LNG). In addition to the noise reduction, natural gas engines provide other environmental benefits, as the emissions produced do not contain any fine dust or particles. Natural gas engines also can operate on renewable biogas without the need for any retrofits. Biogas is a CO_2-neutral energy source that can be produced from fermented food waste (Daimler AG, 2011).

There are CNG and LNG models that operate at a reduced level of 72 dB (A), which meets the PIEK 'Light' certification requirements from the PIEK Program in the Netherlands. More details on CNG and LNG models are included in Appendix 1

Electric Trucks

Electric trucks are another low-noise engine solution. An example is a model being used by Nestle Switzerland that was created specifically for them by Renault Truck's Clean Tech label. The model, nicknamed the "e-truck," includes both a refrigeration system and an engine that are electrically powered. The truck has a 103 kilowatt (kW) electric motor and a pair of lithium-ion batteries with a capacity of 170 kilowatt hour (kWh); providing up to 81 miles of travel on one charge. The batteries can be charged from regenerative braking, so the batteries charge during frequent starts and stops. Nestle Switzerland uses the vehicle on routes up to 60 miles in length, with about 50 stops and with a payload of 3 tons (Katers, 2012).

PepsiCo's Frito-Lay North America division also use all-electric vehicles; the largest fleet of commercial all-electric trucks in the United States (Frito-Lay, 2012). It was announced in August, 2012 that Frito-Lay planned to roll out a total of 105 all-electric trucks in California by the end of 2012; the largest deployment of any state, bringing the total of 275 all-electric trucks in the U.S. for the company. Some of the vehicles' more relevant characteristics include:

- The ability to operate for up to 80 miles on one charge.
- Zero tailpipe emissions.
- 75% less greenhouse gas emissions than standard diesel engines.
- Silent operations, eliminating noise pollution.
- Economically viable alternatives to traditional fuel sources; Frito-Lay aims to reduce its fuel consumption by 500,000 gallons per year after the full deployment.

Hybrid Trucks

A Hybrid truck has a dual engine consisting of a standard diesel engine and an electric motor, and usually uses the diesel engine for the majority of the trip, but switches to electric when entering the city to perform the "last mile" of the delivery. A model created by Colruyt Group is a 44-ton heavy duty truck that is able to operate at 65 dB (A) and is PIEK-certified. The electric motor is able to operate for 10 km (6.2 miles). The model is able to run on either the diesel engine or the electric motor exclusively, but has the option of the two working in parallel. Other benefits include fuel cost savings and reduction in CO_2 emissions (Colruyt Group, 2011). For more details on the Colruyt model see Appendix 1.

Low-Noise Refrigeration Systems

Another source of noise pollution comes from the refrigeration unit attached to refrigerated trucks. These units have their own motors, which generate noise when they are in operation. One approach to mitigating the noise from this source is used by the Carrier Corporation. The Carrier Vector 1850 XLN (Xtra Low noise), has an engine for the refrigeration unit that is extracted from the original host unit and placed in an insulated undermount under the trailer chassis. The undermount is made from special material and is completely insulated, which reduces noise by insulating the noisiest part of the system. The model is PIEK-certified, and operates at an impressive 59.5 dB (A) (MotorTrader.com, 2008).

Another approach taken by Frappa (a company that specializes in refrigerated vehicles) was to use a PIEK-certified cryogenic nitrogen tank placed under the vehicle instead of in front of it. The model, named the "Silent Green," included other low noise features such as electrically operated rolling doors at the rear, and noise-absorption aluminum floors that also prevent skidding. This three-axle semi-trailer is capable of doing the same job as ten 3.5 ton trucks. Investments in this model result in significant cost savings for drivers and vehicles. There is an added benefit in savings in fuel costs for the refrigeration unit compared to conventional refrigerated vehicles; nitrogen-fueled operations are cheaper than diesel-operated (Haldex, 2010). The model offers an engine quieter than 60 dB (A), no CO_2 footprint, a refrigeration unit that does not use a motor or fan, a PIEK-certified retractable tail lift, and a trailer body specifically designed to avoid noise (Frappa, 2013).

Truck Accessories

After addressing the physical structure of the truck and its engine, there are truck accessories that can also reduce noise levels. This section considers tires and lifts, already on the market, which have been shown to meet required noise outputs.

Tires

There are several labeling options available that display the noise levels produced by a tire. One such labeling is "s-marking," which was put forth in the European Council Directive 2001/43/EC. which states that van and truck tires must obtain an "s-marking" in line with the rolling sound regulations starting October 1, 2009 (European Parliament and Council of the EU, 2001). An example of the "s-marking" can be found in Appendix 1. In the directive, maximum allowable noise limits were also given for the various types of tires in the directive; this can be seen in Table 3.

Another organization that provides labels for tire noise measurements tis the Nordic Swan, organized by the Nordic Council. It offers eco-labeling for a number of products to its five member countries, Sweden, Denmark, Norway, Finland and Iceland. The noise limits for gaining a Nordic Swan label for tires are displayed in Table 3 (Sandberg, 2008).

Table 3: Comparison of the Noise Limits for Commercial Vehicle Tires for Nordic Swan and the EU Directive (European Parliament and Council of the EU, 2001; Sandberg, 2008)

Vehicle Type	Class of Tire	Tire Section Width [mm]	Noise Limit [dB (A)]	
			Nordic Swan	EU Directive
Van	C2b	≤ 165	72	75/77/78
	C2c	> 165 ≤ 18	73	75/77/78
	C2d	>185 ≤ 215	74	75/77/78
	C2e	>215	75	75/77/78
Truck	C3 Normal	Normal	76	76
	C3 Snow	Snow	78	78
	C3 Special	Special	78	79

The German Blue Angel organization is another system that labels tires on their environmental properties. In order to receive this label, the tire has to meet the following requirements (Sandberg, 2008):

- Weight
- Noise emission
- Rolling resistance coefficient
- Mileage (service life in km, as specified by the National Highway Traffic Safety Administration(NHTSA) Uniform tire Quality grade (UTQG) standards)
- Braking distance
- Aquaplaning speed

Noise level requirements are more stringent for the German Blue Angel label than for the Nordic Swan, requiring 72 dB(A) for all categories (Sandberg, 2008).

Tail Lifts

The Belgian company Dhollandia, which specializes in vehicle lifts, especially for trucks, created a Noise Abatement Society (NAS)/PIEK-certified tail lift that functions below 60 dB (A). Its features include:

- *Silent power pack* - a silent motor-pump combination and a casing with sound-dampening panels.
- *Sound-absorbing platform coating* – a long lasting heavy-duty coating that has high anti-slip characteristics.
- *Automation* - allows the lift to perform loading functions that are normally done manually, decreasing the human factor of noise creation.
- *Intelligent Interlocks* - prevents the misuse and damage of automatic functions; this characteristic allows for safe operations and extends the life of the lift (Dhollandia, 2012).

Cargo Handling Equipment

Noise also occurs during the loading and unloading portion of the delivery process. Cargo handling equipment helps to reduce the noises that are created, including low-noise forklifts, hand pallet trucks, rolling cages and carts. These technologies focus on the appropriate wheel technology to ensure smooth operation. Other adjustments made to cargo handling equipment to decrease noise include suspension seats and easy-to-use controls for forklifts; and rubber studs to decrease vibrations for the hand pallet truck. For more information on cargo handling equipment, see Appendix 1.

Noise Absorbing Materials

A lower cost means of mitigating some of the noises associated with night deliveries is the use of noise-absorption materials. These materials can be placed in the trailer or body of a truck; in the engine compartment; and/or at the warehouse or store receiving the deliveries. Noise-absorbing materials include: airborne sound-absorption sheets, barrier mats, floor mats, or a composite that is a combination of any of the other types previously mentioned. These materials are used to absorb or insulate sound, and also to curb the generation of structure-borne noises (vibrations). Absorbing materials vary by type of material, thickness and texture, depending on the application, which is determined by the noise source—type and location—and the lower noise level that needs to be achieved (Noisetek, 2011). More information on noise absorbing materials can be found in Appendix 1.

Physical Changes to Store Location

Other measures that may be taken to reduce noise levels include inspecting the store locations and surrounding areas, and making improvements in those locations. For example, in Belgium there are cobblestone roads, which are noisy when trucks traverse them. A solution to this problem was to repave these as concrete roads. Another example is to improve the smoothness of the driveways at receiver locations. The interior of the receiver building can also be improved, by applying such noise-absorption materials as previously described on the floor, walls and ceilings (Gevaers, 2011).

Training Staff about Noise Abatement

Training carriers' as well as receivers' staff on ways to perform their duties with less noise is another method that can be employed to keep noise levels at a minimum. The main training goal is to ensure that drivers abide by the following checklist (Goevaers, 2010a):

- Mind the speed
- Mind the revolutions-per-minute (RPM) level
- Turn off the radio
- Do not slam doors
- Do not drop the cargo storage bar
- Engage roll cage stop using the entire foot

Consideration of Noise Pollution Control

Noise and its negative impacts on surrounding communities is an important potential issue in off-hour deliveries (OHD). To be proactive in this matter, the team has researched existing noise policies and initiatives, and formulated a noise policy which all participants (carriers and receivers) in the switch to off-hour deliveries in this project will abide by, in addition to any outstanding noise regulations in the city of New York. This section includes some background information on how noise issues are managed in in four large cities in the United States; the European perspective on noise and associated noise policies and initiatives; the health effects of noise; and concludes with the noise policy that will be instituted for the project.

The Environmental Protection Agency (EPA) defines noise as unwanted or disturbing sound. The negative impacts of noise include sleep interference, disturbance of other normal activities, and diminishment of quality of life from discomfort or even negative effects on one's health (Environmental Protection Agency, 2011). A study done by the European Heart Journal showed that noises emitted by planes can cause significant damage to health. The results of the study concluded that even while sleeping, subjects' blood pressure increased as a result of the noise (Finlay, 2008). To mitigate the effects of noise pollution the EPA, under the Clean Air Act, established the Office of Noise Abatement and Control (ONAC), whose role was to carry out research on noise and its effects on public health and welfare. The ONAC was responsible for all noise control activity at the federal level, but in 1981 the Administration decided to delegate noise control issues to the state and local level. The EPA still possesses the authority to conduct research on noise and its impacts, make information on noise and its effects available to the public, respond to noise-related inquiries, and to evaluate the efficacy of existing noise policies (Environmental Protection Agency, 2011).

Noise Policies in the United States

Since the responsibility for noise regulations now resides at the state and local level, New York City and other large cities within the United States will be considered to give a sense of the noise policies that currently exist in the US. Three cities were chosen based on population, population density, and how developed the city is, to provide some comparison with New York City: Chicago, Illinois; Los Angeles, California; and Houston, Texas. European countries have been making major steps in addressing noise issues, so, the policies and regulations being implemented there will also be helpful in determining effective noise policies.

Chicago, Illinois

Regulations set by the city of Chicago regarding noise and vibration controls are stated in the Chicago Environmental Noise Ordinance. Those which may apply to freight vehicles include the prohibition of loading and unloading operations of boxes, crates, containers, building materials, garbage cans, dumpsters, etc., between the hours of 10:00 p.m. and 7:00 a.m. in a manner that would cause noise disturbance in a residential or noise-sensitive zone. The document defines noise disturbance as any sound which is audible at least 600 or more feet from the source; or generates a sound pressure level on the public way exceeding 70dB(A) (A-weighted decibels match frequency response from ear.) when measured at a distance of 10 or more feet from the source. Noise sensitive zones are those indicated by signage which specifies that within the boundaries of the zone no person should cause any noise which would interfere with a school, library, church, hospital or nursing home (City Council of Chicago, 2010).

Other noise limitations not specifically addressed by other regulations in the ordinance, and not included in the exceptions, are generally covered by the regulations that state that persons are restricted from generating any noise on the public way above the level of a normal conversation when measured from a distance of at least 100 feet horizontally or vertically from the source between the hours of 8:00 p.m. and 8:00 a.m. The second part of this policy restricts persons on private open spaces from generating noise that exceeds the level of an average conversation from a distance of at least 100 feet from the property line of the compound from which the noise originates (City Council of Chicago, 2010).

The noise policy which directly addresses motor vehicles is addressed in section 11-4-1160 of Article VII: Noise and Vibration Control titled Motor Vehicles. Part one of the policy is the most pertinent to the delivery process, as it states that it is unlawful for operators of vehicles with a gross vehicle weight rating (GVWR) in excess of 10,000 pounds to leave their vehicle standing on a private property and within 45 meters (147.64 feet) of residential properties for longer than two minutes, with the exception of when the vehicle is within a completely enclosed structure (City Council of Chicago, 2001).

Los Angeles, California

The general noise policy in the Los Angeles City Noise Ordinance prohibits a person from intentionally causing or continuing any loud, unnecessary or unusual noise that upsets the peace or quiet of a community, or that causes the annoyance of a resident of the area who is determined to be reasonable and has normal sensitivity. The factors that will be considered in determining if the noise violates this section, as stated in the document are (City Council of Los Angeles, 1982):

- Noise level;
- Nature of the noise (usual or unusual);
- Origin of the noise (natural or unnatural);
- Level and intensity of ambient noise;
- Location of the noise compared to sleeping facilities;
- Nature and zoning of the area;
- Density of inhabitation in the area;
- Time of day or night the noise occurs;
- Duration of the noise;
- Whether the noise is recurrent, intermittent, or constant;
- Whether the noise is produced by commercial or non-commercial activity.

The regulation that specifically addresses the noise caused by motor vehicles prohibits the unreasonable operation of a motor vehicle, acceleration of the engine, or use of the horn in a manner that will cause disturbance of the peace, quiet and comfort of a neighborhood or any resident of the area considered to be reasonable and of normal sensitivity. The noise should be audible to the human at least 150 feet away from the property line of the property from which the noise originates. It should be noted that this regulation excludes motor vehicles operating on public right-of-way (City Council of Los Angeles, 1982).

Houston, Texas

The Code of Ordinance for the City of Houston, Texas does not contain much information that specifically addressed the operation on motor vehicles, but provides a general policy for maximum permissible sound levels. The regulation sets the maximum permissible sound level for residential and nonresidential properties for daytime hours and nighttime hours as shown in Table 4. The regulations state that no person shall produce or cause to produce any noise exceeding the stated maximum permissible sound levels that is distinctly audible beyond the property lines. The sound is measured at, or near the closest property line of the property receiving the sound (City Council of Houston, 1997).

Table 4: Maximum Permissible Sound Levels for Houston, Texas

Type of Property	Time of day	Sound level
Residential	Daytime (7:00 a.m. - 10:00 p.m.)	65 dB(A)
Residential	Nighttime (10:00 p.m. - 7:00 a.m.)	58 dB(A)
Nonresidential	Daytime & Nighttime	68 dB(A)

The regulation which addresses motor vehicle operations states that the use of any motor vehicle that is out of repair, overloaded, or maintained in a manner that will cause it to create loud and unreasonable sound is declared unlawful (City Council of Houston, 1997).

New York City, New York

The general noise prohibitions in the New York City Noise Control Code Title 24, Chapter 2, Subchapter 3 states that no person shall produce, cause, continue or allow to be made any unreasonable noise. Unreasonable noise includes, but is not limited to, sound from any device which exceeds the prohibited noise levels, exclusive of sounds attributable to construction and those with decibel level limits or requirements mentioned elsewhere in the code. The prohibited noise levels are as follows (NYC Department of Environmental Protection, 2007):

- Between the hours of 10:00 p.m. and 7:00 a.m. any sound, other than impulsive sound, that is measured at a level that exceeds the ambient noise level by at least 7 dB(A).
- Between the hours of 7:00 a.m. and 10:00 p.m. any sound, other than impulsive sound, that is measured at a level that exceeds the ambient noise level by at least 10 dB(A).
- Impulsive sound from an identifiable source that exceeds 15 dB (A).

Measurements for the three cases previously discussed may be taken from any point within the receiving property, or at least 15 feet from the source on public right-of-way. In addition to these specifications, when measuring impulsive sound the noise source should be measured in the A-weighted network with the measuring device set to fast response, and the ambient should be taken with the meter set to slow response (The City of New York, 2005).

Regulations included in the code specifically addressing motor vehicles are as follows (The City of New York, 2005):

- With the exception of motorcycles, no person shall cause or allow any motor vehicle with a maximum gross weight of 10,000 lbs. to operate on a public right-of-way with a muffler or exhaust that causes a plainly audible sound when measured from a distance of 150 feet from vehicle.
- No person shall cause or allow any motor vehicle that weighs over 10,000 lbs., to operate with a muffler or exhaust that generates sound plainly audible at a distance of at least 200 feet from the vehicle.
- The use of vehicle horns is illegal, except as a warning in situations of imminent danger.

The code also includes regulations on refuse collection vehicles (The City of New York, 2005):

- It is prohibited for persons to sell, offer for sale, operate or allow to operate a refuse collection vehicle equipped with a compactor that exceeds 80 dB(A) when the compactor is in the cycle but not engaged in compacting a load, when measured at a distance of at least 35 feet from the compacting unit.

- It is unlawful to operate a refuse collection vehicle, including those equipped with compacting devices, within 50 feet of any residential property between 11:00 p.m. and 7:00 a.m. if the aggregate sound of the vehicle and the compacting activities exceed 85 dB (A) when measured at least 35 feet away from the vehicle by a sound meter set to slow response. Beginning July 1, 2012 the noise level for the aggregate sound will reduce to 80 dB (A). In an emergency situation such as a storm, operations of refuse collection vehicles are exempt from this regulation.

Article 10-386 from of the New York Vehicle and Traffic Law provides motor vehicle sound level limits. Table 5 shows the motor vehicle noise limit with respect to their gross vehicle weight. The law states that it is unlawful for any person to operate any motor vehicle or combination of vehicles with the specified gross weight category at any time of day, under any condition of grade, load acceleration or deceleration on a public highway in a manner that exceeds the specified noise limit. The noise limits are for noises audible at a distance of 50 feet or more. For a vehicle with a speed governor, the measurement is taken 50 feet from the longitudinal centerline of the vehicle when the engine is accelerated from idle with a wide open throttle to governed speed with the vehicle stationary, transmission in neutral and clutch engaged (The State of New York, 2010).

Table 5: Motor Vehicle Noise Limits for State of New York

Gross Vehicle Weight Rating (GVWR) (lbs)	Noise Limit		Distance
	≤ 35 mph	>35 mph	
≤ 10,000	76 dB(A	82 dB(A)	50 ft from center of the lane vehicle is travelling
> 10,000	86 dB(A)	90 dB(A)	50 ft from center of the lane vehicle is travelling
> 10,000 with engine speed governor	88 dB(A)	88 dB(A)	50 ft longitudinal centerline of the vehicle

Noise Policies in Europe

Europe is leading the pursuit of noise reduction for freight transportation, specifically for off-peak and night deliveries. The European Council (EC) issued a directive related to the assessment and management of environmental noise. The objective put forth is "to define a common approach intended to avoid, prevent or reduce on a prioritized basis the harmful effects, including annoyance due to exposure to environmental noise (European Parliament and Council of the EU, 2002)." The approach includes noise mapping, public outreach, formulation of an action plan, regular evaluation of the implementation, and evolution of the implementation through technological progress.

In order for the approach to be consistent, it was essential to define 'environmental noise' and the noise indicators that would constitute annoyance and disturbance. The Directive defines environmental noise as "unwanted or harmful outdoor sound created by human activities, including noise emitted by means of transport, road traffic, rail traffic, air traffic, and from sites of industrial activity (European Parliament and Council of the EU, 2002)." Annoyance is defined as the degree of community annoyance and is determined by field surveys. (European Parliament and Council of the EU, 2002).

Another directive issued by the EC is the European Council Directive 2001/43/EC, which focuses on the controlling noise caused by motor vehicle tires. The document states that van and truck tires must obtain an "s-marking" in line with the rolling sound regulations starting October 1, 2009 (previously discussed in the Quiet Truck Technologies Section).

Noise Policy in the Netherlands

Based on the Directives put forth by the Council of the European Union, the Netherlands established the PIEK (PEAK) program, which has been successful in creating and implementing many low-noise truck technologies. The name of the program refers to peak noise levels; the focus of the program is to lower peak noise levels because these are the main culprits of disturbance (Shoemaker, 2005). The main objectives of the project are the promotion of quiet behavior; transfer of knowledge; development of low-noise trucks; development of quiet ancillaries such as roll-cages and forklifts; modification of location and architectural design to improve loading/unloading areas; and the development of electric accessories such as reverse beeping and torque limiters (Finlay, 2008).

Legislation in the Netherlands sets the noise level for off-peak deliveries at 65 dB(A) between the hours of 19:00 to 23:00 and 60 dB(A) for 23:00 to 7:00 (Goevaers, 2010b). The PIEK standard noise level for the technology that have been developed under this program is 60 dB(A), which is the level of a normal conversation, with the exception of trucks and shopping trolleys which are held to a standard of 65 dB(A). The PIEK program also offers certification called PIEK 'Light" which focuses specifically on noises associated with the loading and unloading portion of the delivery. The noise standard for PIEK 'Light' is a maximum of 72 dB(A) (Wieman, 2010; Goevaers, 2011). To be certified under the scheme, each product is acoustically measured from a distance of 7.5 meters (24.6 feet) from the source of the sound, and should meet the stated noise standards. The highest sound level of all the measurements is the one that is used to determine if the truck or equipment receives certification (Noise Abatement Society).

The Noise Abatement Society (NAS) - United Kingdom

The Noise Abatement Society (NAS) in the United Kingdom (UK) works to raise awareness of the issue of noise pollution. They developed the "Silent Approach™ Quiet Night Delivery Scheme" in 2007; a protocol designed for night deliveries, to protect the rights of residents. The scheme was developed to prepare for the eventual extension of delivery hours to off-peak times due to chronic congestion in towns and cities. The environmental benefits realized would be significant CO_2 reductions, from displacing a considerable number of lorry trips from peak hours (Noise Abatement Society).

The scheme arose from collaboration between the NAS, the Dutch Senter Novem PIEK scheme, the Freight Transport Association (FTA) and Dublin University. As a result, the Dutch government granted the Society a license to operate the PIEK program in the UK, and to adopt the Dutch PIEK certification scheme for delivery vehicle and equipment whose operating noise levels do not exceed 60 dB(A) (Noise Abatement Society).

Health Effects

The World Health Organization (WHO) Regional Office for Europe conducted a study which provided advice to the Member States on assessment and control of night noise for the purpose of developing future legislation and policies. The group of working experts at the Regional Office developed guideline values based on a review of scientific evidence of the impacts on health caused by night noise. The collaboration of the working group and stakeholders from industry, government and nongovernmental organizations resulted in the document entitled "Night Noise Guidelines for Europe" in December 2006.

The research shows the effects on health at specified noise ranges, and offers a recommendation on the noise limits that are best for public health. The summary of the health effects of night noise based on epidemiological evidence and experimental studies is shown in Table 6 (World Health Organization, 2006).

Table 6: Summary of Health Effects of Night Noise (World Health Organization, 2006)

Average Night Noise level Over a Year	Health Effects Observed in the Population
Up to 30 dB (A)	It appears that up to this level no substantial biological effects are observed. $L_{night,outside}$ of 30 dB is equivalent to the no observed effect level (NOEL) for night noise.
30 to 40 Db (A)	Observed effects on sleep: body movements, awakening, self-reported sleep disturbance, arousals. The intensity of the effect depends on the nature of the source and the number of events. Vulnerable groups (for example children, the chronically ill and the elderly) are more susceptible. However, even in the worst cases the effects seem modest. $L_{night,outside}$ of 40 dB is equivalent to the lowest observed adverse effect level (LOAEL) for night noise.
40 to 55 dB (A)	Adverse health effects are observed among the exposed population. Many people have to adapt their lives to cope with the noise at night. Vulnerable groups are more severely affected.
Above 55 dB (A)	The situation is considered increasingly dangerous for public health. Adverse health effects occur frequently, a sizeable proportion of the population is highly annoyed and sleep-disturbed. There is evidence that the risk of cardiovascular disease increases.

The table shows that significant health effects are realized at 40 dB (A) and higher. Therefore, the WHO Regional Office for Europe recommends that 40 dB (A) be set as the target night noise guideline (NNG), to protect public health, including the vulnerable members of society such as children, the elderly, and the sick. The group also recommends an interim target of 55 dB (A) for those Member States that cannot achieve the NNG in the short term, or for those policy makers who prefer a stepwise approach (World Health Organization, 2006).

Noise Policy for USDOT Off-hours Deliveries Project

The team proposes a three-stage approach to address the issue of noise associated with off-hour deliveries. The structure of the noise policy applied to the project is as follows:

1. The first stage is educating participants on proactive noise mitigation measures. The education program will encompass a comprehensive suite of noise mitigation strategies and technologies. Emphasis will be placed on simple low-cost measures that can be easily implemented, progressing to measures that require more resources and investment. The topics for the noise training seminar are listed below:
    a. Driver behavior

    b. Low cost/ minor measures – noise absorbing materials (various types of foams and other materials that absorb noise and vibrations)
    c. Low noise trucks and equipment
2. The second stage requires participants to commit to proactively addressing the noise issue. Participants will agree to a code of conduct to take steps to avoid and/or mitigate noise issues that may occur during off-hour deliveries through the use of noise mitigation strategies and technologies.
3. The third stage is to direct stakeholders (for example, community group leaders) with any questions or concerns related to noise issues, to the assigned point of contact at New York City Department of Transportation (NYCDOT) for further assistance outside the scope of the first two stages.

Project Area and Identification of Large Traffic Generators (LTG)

Another project focus was to identify Large Traffic Generators (LTG) that could benefit from implementing OHD. This section presents the project area, and summarizes the identification procedure as well as the basic statistics of the selected LTGs. Potential problems that make LTGs not feasible participants for off-hour deliveries are also discussed.

Project Area

The project area was selected as Midtown and Lower Manhattan from river to river. This area was chosen because it houses several key Business Improvement Districts and business centers, including the Javits Center, Madison Square Garden, Grand Central Terminal, and Times Square. NYCDOT also has abundant traffic data in this area, data such as taxi GPS data and the Mid-Town in Motion project that can be leveraged for the project.

Identification of Large Traffic Generators

LTGs can be defined as specific businesses or facilities housing businesses, which individually or collectively (clusters) produce and attract a large number of daily truck trips. Depending on the definition of "large traffic," and the facility type of interest, LTGs could be identified in a number of ways. This section explains two effective and complementary identification procedures. The first corresponds to a group of large buildings and landmarks that house scores of establishments, such as the Empire State Building. Although the establishments contained in the building may each generate small amounts of freight, the aggregate of the freight generated by the building as a whole translates into significant freight traffic.

The second procedure involves identifying large establishments (businesses) that, because of their size, generate significant amounts of freight. This requires defining a measure of business size or other variables that capture the scale of the operations at the establishment. These variables have significantly different levels of explanatory power, depending on their inherent ability to capture the intensity of freight generation (FG) and freight-trip generation (FTG). As discussed in (Holguín-Veras et al., 2011a) and (Holguín-Veras et al., 2012b), FG is expected to be proportionally related to business size, however, there are other important logistics and economic considerations that affect the generation of truck traffic. Nevertheless, business size plays an important role in FTG. Considering the most common measures of business size used, the authors identify large establishments based on two different criteria: number of employees, and square footage.

Large Buildings

The first procedure focuses on large buildings and landmarks. Most of these buildings are easily identifiable in Manhattan since they each have their own ZIP code. 56 such LTGs were identified in NYC (their location is shown in Figure 4). As shown, the majority of these are located at Manhattan's central business district (CBD), or south of Central Park (midtown and downtown Manhattan). After these buildings were identified, employment and establishment data from the ZIP Code Business Pattern Database (ZCBPD) (U.S. Census Bureau, 2011) were used with the employment level FTG models developed by the authors (Holguín-Veras et al., 2011a) to estimate the amount of FTG. As shown in Table 7, these LTGs attract and produce approximately 7,030 and 6,761 daily truck trips, respectively. These values are about 3.8% and 4.2% of the city's daily FTG.

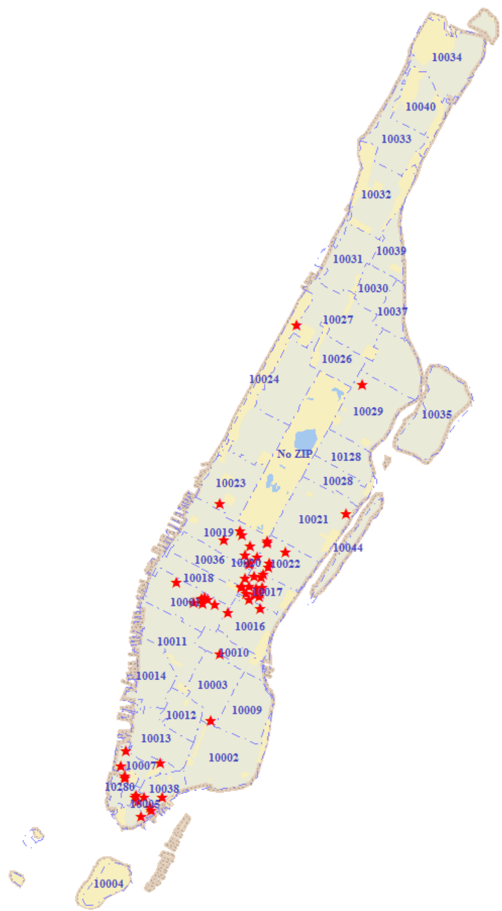


Figure 4: Location of Large Buildings and Landmarks in Manhattan

Table 7: Large Buildings and Landmarks in Manhattan

Zip Code	Zip Code Description	Establishments	Estimated Daily FTA	Estimated Daily FTP	Estimated Total daily FTG	Zip Code	Zip Code Description	Establishments	Estimated Daily FTA	Estimated Daily FTP	Estimated Total daily FTG
10118	Empire State Building	594	1,014	898	1,912	10152	Seagram Building	88	98	101	200
10165	Lincoln Building	462	573	546	1,119	10178	101 Park Avenue	73	85	89	174
10119	1 Penn Plaza	300	460	454	914	10115	475 Riverside Drive	66	79	71	150
10170	Graybar Building	309	373	375	748	10069	---	55	81	68	149
10123	450 Fashion Avenue	240	337	330	667	10104	1290 Avenue of the An	36	69	68	137
10166	Met Life Building	130	345	277	622	10171	West Vaco Building	54	64	71	135
10282	---	227	283	272	555	10041	55 Water Street	39	81	46	127
10112	General Electric Buildin	130	232	316	548	10154	Bristol Myers Building	52	66	61	127
10107	Fisk Building	222	279	262	542	10172	Chemical Bank Building	57	62	63	125
10120	112 W 34th Street	68	332	198	530	10285	Shearson American Ex	20	29	86	115
10169	Helmsley Building	227	265	249	514	10105	Burlington Building	48	58	54	112
10281	---	153	263	239	502	10158	605 3rd Avenue	49	51	56	107
10103	Tishman Building	103	266	199	464	10270	AIG	46	57	49	106
10122	Pennsylvania Building	169	235	227	463	10055	Park Avenue Plaza	44	44	49	93
10168	Grand Central Station	184	241	221	462	10177	Marine Midland Buildin	33	39	46	85
10110	500 5th Avenue	177	226	205	431	10286	Bank of New York	40	43	41	84
10155	Architect & Design	140	253	166	419	10173	342 Madison Avenue	30	39	41	80
10111	International Building	164	208	193	401	10080	Merrill Lynch	29	32	32	64
10106	888 Fashion Avenue	118	182	147	329	10043	CITIBANK	29	30	31	61
10121	2 Penn Plaza	86	134	189	322	10162	Pavilion Building	17	23	26	49
10174	Chrysler Building	125	149	164	313	10199	GPO Official Mail	5	30	9	39
10153	General Motors Building	101	126	177	302	10102	Radio City BRM	9	24	13	37
10167	Bear Sterns Building	118	147	142	288	10072	Philip Morris	5	25	7	32
10279	Woolworth Building	117	132	150	282	10292	Bache Halsey Stuart Sl	14	14	14	28
10176	French Building	103	143	124	268	10081	JP Morgan Bank	12	12	13	25
10175	521 5th Avenue	92	129	110	239	10278	Jacob K. Javits	7	7	9	16
10271	Equitable Building	93	104	103	207	10179	Bear Sterns Building	7	7	7	14
10151	745 5th Avenue	72	103	102	205	10260	JP Morgan Bank	6	6	6	12
							Total	**4,912**	**7,030**	**6,761**	**13,791**

Large Establishments

The second procedure identifies large establishments on the basis of their employment and square footage. This approach is important because it identifies large establishments that might otherwise go unnoticed since they usually do not have any landmark status. On the other hand, this method's drawback is that since official employment or area data are only available at the ZIP code or tax parcel level, no accurate geo-location is possible. (The authors recommend care when using employment and area data information from commercial data aggregators.)

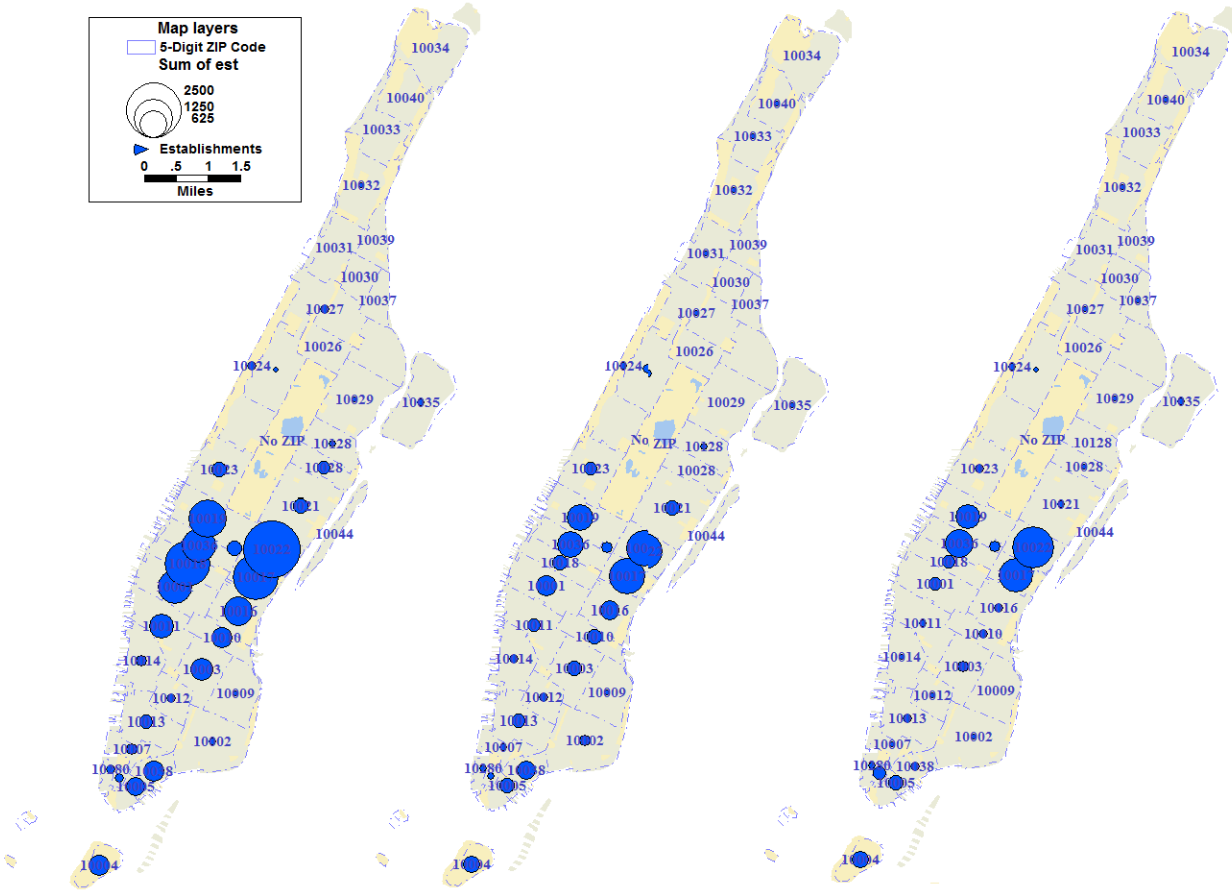
Employment

Data from the ZCBPD (U.S. Census Bureau, 2011) can be used to select ZIP codes that have establishments with large numbers of employees (e.g., 250, 500, and 1000+). Further, by using FTG models, aggregate truck traffic can be estimated. Table 8 shows a summary of the FTG—using models from (Holguín-Veras et al., 2011a)—of the establishments identified as LTGs. As shown, 13,542 establishments have between 250 and 499 employees, representing 13.2% of the city's total establishments, and about 14.1% and 15% of the total deliveries received, and truck trips produced, respectively. It is important to mention that these establishments also have a large share of the city's total employment, representing around 34.24%. In addition, there are 6,203 (6.05%) establishments with between 500 and 999 employees, which account for almost 24% of the total employment, and about 6% of the total FTG. Finally, 4,922 (4.8%) of establishments have more than 1000 employees, accounting for another quarter of the city's employees, and about 3.53% of city's total daily deliveries received. As these numbers show, these large establishments represent a quarter of the city's establishments, and yet account for about 84% of its total employment. Furthermore, these numbers evidence the discussion in (Holguín-Veras et al., 2011a), where FTG is not proportionate with employment, since 84% of the city's total employment only accounts for about 25% of its total FTG. Although these large establishments may generate additional truck trips not estimated with the available FTG models, these values provide insight about the magnitude of the FTA and FTP, and the estimates shown could be considered on the low end of the possible range.

Table 8: Large Establishments by Employment

	No. of ZIP Codes	Establish-ments	Estimated employ-ment	Estimated daily FTA	Estimated daily FTP
Large Establishments		24,667	1,732,875	43,224	40,274
250-499 employees	65	13,542	706,010	25,796	24,093
500-999 employees	52	6,203	493,294	10,982	8,866
1000+ employees	53	4,922	533,571	6,446	7,314

Figure 5 shows the spatial distribution of these establishments. Since only ZIP code data was available, the exact geo-location of the individual establishments is not shown, but an understanding of the spatial aggregation of these large establishments is useful for planners. In Manhattan, for instance, it is clear that the largest concentration of large establishments corresponds to Midtown Manhattan. In addition, when employment information is available for individual establishments, FTG models can be used to identify critical employment levels for establishments in different industries.



a) 250-499 employees b) 500-999 employees c) 1000+ employees

Figure 5: Geo-location of ZIP Codes with LTGs Selected by Employment

Square Footage

For identifying the LTGs the team used a procedure based on square footage, the area data for Manhattan was obtained from the tax parcel PLUTO dataset (New York City Department of City Planning, 2011), which contains information for 43,316 parcels in the area. These parcels were ranked based on the total square footage of "commercial" use, as previous research found this group to be highly correlated to business employment (Holguín-Veras and Jaller, 2012a; Holguín-Veras et al., 2012b). After analyzing the distribution of the commercial areas, the authors selected the top 1% largest areas (between 797,477 and 17,616,756 sq. ft.), as the preliminary candidates for LTGs. These 146 parcels are likely to generate a larger number of freight trips. In Figure 6, the color scale indicates the ranking of commercial square footage, and the parcels highlighted with the cross symbol are the LTGs in Midtown and Downtown Manhattan, including Rockefeller Plaza, 55 Water Street, and the Empire State Building. Most of the LTGs are (groups of) high-rise building complexes with mixed-use commercial and office space. For example, Rockefeller Plaza, located between 48th and 51st streets, is a complex of 19 commercial buildings, with a commercial area of 5,080,345 sq. ft., ranking it the largest in Manhattan. Another example is 55 Water Street, which houses hundreds of corporations. The Empire State Building is a 102-story skyscraper, with such residents as Walgreens and Starbucks, among others, with a total area for commercial use of 2,812,739 sq. ft. Figure 6 shows the location of these buildings.

The tax parcel database contains the NYC Zoning Resolution land use category for each of the parcels. Using the models to estimate the number of employees, and number of establishments based on commercial area provided in (Holguín-Veras and Jaller, 2012a; Holguín-Veras et al., 2012b), and the FTG models for the different land use categories developed by (Lawson et al., 2012), the team estimated the FTA by the selected establishments. Empirical results indicate that the 146 tax parcels have an estimated number of 20,778 establishments (20.25% of the city's total), accounting for 22.66% of the total city employment. More importantly, these LTGs attract 67,949 daily truck trips, or about 37% of the city's total FTA.

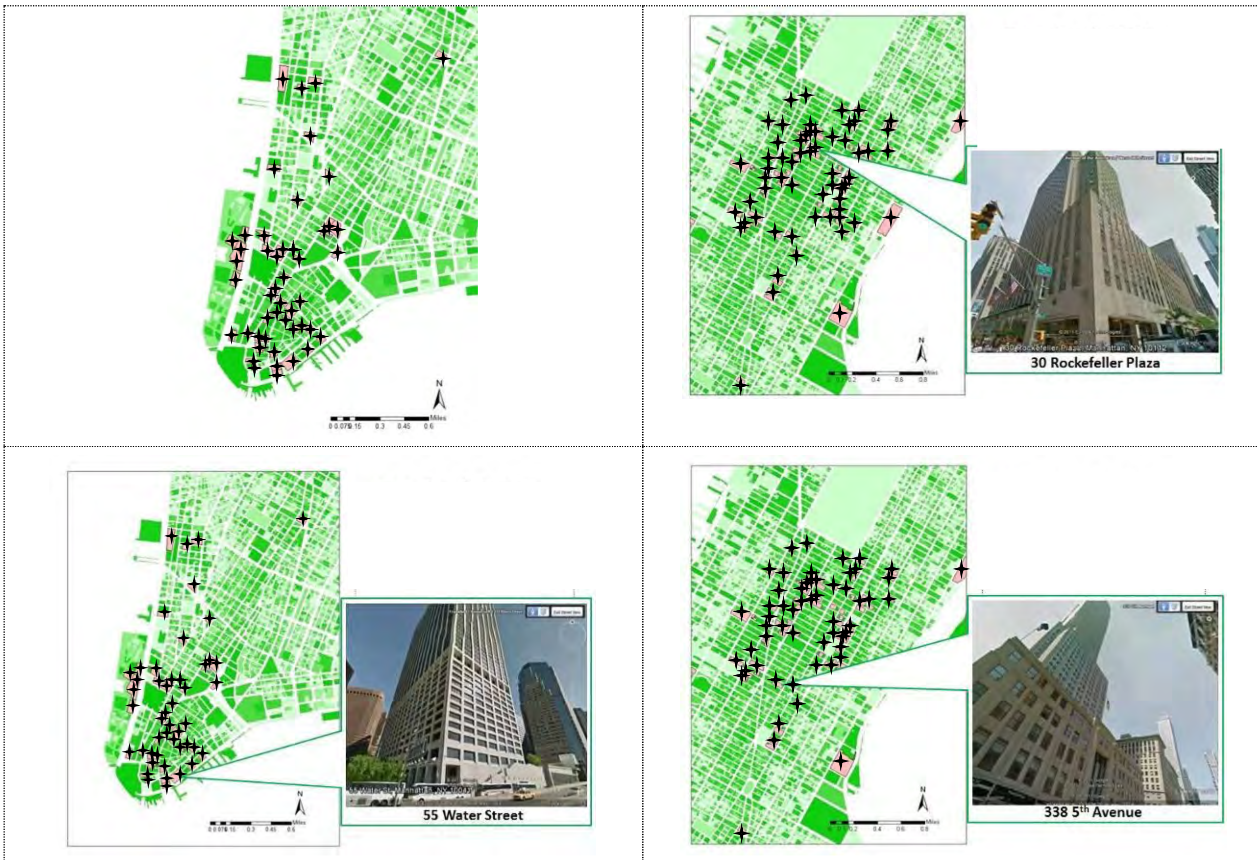


Figure 6: LTGs by Commercial Area

Summary of Results from Identification Procedures

LTGs have been identified based on three main criteria: i) large building and landmarks; ii) large establishments defined by large employment numbers; and, iii) large establishments based on large commercial area. Although these analyses have been performed for Manhattan, the procedures can be used for other urban areas. Table 9 shows a comparison of the selection results, and the total establishment population in Manhattan. These results have important planning implications, showing that a limited and small number of facilities (i.e., large buildings and establishments) generate a considerable number of freight trips.

As discussed, the 56 LTGs selected as large buildings (a very small number of the city's total buildings) account for about 4% of the city's total FTG. This makes them ideal candidates for urban freight management initiatives. The other two criteria (employment numbers and commercial space) are also effective in identifying large establishments that can be expected to generate a large proportion of FG and FTG. While large establishments selected by employment size represent about 25% of the city's FTG, the parcels selected by commercial area account for almost 37% of the daily FTA. It is important to mention that research (Holguín-Veras and Jaller, 2012a; Holguín-Veras et al., 2012b) has shown that there is a high statistical relationship between employment and commercial area, so it can be expected that the LTGs identified by these two criteria overlap, though data limitations do not allow for their individual identification.

Table 9: Comparison between the Region and the LTGs Identified

	No.	Establish-ments	% ***	Estimated employ-ment	% ***	Estimated daily FTA	% ***	Estimated daily FTP	% ***
Manhattan		**102,597**		**2,062,079**		**182,427**		**161,144**	
Landmarks*	56	5,994	5.84%	196,497	9.53%	7,030	3.85%	6,761	4.20%
Large Establishments		24,667	24.04%	1,732,875	84.04%	43,224	23.69%	40,274	24.99%
250-499 employees		13,542	13.20%	706,010	34.24%	25,796	14.14%	24,093	14.95%
500-999 employees		6,203	6.05%	493,294	23.92%	10,982	6.02%	8,866	5.50%
1000+ employees		4,922	4.80%	533,571	25.88%	6,446	3.53%	7,314	4.54%
Large Area Parcels	146	20,778	20.25%	467,350	22.66%	67,949	37.25%	**	

* More than 5 establishments
** No models available
*** Percentage from total values for Manhattan

FTA = Freight Trips Attracted
FTP = Freight Trips Produced

Opportunities for Urban Freight Management Initiatives

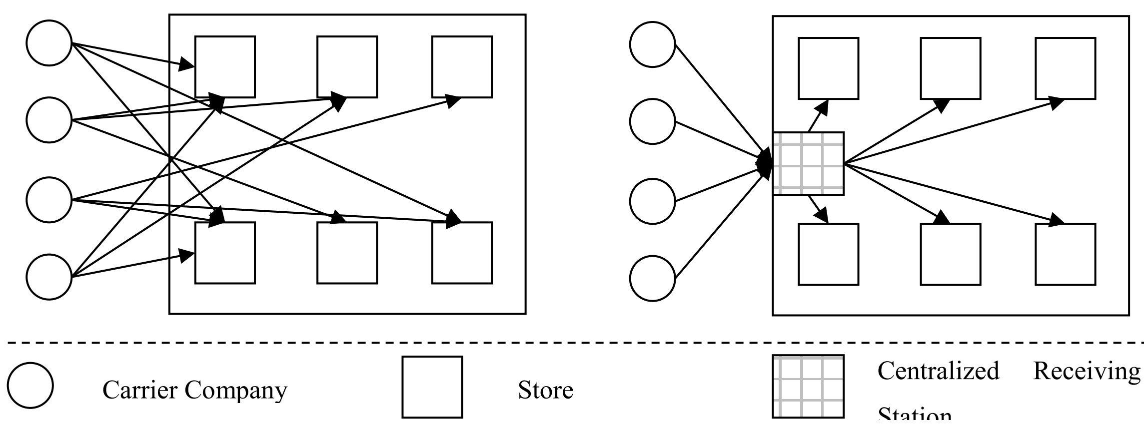
Urban freight management initiatives are strategies for moving urban goods that take into account the social costs of congestion and pollution, as opposed to practices that only consider costs and profits. Urban freight management strategies usually involve cooperation between different agents, such as joint efforts of private and public sectors, or strategies to globally optimize logistics systems in urban areas. Examples of management initiatives include: urban consolidation or transshipment centers, freight villages, central goods sorting points, co-operative delivery systems, off-hour delivery schemes and first/last mile solutions such as pick-up/drop-off locations.

The research reported here makes clear that relatively few LTGs in Manhattan account for a disproportionately large percentage of the city's freight activity: 56 large buildings and landmarks account for roughly 5% of the city's daily FTG; 146 out of 43,316 parcels attract 37.25% of total truck trips. These LTGs offer great opportunities for the development and implementation of city logistic initiatives. In terms of co-operative delivery systems, for example, LTGs usually have central receiving stations that could easily accommodate coordinated deliveries. These would allow the LTGs to receive deliveries during the off-hours, and then distribute the shipments to the consignees during regular hours, without causing major inconveniences to receivers (shipments going out of the facility could flow in the opposite way). In essence, the availability of centralized receiving stations makes LTGs great targets for the implementation of a variety of initiatives, such as off-hour delivery programs and consolidation strategies.

In addition, the analyses display a spatial concentration of large establishments (both by employment and area) in the midtown and downtown areas. Although the spatial concentration aggravates problems associated with urban goods movements (congestion, pollution), it could also offer great opportunities for initiatives such as parking and loading zones management, and last-mile distribution strategies. The following sections discuss these opportunities in more detail.

Off-Hour Deliveries and Centralized Receiving Stations

LTGs are well suited for the implementation of off-hour delivery programs. Imagine a large building such as Grand Central Station, where between 100 and 250 trucks arrive each day to deliver shipments to approximately 184 establishments. In the absence of a centralized receiving station, each carrier needs to directly deliver the goods to their recipient stores. Deliveries are then constrained by the stores' hours of operations, delivery windows, and staff availability, among other considerations. More importantly, these separate deliveries create an unnecessary flow of equipment, goods and personnel inside the facilities. In contrast, when a centralized receiving station is allocated, deliveries to different stores can be received at one location, without time constraints, and shipments to the different stores can then be consolidated and distributed when most appropriate. Schematically, this concept is illustrated with the assistance of Figure 7, below.



a) Direct shipments **b) Through receiving station**

Figure 7: Schematic of Centralized Deliveries at Large Traffic Generators

Deliveries and truck trips are generally attracted and produced during regular hours since they are constrained by the retailers' hours of operation. This has been identified by previous studies as one of the major constraints preventing carrier companies from shifting operations to the off-hours (New York State Thruway Authority, 1998; Vilain and Wolfrom, 2000; Holguín-Veras et al., 2006a; Holguín-Veras, 2008; Holguín-Veras et al., 2011b). However, the central receiving station of LTGs would allow for deliveries to the building during the off-hours. Since the receivers are, for the most part, indifferent to how the shipments are transported as long as they arrive on time, it is fair to assume that, once liability issues are sorted out, most store owners would not object if their deliveries are brought to a central receiving station instead of directly to them.

It is important to mention that unlike smaller buildings and individual establishments, these LTGs are often managed by property management firms. These firms are responsible for the typical day-to-day building operations, such as tenant management, maintenance and security. In spite of the fact that these managers are responsible for the deliveries entering the buildings, a coordinated effort between property managers and the tenants as well as their supplier/carrier companies, would be required for the success of these types of strategies. In addition, some of these buildings or businesses may operate in high-value locations where space is at a premium. Therefore, some of the buildings may have minimal storage space for deliveries, and the installation of a large central receiving station may not be feasible, or the cost to be internalized by the management firm or the tenants may be too high. Space is also limited at individual establishments, reducing the inventory buffer that can be stored, and thus increasing the frequency of deliveries. For LTGs, space may be the most challenging barrier to overcome when implementing city logistics strategies that involve cargo consolidation.

To overcome some of these limitations, incentives (public and private) will be needed to encourage participation in OHD, and the implementation of central receiving stations. For example, city authorities could provide exemptions from development ordinances that might otherwise prevent buildings from using spaces for these activities, or even allow businesses a higher floor area ratio if they provide receiving or consolidating stations at the ground level. Moreover, additional incentives should be provided for retrofits of facilities, or for the use of technologies such as access and internal surveillance and control, to mitigate the risks associated with handling and storing goods. Incentives could be one-time financial incentives, discounts from carriers, tax breaks, public recognition programs, or the provision of business support services. Monetary incentives are a good way to foster a shift to OHD, as the case of New York City has shown.

Along the lines of receiving stations, and OHD programs, LTGs could implement a Delivery and Servicing Plan (DSP) to manage the delivery and service trips produced or attracted. This Plan, developed by Transport for London, seeks improvements in the freight activities at buildings by: managing deliveries to reduce the number of trips; identifying the location and time for safe and efficient delivery activities; and promoting good practices (Transport for London, 2013a). The implementation of this type of initiative has shown to provide important reductions in the number of deliveries being made to a single location (between 20 to 40%), by fostering receiver-led consolidation and cooperation (Transport for London, 2013b).

Pick-up/Drop-off Points and Unattended Deliveries

(Augereau and Dablanc, 2007) define pick-up and drop-off points as local collection and distribution depots, or boxes, from which consumers can pick up goods ordered via home retail services (e.g., by mail, phone or the internet). Although initial experiments with pick-up points were not successful (2007), recent developments with relay points and drop-off boxes (e.g., Kiala relay points in France, and Packstation locker banks in Germany) have produced different results.

Successful systems vary from networks of automated locker banks to storage points managed by local businesses. As such, locker bank/box systems can serve as centralized receiving stations without requiring staff. This offers great advantages, as commodities can be delivered and picked up at any time. While a large bank system might not feasibly serve all of the establishments of a LTG, with combined implementation strategies, these systems can be installed in public or private spaces in or near LTGs quite effectively. In addition, private spaces (e.g., parking lots) could be rented, or public facilities near the LTGs (e.g., service and transit stations) could be used for such centralized receiving stations. For a comparison of the different types of drop-off and collection point alternatives, readers are referred to (BESTUFS, 2007).

Given staffing and security considerations, LTGs are also ideal candidates for the implementation of other unattended delivery strategies. These would allow carriers to deliver goods during the off-hours, through a set of double-door systems, virtual cages inside the establishments, or with the use of other video- or alarm-monitored equipment (Ogden, 1992; Holguín Veras et al., 2013). It may be important to complement these strategies with initiatives to decrease liability exposure issues.

Parking and Loading/Unloading Initiatives for LTGs

A recent study by (Holguín-Veras and Jaller, 2012b) of parking requirements for freight activity in New York City found that the largest occupancy rates (function of demand over capacity) of on-street parking are in Midtown and Lower Manhattan. These are also the areas where most of the LTGs were identified. Parking is a major issue in large urban areas, one that aggravates congestion and increases vehicle miles traveled. For example, in Manhattan a vehicle spends about 9 minutes on average searching for a parking spot (Shoup, 2005). And given specific requirements for freight deliveries, the time a carrier spends finding a parking spot close to the customer's location may be even larger.

As a result, it is important to implement parking and loading-unloading initiatives, which have been effective in reducing urban congestion, and mitigating illegal parking and on-street unloading (2008). Usually, these types of initiatives are easy to implement in the short term. They require low capital investments, and since they improve delivery operations efficiency, they enjoy great receptivity from carriers. These initiatives include: parking pricing, reserved parking, low-scale nearby delivery areas and on-street loading bays. Given their size and establishment concentration, LTGs are well suited for the implementation of these types of initiatives.

Parking pricing which involves time of day prices is intended to increase turnover, optimize use of curb space, reduce traffic infractions and reduce vehicles from circling the blocks by trying to maintain curb space available. In this context, NYC is experimenting with market-rate pricing through its Smart Pilot Program (New York City Department of Transportation, 2012) and the use of Muni-Meters (Cambridge Systematics, 2007; NYC Department of City Planning, 2011; Jaller et al., 2013a). Although carriers are not always able to pass the increased parking costs on to their customers, if parking pricing programs result in increased parking availability, such a benefit would be well received by most carriers, whose average parking fines can be in excess of $2,000 per month per truck (Holguín-Veras et al., 2005b).

The areas near LTGs could be the subjects of these and other types of parking pricing initiatives. Implemented together with centralized receiving stations and off-hour delivery programs, they could have a huge positive impact in reducing externalities. Areas adjacent to LTGs can be assessed for reserved parking or on-street loading bays initiatives—with time limits—or for the installation of urban transshipment platforms from which the last mile distribution to the different large buildings or establishments can take place using trolleys, carts, electric vehicles, or even bicycles.. The NYCDOT has developed specific parking, standing and stopping rules for commercial vehicles. These measures could easily be adjusted in terms of time constraints, types of vehicles and other equipment requirements to better fit the needs of LTGs.

Summary of Findings

Off-hours deliveries (OHD) is a traffic demand management measure used to decrease congestion during the daytime hours by switching a portion of the truck traffic to off-hours or night hours, defined for this project as between 7 p.m. – 6 a.m. Unassisted Off-Hours Deliveries (UOHDs) are those OHDs that occur without receiving staff on hand to assist in the delivery. In this type of delivery, the receiver's role is to provide access to the drop-off location to the carrier, and it's the carrier's responsibility to complete the delivery without damaging the receiver's property. Implementation of UOHD may result in higher benefits than staffed-OHD, as costs are reduced. The fundamental tradeoff comes between these savings and the possibility of a negative outcome, or the risk of damage or theft, particularly without staff on hand. Clearly identifying the costs and risks to receivers, and developing programs to reduce or eliminate those risks, are crucial for a successful unassisted off-hours delivery (UOHD) implementation.

To reduce or eliminate security issues that may occur during UOHD, receivers can consider three levels of defense: (1) access surveillance; (2) access control; and (3) internal surveillance; and carrier-supplied insurance coverage in case of a negative outcome. The program options include systems that range between basic to advanced, and include precautionary as well as reactive measures. Due to risk, and the possibility of increased costs and inconvenience, receivers prefer to receive deliveries during the regular hours; therefore incentives need to be provided to persuade them to switch to the off-hours. Possible incentives include: one-time monetary incentive (e.g. tax deduction); financial incentives specifically to offset the cost of security devices or enabling equipment (e.g. walk-in refrigerators); and non-monetary incentives such as public recognition, preferential parking, and business advice and assistance.

The use of quiet strategies and technologies accompanied with a noise policy will address the noise issue that may affect the surrounding community during OHDs. As the source of most OHD-related noises, the carrier is primarily responsible for addressing noise issues. There are strategies to address noises associated with the various aspects of the delivery process, including the delivery truck, loading/ unloading of the goods, the physical structure of the receiving location, and driver/staff behavior.

Large Traffic Generators (LTGs) can be defined as individual businesses or facilities housing multiple businesses (clusters) that individually or collectively produce and attract a large number of daily truck trips. Using freight-trip generation models, these LTGs can be easily identified using the following criteria: i) as large building or landmarks (usually with their own ZIP code); ii) large establishments defined by large employment numbers; or, iii) large establishments based on commercial area. LTGs offer great opportunities for the implementation of such freight demand management initiatives as: off-hour delivery programs, the use of centralized receiving stations, placement and use of pick-up and drop-off points, delivery and servicing plans, and parking and loading/unloading initiatives.

There are limitations in terms of space associated with LTGs, especially in dense urban areas. In some cases, the use of receiving stations may be hindered, forcing the implementation of other alternatives. Space may be the most challenging barrier to implementing urban freight management strategies that relate to cargo consolidation. Some buildings have minimal storage space for deliveries, and installing a large central receiving station may not be feasible. In light of these limitations, a combined approach involving multiple urban freight management strategies is recommended. In-depth analyses would be required per location, to identify the most suitable strategy or combination of strategies, to implement. If no space is available inside the buildings, curb and parking management strategies may be most appropriate. Further, locations in the vicinity of the LTGs must be identified that could provide additional space for pick-up/drop-off points, or for loading-unloading activities.

To overcome some of these limitations, incentives (public and private) will be needed to encourage participation in OHD, the implementation of central receiving stations, and other initiatives.

Complementary policies and programs with other agencies need to be explored to support implementation of OHD. These may include policies and programs that would assist in providing incentives to receivers; assist carriers in acquiring low-noise or environmentally friendly equipment; or encourage LTGs to participate in OHD; among other possibilities.

CHAPTER 3 - INSTITUTIONAL COORDINATION AND OUTREACH

Introduction

Such a complex and dynamic program as the Off-Hour Delivery (OHD) Program requires ample outreach to both the public and private sector. This chapter describes the institutional coordination, and community and private sector outreach undertaken through the entire project length, to maximize participation in both staffed and unassisted off-hour deliveries. The following sections discuss the creation of advisory groups, the branding and marketing of the OHD program, and general results from the outreach campaign.

Advisory Groups

The team assembled multiple advisory groups to ensure success and input from a wide range of stakeholder groups within New York City. The Industry Advisory Group (IAG) represents carriers, receivers, shippers, business improvement districts and economic development groups, which in turn represent both large and small companies and groups within the NYC metro area. The Public Agency Advisory Group includes representatives from NYC Economic Development Corporation (NYC EDC), NYC Small Business Services (NYC SBS), NYC Department of City Planning (NYC DCP), NYC Department of Health (NYC DoH), NYC Department of Environmental Protection (NYC DEP), NYC Department of Buildings, Port Authority of New York and New Jersey (PANYNJ) and NYC Department of Housing and Urban Development (NYC HUD).

Industry Advisory Group (IAG)

One of the first outreach activities completed by the team was the creation of the Industry Advisory Group (IAG), to aid in the recruitment of OHD participants, and to act as a sounding board for various ideas related to OHD and to freight movement in the NYC area. The goal was to build a group of people familiar with urban goods movement from a range of perspectives, and from various business sectors of different sizes. The IAG was comprised of key stakeholders representing the primary project study area of Midtown and Lower Manhattan. It was constructed from contacts who had participated in the previously completed pilot phase, or who had inquired to the project team about possible participation in the program to, members of the project team.

The IAG member roles included participating in meetings, providing feedback on outreach and branding, posting press releases, and helping to recruit participants in the OHD program.

Twenty-one individual groups comprised the IAG, including four business improvement districts (BID); seven trade groups representing various sectors in Manhattan, including carriers and receivers; and ten businesses, including both carrier and receiver-based, and a mix of chains and non-chains. The complete list of IAG members for this phase of the project can be found in Table 10.

Table 10: Industry Advisory Group (IAG) members

Name	Organization
Mr. Dan Pisark	34th Street Partnership
Mr. Jesse Goldman	Downtown Alliance
Mr. Charles Hayward	Duane Reade
Mr. William R. Mandly (Bill)	National DCP, LLC (Dunkin Donuts)
Mr. Jay Peltz	Food Industry Alliance of NYS, Inc.
Mr. Daniel Wald / Mr. Nimish Dixon	Fresh Direct
Mr. Herve Houdre	Hotel Association of New York - Sustainable Hospitality Committee
Mr. Peter Lempin	Grand Central Partnership
Mr. Nick Kenner	Just Salad, LLC
Ms. Nancy Poegler	Manhattan Chamber of Commerce
Mr. Jan Larsen	Millennium Hotel
Mr. Joseph Killeen	New Deal Logistics
Mr. Thomas W. Connery	New England Motor Freight
Ms. Gail Toth	New Jersey Motor Truck Association
Mr. Andrew Rigie	New York City Hospitality Alliance
Mr. James Versocki	New York City Restaurant Association
Ms. Kendra Adams	New York State Motor Truck Association
Mr. Brett Gipe	Smith Electric
Mr. Robert (Bobby) Heim	Sysco Foods
Ms. Felicia Tunnah	Union Square Partnership
Ms. Mary Snow-Thurber	Whole Foods Market

Throughout the course of the project, IAG members were engaged in various capacities. The team had periodic IAG meetings to have discussions with the entire group, as well as individual phone calls and in-person meetings with members to learn more about their industry sector. In some cases, IAG members, particularly those who represent trade groups, would facilitate introductions whereby the team could make presentations at board meetings to select groups of individuals who might benefit from OHD.

IAG Meeting #1

On November 30, 2011 the first IAG meeting was held at the NYC Department of Transportation's 55 Water Street, New York location. The team introduced the current implementation phase of the project, and briefed members on the work previously conducted during the pilot phase. Other discussion topics included a presentation on UOHD, low noise technologies, and branding and marketing for this implementation phase of the project. Photos from the meeting can be seen in Figure 8. Appendix 2A – 2D contains materials from this meeting, including: the sign-in sheet; the presentation; a Recognition Scheme Survey and Survey Responses Summary. This first meeting had 24 participants, who were particularly interested in how the program could benefit retailers, and what incentives could be provided. They also expressed an interest in the press, and in branding strategies for the expansion of the program.

As a result of the meeting, the study team developed a press and branding plan and further outreach mechanisms for IAG members to use, including:

- surveys to be conducted when following up with businesses;

- a standardized letter to explain the program to participants (for shippers to give receivers);
- standardized text that could be used to promote the project on participant websites and newsletters; and
- recognition schemes to encourage participation in the program.

Figure 8: Photos from the IAG Kickoff Meeting

IAG Meeting #2

The second IAG meeting was held on April 19, 2012 also at NYCDOT's main office on Water Street in Manhattan. The meeting's primary purpose was to solicit input from the IAG members, to discuss the project's progress, and to define a set of incentive strategies for current participants, or to attract new participating companies. Members were given a participation letter to forward to their constituents, which explained the program and encouraged new businesses to participate. Sysco, New Jersey Motor Truck Association, Millenium Hilton Hotel, The Alliance for Downtown New York and others have sent this letters to their receivers and vendors, while tailoring it specifically to each group. Figure 9 shows some photos from this meeting. Appendix 2A – 2D contains materials from this meeting, including: the sign in sheet; the presentation; a Recognition Scheme Survey and Survey Responses Summary.

Figure 9: Photos from the Second IAG Meeting

IAG Meeting #3

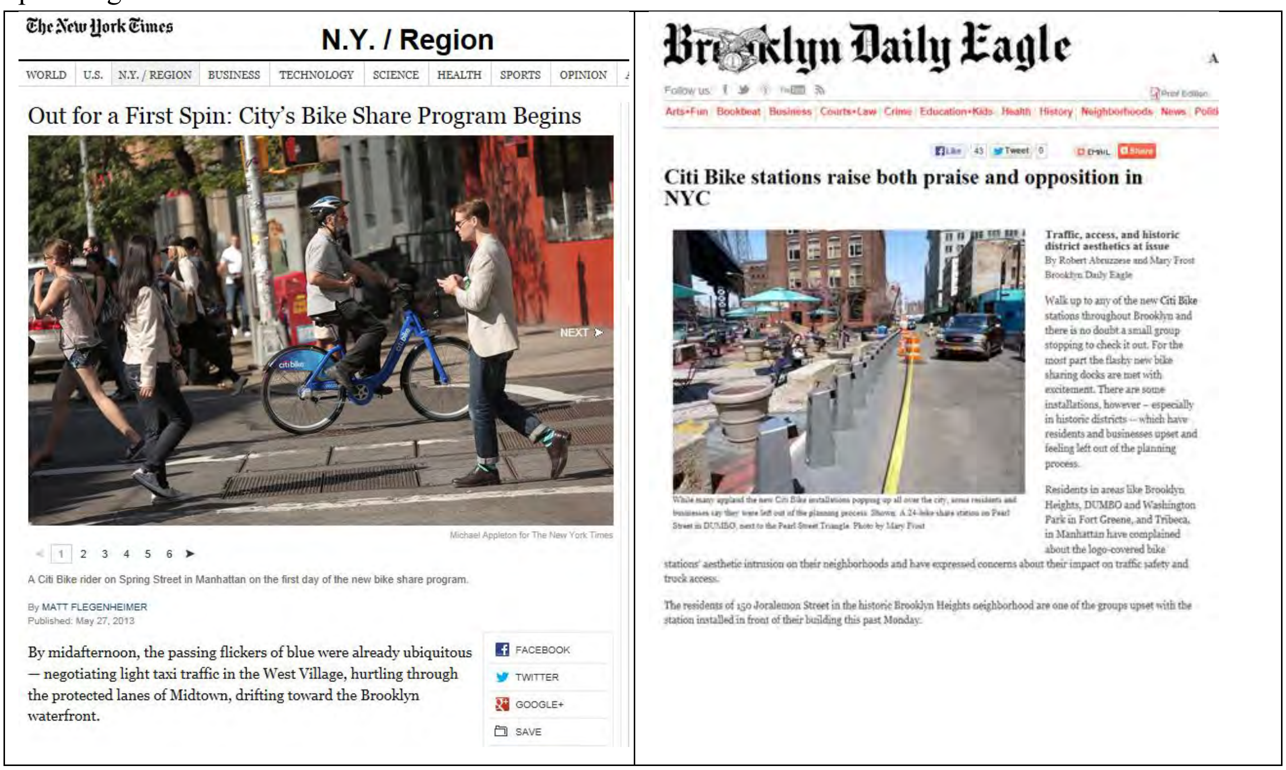
On September 7, 2012 the third IAG meeting was held at the NYCDOT main offices to discuss various outreach strategies. In addition, the United States Postal Service (USPS) gave a presentation on their new GoPost delivery locker system, which it was deploying as a pilot in several major cities including New York. The GoPost delivery locker system could help in unassisted overnight deliveries, in addition to its primary use in participant locations. The USPS has deployed numerous GoPost lockers for their pilot. The locations are primarily dense locations such as Grand Central Terminal, but there are plans to expand this to other businesses and residential areas within NYC. Appendix 2E – 2F contains materials from this meeting, including the sign in sheet and the presentation.

Agency and Community Advisory Groups

The NYCDOT typically contacts community boards for their input on a project in coordination with borough commissioners, who attend the community board meetings throughout the year and act as the liaison between agency staff and the community. In terms of OHD, the NYCDOT preferred to manage the public outreach to community boards itself, rather than having the research team interview the community boards directly. The reasoning behind this was simply to limit the number of NYCDOT initiatives being brought before the community boards. There was a high profile NYCDOT project, the Citi Bike program, being planned at the same time that the OHD project was being expanded. Many community boards in Manhattan were being engaged to provide input on the Citi Bike project. It is common for the Department to stagger or delay the introduction of a project if community members need to focus on another high-profile initiative. The OHD program needed high receiver buy-in to succeed, and the Department decided to focus on receiver outreach, rather than community board outreach, at this time. A community board-based outreach to residents will be pursued at a future date.

In the summer of 2013, some community board members were invited to the OHD 'Think Tanks' in July and September, but those community board members did not participate despite repeated attempts by the NYCDOT Consultant team to set up a time to interview them individually. The benefits of the OHD program for both the public and private stakeholders would need to be clearly outlined before community boards would be approached.

NYCDOT held nearly 400 meetings for the Citi Bike program over two years of planning. The outreach experience with the Citi Bike program, which unfolded as OHD was expanding, showed that community involvement is critical but often fraught with confusion and misconceptions, despite careful planning and conscious effort.


The New York Times

N.Y. / Region

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Out for a First Spin: City's Bike Share Program Begins

Michael Appleton for The New York Times

A Citi Bike rider on Spring Street in Manhattan on the first day of the new bike share program.

By MATT FLEGENHEIMER
Published: May 27, 2013

By midafternoon, the passing flickers of blue were already ubiquitous — negotiating light taxi traffic in the West Village, hurtling through the protected lanes of Midtown, drifting toward the Brooklyn waterfront.

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Citi Bike stations raise both praise and opposition in NYC

While many applaud the new Citi Bike installations popping up all over the city, some residents and businesses say they were left out of the planning process. Shown: A 24-bike share station on Pearl Street in DUMBO, next to the Pearl Street Triangle. Photo by Mary Frost

Traffic, access, and historic district aesthetics at issue
By Robert Abruzzese and Mary Frost
Brooklyn Daily Eagle

Walk up to any of the new Citi Bike stations throughout Brooklyn and there is no doubt a small group stopping to check it out. For the most part the flashy new bike sharing docks are met with excitement. There are some installations, however – especially in historic districts -- which have residents and businesses upset and feeling left out of the planning process.

Residents in areas like Brooklyn Heights, DUMBO and Washington Park in Fort Greene, and Tribeca, in Manhattan have complained about the logo-covered bike stations' aesthetic intrusion on their neighborhoods and have expressed concerns about their impact on traffic safety and truck access.

The residents of 150 Joralemon Street in the historic Brooklyn Heights neighborhood are one of the groups upset with the station installed in front of their building this past Monday.

Figure 10: Press on Citi Bike after Its Launch

NYCDOT Outreach Strategy and Residents

During the OHD project, NYCDOT hired a marketing consultant to interview stakeholder groups to help develop an outreach strategy. Stakeholders need to be aligned to get businesses on-board with the program, and to make sure residents will clearly understand how the Department would manage any negative externalities. The focus groups and interviews determined that the stakeholders should be engaged in this order:

1. **Shippers & Large Chain Businesses**. This group controls the largest truck fleets involved in urban traffic; their daytime activity is a visible sign of program success.
2. **Business Improvement Districts and General Receivers**. The Industry Advisory Group includes several BIDs, and these members could help to promote the program to retailers within their districts.
3. **Residents**. New York City residents are clearly a key audience for the program. However, our focus groups and past agency experience determined that direct engagement with residents could in fact be detrimental if unwarranted concerns regarding noise levels become a primary focus before the program can launch and prove otherwise. As such, a two-pronged approach was adopted to address resident concerns about noise:
   - Provide education tools with adequate explanation of the noise risks, as well as mitigation strategies, including part replacement projects, being deployed within the program.
   - Provide transparent access to noise-monitoring data once the program is underway, to refute any concerns or to address real issues that might arise.

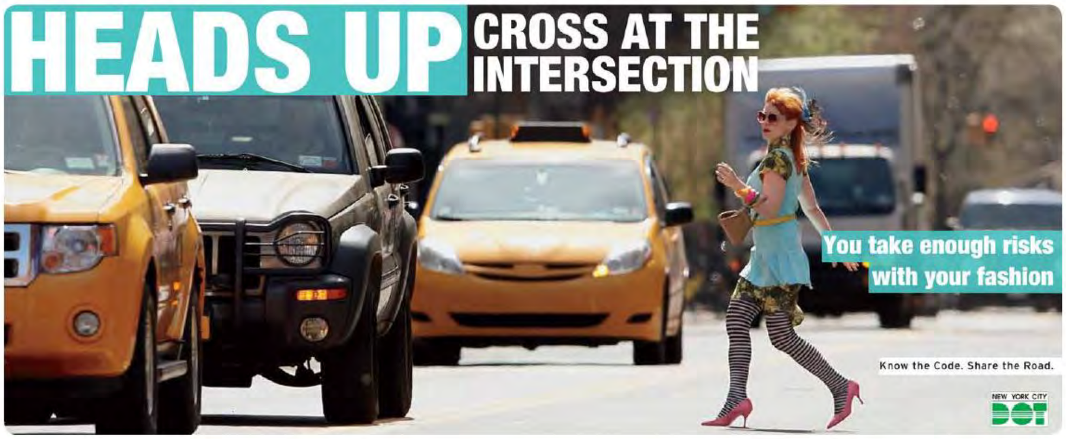
The marketing consultant team's recommendation to the NYCDOT was to ensure that at a minimum, noise mitigation tools and mitigation strategies were in place prior to engaging residents.

Branding and Marketing

Branding and marketing are key parts of any plan to broadly expand the use of a product or service. New York City in particular has a lot of programs and initiatives competing for the attention of its residents and consumers. NYCDOT has launched such citywide programs as Bike Share, utilizing a smart professional marketing campaign to help get them noticed, to frame their benefits, and to gain the support of the public. The OHD program would need similar professional marketing and branding to be noticed by the city's eight million people, who have countless marketing ads vying for their attention. The branding would need to make clear to retailers and residents that off-hour deliveries could improve their quality of life, with benefits that are not as simply conveyed as benches, plazas, trees or other amenities.

Some examples of NYCDOT citywide programs, and the types of marketing and branding used to promote them, are described below: City Bench, Heads Up, You the Man, and Look! Campaigns.

Heads Up!



The Heads Up Campaign: The "Heads Up" campaign began appearing this month on billboards at high-traffic and serious crash locations, in over 300 bus shelters, and dozens of other eye-catching sites like newsstands and storefronts citywide. The ads will appear on 250,000 coffee cup sleeves in delis and coffee shops around the city. Source: NYCDOT May 2012 Byway NYCDOT Official Internal Newsletter.

Figure 11: "Heads Up" Campaign

You the Man Safe Rides Home Giveaway

This holiday season, DOT distributed 5,500 free rides – 1,500 $15 debit cards for use in NYC Taxi Cabs, participating livery car services, at MetroCard vending machines and select other ticket vending machines, as well as 4,000 single-ride MetroCards – as part of its You the Man campaign, which is designed to curb drinking and driving, reduce traffic crashes and make New York City's streets even safer. Former NFL quarterback and WFAN morning sport show host Boomer Esiason kicked off the giveaway announcement inTimes Square.

Safe Rides Home reminded revelers that New Yorkers can count on friends and family members as designated drivers, as well as the city's transportation professionals: cab, livery and bus drivers and subway operators.

New ads, using humorous winter holiday scenarios, ran through the New Year online as well as outdoors. The campaign features a website, Facebook and Twitter social media channels, and a free iPhone app that uses GPS to help users find the closest subway stops and livery car services.

You the Man Campaign: Right: Commissioner Sadik-Khan with former NFL quarterback and WFAN morning sport show host Boomer Esiason kicked off the announcement of the giveaway in Times Square. Source: NYCDOT Byways, October 2012.

Figure 12: "You the Man" Campaign

Commissioner Janette Sadik-Khan and U.S. Transportation Secretary Ray LaHood unveiled the innovative LOOK! street markings

The LOOK! decal will appear on taxi windows

The LOOK Message: Using the same durable, high-temperature thermoplastic used for street markings, decals of the word "LOOK!" have been installed in crosswalks at intersections that have had histories of serious crashes. U.S. Transportation Secretary Ray LaHood joined NYCDOT to unveil the LOOK! Markings, which will be installed at nearly 200 locations. The LOOK! message is also being added to taxis for taxi passengers to reduce dooring.

NYC deliverEASE

NYCDOT held an internal staff branding brainstorming meeting on October 7, 2011, and again on November 18, 2011. The goal was to find a name for OHDs, and to begin to develop a logo and a tagline. The team was asked to think of a clear, focused one sentence objective for the brand. The overarching question was how to translate the benefits of OHD (less congestion & air pollution, uncluttered sidewalks) to community members. The sessions included staff members knowledgeable about the project, and two to three others who were not, to make sure that the logos and tools adopted would be understandable and effective with citizens who had no prior awareness of the project. Each session lasted at least two hours.

At the end of the brainstorming session, the NYCDOT team had found a name for the program: ‘deliverEASE,’ a play on the word “deliveries,” and an emphasis that OHD is easy. The NYCDOT legal team conducted a search for this name, and found that there was one company using deliverease, but it was not a transportation company. The team was advised to put the word NYC in front of deliverEASE, and to move forward with the name. The team then started to collaborate on a logo design which has not yet been finalized. Example logos for other City programs were reviewed, some of which are shown below:

Figure 13: NYCDOT-created Logos

Participation Packet

To completely describe the program, and the steps potential participants must take to join, NYCDOT and RPI created a participant packet. The packet was to serve as a simple handout that provided all of the pertinent information a potential participant would need. The participant packet, which also includes the Code of Conduct, can be seen in Appendix 2G. The NYCDOT Graphics Division created the document using input from RPI and NYCDOT staff.

Off-Hour Delivery Marketing Think Tank

NYCDOT wanted to build on the success of the pilot program, and implement OHD in other parts of the city, specifically Lower and Midtown Manhattan. A defined messaging framework was needed to explain and ‘deliver’ the OHD program to other areas. NYCDOT hired a consultant team to identify issues through stakeholder interviews, and to conduct behavior change workshops. The generated ideas would be used to create a strategic recommendation for the program.

On February 6, 2013, the Grand Central Partnership (GCP) BID hosted a meeting for the project team with representatives from within their BID at the Hyatt Hotel. In addition to the project team, nine businesses from the GCP were represented. The purpose of the meeting was to gather feedback, and gauge the level of interest in off-hour deliveries.

The GCP manages one of the largest business improvement districts in the world, comprising 76 million square feet of commercial space in a 70-block area with irregular borders stretching from 35th Street to 54th Street, and from Second Avenue to Fifth Avenue. GCP helps to ensure that Midtown

Manhattan looks its best and functions as one of New York City's most exciting areas. In addition to pioneering the "Clean & Safe" approach to urban revitalization, the organization has led the way in introducing supplementary services and programs that contribute to the neighborhood's overall appeal.

Ms. Stacey Hodge, Director of Freight Mobility at the New York City Department of Transportation (NYCDOT) welcomed the GCP, introduced the intent of the meeting, and provided background on the OHD pilot program. Several participating businesses described their current delivery operations, including these comments:

- "We share a loading dock with another business that receives deliveries all day. Street closures related to visiting dignitaries also create delivery issues. Off-hour deliveries could help."
- "My building wants an exact delivery time or a six-hour window, but finding a window is difficult, as deliveries cannot be made during lunch. "
- We schedule deliveries through our vendors for the early morning time period.

Some of the initial reactions to the program voiced by meeting attendees included:

- Interest; because of current stresses, including time wasted on deliveries.
- Questions; regarding the associated benefits and incentives.
- Mixed; enthusiasm for pollution reduction and operational advantages, tempered by concerns related to staffing and overtime.
- Recognition; among those that already have deliveries in the off-hours.
- Concern; regarding possibly disturbing tenants.
- Enthusiasm; recognition of program success in London.
- Curious; desire to know more given an initial sense of OHD as positive, beneficial.

NYCDOT understood that communication was critical to the program's success, just as one of the GCP participants stated. After this initial meeting, the NCYDOT worked with their consultant team to plan two Think Tanks, one for the industry and the other for the public sector to further develop a marketing strategy to expand the program.

The purpose of the Think Tanks was to inform the NYCDOT on ways to structure and promote the program to maximize the participation of local businesses, and to ensure that stakeholder ideas and concerns would be incorporated. The Consultant team developed a behavior change strategy, and conducted interviews with key stakeholders. Behavior changes related to these topics were explored:

- How to get truck drivers to sign up for off-hours shifts
- How to get restaurants to embrace keyless entry into their cold storage
- How to get community organizers to rally for less day-traffic congestion

The process determined that NYCDOT should concentrate on communicating first with chains and shippers. Only after these groups were engaged should the focus be broadened to general receivers and BIDs. It was also determined that clear financial incentives and implementation tools were needed for the program to be successful.

The last group to be addressed in the Think Tank process would be the residents of NYC. Before taking this program to the public forum, it is necessary to have well-defined program costs and benefits in hand . In July 2013, the Industry Think Tank was hosted by the Consultant marketing team, with over eleven different organizations represented, including Manhattan BIDs, building management companies, The Real Estate Board of New York, Whole Foods, and a community noise reduction expert. Members identified what they felt would be the most popular strategies to motivate businesses and residents to seek OHD in their areas. See Appendix 2H for the invitation to the OHD Think Tank.

A second Think Tank meeting was held in September 2013. The OHD Public Agency Think Tank, a diverse group of City, State and Federal agency staff, was asked to identify strategies they believed would be the most promising for New York City to use in advancing the program. Some of the participating organizations included NYSDOT Region 11, US EPA Region 2, NYC EDC, PANYNJ, NYMTC, NYC Departments of Planning and Buildings, NYC Finance and personnel from the NYCDOT Alternative Fuel program.

Based on the outcomes of these Think Tank discussions, a NYCDOT consultant team developed strategies for the expansion of the OHD program. NYCDOT will work to implement the recommended strategy in 2014.

Public Outreach

To maximize the project's success, a rigorous outreach campaign was instigated from the outset, with a multi-pronged approach. Shippers, carriers and receivers, as well certain trade groups were engaged. The trade groups included motor carrier associations; business improvement districts (BIDs); the Manhattan Chamber of Commerce; food and retail trade groups within Manhattan; and other public agencies.

To inform and engage as many potential participants as possible, both large and small companies were contacted. In many cases, the team reached the smaller companies by working jointly with some of the larger companies or trade groups. By working closely with the larger companies, the team was able to leverage their position to recruit their customers and other smaller companies to switch to the off-hours. This sometimes had a cascading effect; once a business switched to OHD they might inquire with their other carriers about switching additional deliveries to the off-hours. In some cases the team worked as a liaison to shift these additional deliveries, and in other cases the business would make arrangements directly with the other carriers. The following sections discuss in more detail the meetings, findings and lessons learned from these outreach efforts.

Both RPI and NYCDOT have developed websites to promote the OHD project and help with outreach. The websites disseminate useful information for citizens, or any group interested in learning more about participating in OHD.

Trade Groups

Throughout the project, the team arranged several meetings and phone calls with various Manhattan trade groups, including the Manhattan Chamber of Commerce and several BIDs, including the Grand Central Partnership and the Real Estate Board of New York. Since each of these groups has several thousand members, their engagement was essential in reaching large numbers of potential project participants.

Real Estate Board of New York

The Real Estate Board of New York is the city's leading real estate trade association, with more than 12,000 members. REBNY represents major commercial and residential property owners and builders, brokers and managers, banks, financial service companies, utilities, attorneys, architects, contractors and other individuals and institutions professionally interested in the city's real estate. REBNY is involved in crucial municipal matters including tax policy, city planning and zoning, rental conditions, land use policy, building codes and legislation. In addition, REBNY publishes reports providing indicators of market prices for both the residential and commercial sectors.

To continue to solidify the institutionalization of OHD, the NYCDOT briefed REBNY in 2010 during the initial pilot phase, and again in 2011 during the implementation phase. During the December 20, 2011 discussion REBNY staff agreed to reach out to the commercial managers who manage buildings that operate 24/7, and those who have stores that remain open late, to make them aware of the OHD program.

NYCDOT staff advanced many of the suggestions that REBNY made in the 2011 meeting, and on February 12, 2013 NYCDOT briefed 12 members of the REBNY team. Industry partner Mr. Bobby Heim of Sysco participated in the meeting by phone to provide a perspective on participating in the Off-Hour Delivery Program from the private sector. MBOD consists of leading commercial property managers and advocates on building codes and regulatory issues charged with reviewing the official acts and decisions of all other Commercial Division committees, and taking whatever steps necessary to ensure the effective running of the division. This briefing led to NYCDOT coordinating with Brookfield Properties later in 2013, about the possibility of instituting off-hour deliveries and other sustainable delivery strategies at several of their larger NYC properties. Brookfield Properties is very much interested in incorporating changes such as off-hour deliveries at their complexes, but not immediately, due to the complexity of these buildings and the need to first make physical changes. Having been briefed on these programs, the building managers are going to incorporate them over the next several years, as necessary building changes are made.

Other Trade Group Discussions

The trade groups that were also IAG members were instrumental in allowing the off-hour delivery team to present at their meetings. Below are some outcomes from the various groups.

- **Food Industry Alliance of NY (FIANY)**: The primary goal of the FIANY is to represent their members on regulatory affairs, answer questions, and provide education to the food industry. Members in the NYC metro area primarily include supermarkets and drug stores. The FIANY allowed the team to present at a Board of Directors meeting, where a lot of interest in the program was expressed, but the issues of lease agreements and union contracts (with grocery workers) were stated as the main barriers to implementation. As a result of this meeting, several of the members including Wakefern Food Corp signed up for the program.
- **Manhattan Chamber of Commerce (MCC)**: The MCC is a non-profit member organization that serves as a primary resource for small and mid-size firms doing business in Manhattan. The MCC is the voice of over 100,000 companies in Manhattan, and partners with over 300 diverse business organizations. The MCC provided advice to the team during this project on how to reach out to the business community in Manhattan, and also distributed flyers to their members via email and their website, as shown in Figure 14. The MCC suggested that a spokesperson for the project should be assigned to promote OHD on a larger scale. This person could be a political

figure, a star, a large business owner, or someone else who would be easily recognized. Due to budget constraints, the team was not able to pursue this suggestion.

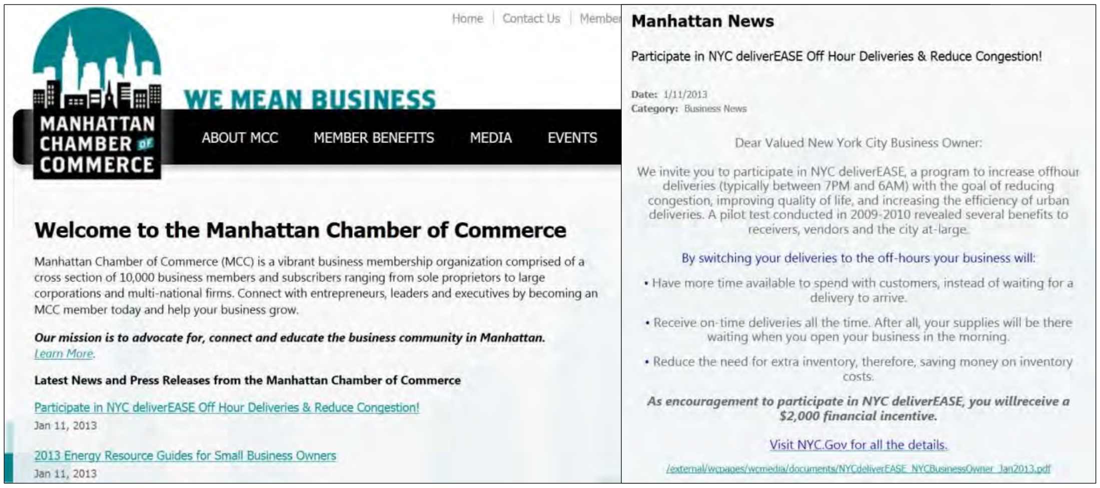


Figure 14: OHD Advertising on the Manhattan Chamber of Commerce Website

- **Grand Central Partnership (GCP)**: Geographically, GCP is the largest BID in New York City, and includes several notable buildings such as the Chrysler and Metlife Buildings. The GCP was instrumental in distributing OHD information to their members, through emails, posting information about the project on their website, and even making individual phone calls to potential participants. On February 6, 2013 the GCP arranged a meeting at the Hyatt Grand Central Hotel for approximately twelve distinguished businesses within the GCP area, including some that are already accepting OHD, to discuss how to better promote OHD.
- **New York State Restaurant Association (NYSRA)**: The NYSRA, in particular, its NYC Chapter, was also instrumental in disseminating information to their members. The NYSRA emailed promotional flyers about the program, and organized several meetings for the team to present the OHD program. During the first meeting nineteen members were present, representing a variety of businesses including both independent restaurants and chains. NYSRA provided a complementary exhibit booth for the program at the International Restaurant and Foodservice Show at the Jacob Javits Center in NYC March 3 through 5, 2013. Thousands of restaurant personnel attended the show. Many people who talked to the team were in the process of opening up a food or beverage establishment in the NYC area, and were receptive to including off-hour deliveries as part of their operations. During the show the team was also able to make initial contacts with several large food service providers servicing the NYC area. At the show, the team had simple posters to get the attention of both carriers and receivers; Figure 15 shows an example.
- **The NYC Hospitality Alliance (NYCHA):** The NYCHA is a broad-based membership association founded in 2012 to foster the growth and vitality of the industry that has made NYC the Hospitality Capital of the World. It is the first association ever formed in New York City representing all facets of this diverse industry: restaurants, bars, lounges, destination hotels and major industry suppliers. The NYCHA arranged numerous in-person meetings with businesses in Manhattan, and was going to provide complementary exhibit space at the International Hotel,

Motel and Restaurant Conference in November 2012. However, due to Hurricane Sandy, this conference was cancelled.

- **NYC Hotel Association:** In May 2013, the team had a meeting with the Director of the NYC Hotel Association. Based on this meeting and subsequent conversations, eighteen large hotels were identified in the Midtown Manhattan area as potential program participants. The Hotel Association Director was going to reach out to the managers of these hotels and brief them on the Off-Hour Delivery Program, and based on their responses, arrange in-person meetings.

Figure 15: Outreach Posters for Receivers and Carriers

Carriers, Shippers and Receivers

Just as the trade groups were a critical component of the outreach effort, it was necessary to connect with those who would be the real project participants: carriers, shippers and receivers servicing businesses in Manhattan. Early in the project the team reached out to companies that had previously expressed an interest in participating. Many of these companies contacted the team between the pilot phase and this implementation phase. When talking to these companies, the team followed a scripted interview process that solicited information about business operating characteristics and their willingness to accept both assisted and unassisted off-hour deliveries. In general, the carriers and shippers were very enthusiastic to create their first off-hour delivery routes or add customers to their existing off-hour delivery routes. The receivers however, often had concerns about shifting to the off-hours, mainly in terms of issues outside of their control, such as lease agreements, community board concerns and union contracts. When talking to larger companies, especially shippers, the team offered to supply them with a one-page letter outlining the benefits of the program. Many of the companies were eager to distribute this jointly-authored letter, feeling that it would help them address concerns and shift deliveries to the off-hours. An example of the letter can be found in Figure 16.

One barrier encountered during the outreach effort was the difficulty of reaching out to the large number of individual receivers. Often the receivers were preoccupied, trying to run their business, and did not have time to talk about a program such as OHD. The businesses were often small, with limited resources for education or research into this or any other program; as a result, these calls from the team were often short and unsuccessful. However, these same business owners were always in contact with shipper sales representatives. To reach the individual establishments, the team came to rely on a two-pronged approach. A representative from the shipping organization with whom the receiver was already familiar would make the initial pitch for off-hour deliveries. If the receiver expressed an interest in the program, the team followed up with him/her, providing more details. This approach worked well in getting small businesses to participate in the program.

Throughout the project, both RPI and NYCDOT conducted site visits to retail locations of companies interested in participating in the Off-Hour Delivery Program. As an example, one of the first locations contacted was Dick's Hardware at 9 Gold Street, in Lower Manhattan. This establishment has difficulty getting deliveries at the curb since the street is very narrow and often blocked by trucks. Curb regulations will need to be changed in this retail location to support truck deliveries in the off-hours. The team also made several visits to the Waldorf Astoria Hotel in Midtown Manhattan. The management at the Waldorf saw the benefits of off-hour deliveries right away, and was very excited about the possibility. The Waldorf was able to quickly shift some of their deliveries to the off-hours, and made other physical changes to the building such as adding an auxiliary refrigeration unit to allow additional off-hour deliveries. The conversations at the Waldorf promoted internal discussions with the eighteen other Hilton-branded hotels in the NYC metro area. These discussions included off-hour deliveries and other sustainability practices that they could implement.

Many of the larger receivers such as GAP, CVS Pharmacies, Duane Reade and Dunkin Donuts were enthusiastic about the program. They saw the immediate benefits of off-hour deliveries, and had the ability to shift their delivery practices fairly easily. Due to these immediate benefits they often made the switch to the off-hours without requesting any financial incentive from the team.

Grand Central PARTNERSHIP — NEW YORK CITY DOT

Request for Participation in the NYC deliverEASE Program

Dear Member of the Grand Central Partnership:

We invite you to participate in NYC deliverEASE, a program to increase off-hour deliveries (typically between 7PM and 6AM) with the goal of reducing congestion, improving quality of life, and increasing the efficiency of urban deliveries. A pilot test conducted in 2009-2010 revealed several benefits to receivers, vendors and the city at-large.

By switching your deliveries to the off-hours your business will:

- Have **more time available to spend with customers**, instead of waiting for a delivery to arrive.
- Receive **on-time deliveries all the time.** After all, your supplies will be there waiting when you open your business in the morning.
- **Reduce the need for extra inventory,** therefore, saving money on inventory costs.

As encouragement to participate in NYC deliverEASE, you will receive a $2,000 financial incentive.

60% of the incentive will be provided for one successful quarter of participation and the remaining 40% for the second quarter. In addition, you will earn **public recognition** as one of the participants in this pioneering program.

In addition, you may also be able to negotiate reduced shipping costs from your vendors.

If you are interested in learning more about this exciting project please complete the form on the following page.

> *"Whole Foods has enjoyed the ability to take deliveries in overnight. It has allowed us to serve our customers better through better in-stock position, enhanced our commitment to our Green Mission through more efficient trucking operations and improved our collaboration with our vendors."*
>
> ROB TWYMAN, Regional VP Whole Foods Market Northeast Region

To learn more, contact Jeff Wojtowicz at RPI at **518-276-2759** or wojtoj@rpi.edu. Please email or fax (518-276-4833) the form on the following page. Additional project information and testimonials from participants can be found at cite.rpi.edu/off-hour-deliveries and www.nyc.gov/html/dot/html/motorist/offhoursdelivery.shtml

Figure 16: Sample Outreach Letter

NYCDOT Stance on Incentives and Focus Groups

NYCDOT believes that incentives to support off-hour deliveries can take many other forms in addition to financial incentives. But, NYCDOT is an agency with jurisdiction over transportation; financial incentives and business support programs are not within their toolbox. However, those types of incentives were identified by the industry advisory group as very important in helping businesses make the shift to OHD. Industry stated that the OHD program is not yet a core focus for any business. Participation will often require supporters to fight internal battles to secure permission from their organizations to participate. Getting involved in OHD must be easy to justify to corporate decision makers, and even easier to do. Providing incentives to motivate companies to change their behavior is not a new idea. For example, there are business incentives provided by other agencies to encourage grocery stores to be opened in underserved neighborhoods without access to fresh produce. There are incentives to help companies purchase alternative fuel trucks that are better for air quality with quiet operating technology. To get businesses to make a shift from the status quo of truck deliveries, including: day time deliveries, double parking, and loading docks only open between 8am and 5pm, NYCDOT would need to engage other partners who have the types of incentives that would be needed to expand off-hour deliveries on a large scale.

With this in mind, NYCDOT set out to promote a multi-agency approach to expanding off-hour deliveries in New York City. NYCDOT and their consultant team held focus groups with the Department of City Planning, the Port Authority of New York and New Jersey (PANYNJ), the Department of Environmental Protection, the Department of Finance, the New York City Economic Development Corporation, the Real Estate Board of New York and others. Participants were asked to sketch their vision of what New York City would look like if they could make changes to improve livability. Almost every participant sketched a picture of a New York City with no congestion, flowers, clear clean skies and open sidewalks. They wanted to experience plazas and bikes lanes, without negative impacts from truck deliveries and other vehicular traffic. To accomplish this, truck deliveries will need to become more invisible to the public. It is important to note that in the July 2013 issue of Monthly Economic Indicators for the PANYNJ, off-hour deliveries were highlighted as an impactful strategy to reduce shipping costs and improve traffic conditions throughout the day. This analysis was conducted by the PANYNJ using GPS data from the American Truck Research Institute (ATRI).

These livability goals can be accomplished using the tools that those external agencies control: land use policies, office building truck delivery management plans, bridge toll policies, curbside commercial parking policies and technologies, tax incentives and public education. The participants came to understand the fact that they too had a role to play to help solve transportation and livability issues. The work involved in expanding the partners who are providing incentives for off-hour deliveries will continue, as this will be an iterative process.

A summary of incentives that the focus group participants identified includes: financial Rewards, tax incentives, EPA credits, LEED program credit, parking ticket discounts, road toll subsidies and BID-Led Competitions. Inspiration Tools were also suggested, which are web applications that can demonstrate the financial and non-financial benefits of being involved, and the programs needed to feel relevant and credible. A Delivery Personnel Accreditation program was also suggested where the City would provide a specific training program for workers who are currently delivering off-hours, or who are interested in doing so in the future. Any worker who completes the program would be OHD-certified.

Additionally, the marketing analysis conducted using the information learned during the focus groups identified a strategy for the Department to follow to expand the program. That strategy is:

> *"Focus on shippers and large chain businesses first as the program champions, because you can't receive goods without a shipper servicing you, and many chains are their own shippers. These groups control the largest truck fleets, whose daytime activity is the visible sign of program success, and lastly, chains play a critical role as models of good behavior to inspire smaller businesses to act."*

Summary of Findings

The outreach efforts conducted during this project by RPI and NYCDOT, as well as the members of the IAG, were enormous. Representing a diverse group of businesses from across the Manhattan target area, the IAG was also instrumental in promoting the project, and interesting private sector businesses in participating.

One of the many important lessons learned during the outreach effort was the importance of finding a 'champion' for the project within each business. This person would be the one with whom the team could interact, who could most effectively carry the program concept forward within the company. This insight held true for carrier, shipper and receiver businesses. When there was no internal champion, a switch to the off-hours was often difficult to achieve; not because they didn't like the idea but because of internal logistics. The dynamic employment market in the NYC region further complicated matters. Often, especially in the restaurant and retail industry, the team would find a champion, but that person would either be promoted to another position within the company or change employers. This typically meant that the team was forced to 'resell' off-hour deliveries from scratch. It therefore became clear that once a business expresses interest in the program, the team needed to move expeditiously.

It is also important to mention that many businesses (both carriers and receivers) are against changing their operations in the fourth quarter of the year (October through December). This is typically the busiest period, when businesses gear up for the holidays.

Multiple shippers said that they would consider offering shipping discounts to businesses that received goods in the off-hours. However, in order to make these discounts feasible, the shippers would have to significantly increase the number of off-hour delivery routes. It is likely that in the future, once a certain level of off-hour deliveries has been achieved, this shipper discount model could replace the need for a public sector incentive.

It may also be possible for some larger companies to offer an incentive to their sales team to promote off-hour deliveries. Since the shipper would have lower operating costs when making OHDs, they may be able to provide a higher commission to the sales people for all deliveries or accounts switched to the off-hours. This would have to be investigated on a case-by-case basis by each company, but it is a potential mechanism for shippers to increase the amount of off-hour deliveries.

Lastly, a major hurdle the team faced during the outreach efforts were the impacts from Super Storm Sandy. The storm arrived in the New York and New Jersey region on October 29, 2012, and left much devastation in its wake. As a result, the freight staff at NYCDOT was re-assigned to assist with the Office of Emergency Management's efforts to route large trucks bringing in generators and other equipment to assist affected communities. The NYCDOT offices in Lower Manhattan were flooded, and staff was unable to access computer network drives for several weeks. Overall, the project experienced delays until 2013 when NYCDOT staff was once again able to focus on off-hour delivery efforts. Some receivers had to refurbish their buildings because of the storm, and some of the participating trucking companies had significant damage to their fleets due to flooding. For several months following the storm the team proceeded cautiously with outreach efforts; many of the affected carriers, shippers and receivers did not fully recover until the spring of 2013.

Overall, the outreach campaign for the project's implementation phase was highly successful. Carriers, shippers, receivers, economic development groups and trade groups all played pivotal roles in getting the word out, promoting the project benefits, sharing their experiences, and thus in expanding the Off-Hour Delivery Program well beyond its initial, pilot phase participation levels. Without their positive support, the program could not have realized the same degree of success.

CHAPTER 4: MARKET POTENTIAL

Assessment of the Effectiveness of Proposed Policies and Programs

Off-hour deliveries are initiatives that rely on incentives (financial and otherwise) to induce receivers to accept deliveries outside regular business hours. Since the incentives help to remove the receivers' opposition, and the carriers are generally in favor, entire supply chains could potentially switch to the off-hours. The economic impacts would be considerable; a full implementation of OHD in Manhattan could generate benefits of about $150 to $200 million/year (Holguín-Veras et al., 2011b). However, to successfully implement off-hour deliveries (OHD) and unassisted off-hour deliveries (UOHD), proper planning for the implementation is crucial. This chapter presents the key findings from the planning process followed to assess market potential in Manhattan.

In 2010 a pilot test was implemented with both staffed OHD, conducted with staff from the receiving establishment present, and UOHD, whereby deliveries are conducted without the assistance or oversight of staff present (Brom et al., 2011; Holguín-Veras et al., 2011b). During the pilot test, half of the receivers elected to do UOHD, while the other half relied on staffed OHD. At the end of the pilot test, the receivers that used staffed OHD reverted to regular-hour deliveries; without incentives, they could not afford to make the OHD work. In contrast, the vast majority of the receivers testing UOHD opted to stay in the program, to the great delight of their vendors. From the public-sector standpoint, focusing on UOHD makes perfect sense. Public funds are used efficiently for UOHD, as ongoing financial incentives aren't required, as they would be for staffed OHD. Therefore, this project focuses exclusively on UOHD.

The main goal of this chapter is to study the different factors that could affect a firm's willingness to participate in UOHD. The starting point is a preliminary outreach phase, to define which UOHD incentives and programs should be proposed. After defining the set of incentives, the team designed and conducted an attitudinal survey to gather primary data. This data was then used to model firms' reaction to incentives, using advanced econometric techniques. The resulting models provide the basis to assess multiple factors: which market segments are the most inclined to participate; potential market response; and policy implications. The insights gained provide the foundation to design the features of an UOHD Program.

This chapter has two main components. The first component has four subsections covering: the data collection effort; a detailed analysis of the Survey Responses; the Discrete Choice Models and modeling methodology; and the Summary of Findings. The second component covers the Behavioral Micro-Simulations, with subsections including Literature Review on the topic; the Methodology; discussion of Carrier Behavior; Implementation Considerations; the Applications to Manhattan; the Impact of Incentives on Manhattan; the Impact of Incentives According to Geographic Location; the Impact of Incentives According to Industry Segment; and a discussion of Self-Supported Freight-Demand Management. The chapter concludes with a Summary of Findings.

Behavioral Data Collection

These are the objectives of the proposed experiment: (1) to study how a firm's attributes affect its willingness to accept UOHD: (2) to determine which market segments are the most inclined to enter the program: (3) to assess the effectiveness of different policy combinations and programs to foster UOHD; and (4) to estimate potential participation.

Empirical evidence and game theoretical analyses have proven that the decision of time of travel is not unilateral; it is an outcome of the interaction between receivers and carriers. Previous publications have shown that carriers cannot do off-hour deliveries without the concurrence of receivers (Holguín-Veras et al., 2007; 2008b). Moreover, Holguín-Veras (2011) shows that for New York City, the total costs of adopting OHD are on average 85% larger for receivers than the total savings for the carriers. Therefore, changing the joint behavior of carrier and receivers to foster unassisted off-hour deliveries requires policies that focus on receivers.

In setting the spectrum of incentives and programs that could produce the desired effect from receivers, the starting point was the private sector input concerning operational concepts and potential public sector policies. Based on insight gained during this outreach, the following features of the experiment were defined: the set of variables that could influence the decision to implement UOHD; the range of values of the policy variables (treatment levels) to be considered in the stated preference surveys; and the combinations of treatment levels. The variables that influence the decision to implement UOHD include the industry sector, the number of deliveries received, and an indicator of the business size (e.g., area and employees). In terms of the treatments, the policy variables were designed to involve the different agents that would benefit from the UOHD program. In this experiment, both the Public Sector and the carrier apply stimuli to the receiver to induce a switch to off-hour deliveries. The receiver-centered policies include a one-time incentive, public recognition, and business support provided by the Public Sector; and a price signal (i.e., carrier discount) provided by the carriers. The efficiency of a trusted vendor program was also studied as part of the stimuli to the receivers. This multi-layered benefit approach is bound to produce larger switches to UOHD, without imposing the whole burden to the public sector.

The outreach conducted suggested a range for the one-time incentive defined to vary from 0 to US $9,000, and the carrier discount from 0 to 50%. The other incentives, business support and public recognition, were defined as binary variables (i.e., provided or not). The combination of treatment levels was set to provide an indication of the potential response for all industry segments, with each firm responding to four different potential treatments (i.e., combinations of incentives). The treatment applied is randomly selected from the range of all possibilities.

In terms of the receiver's response, the best way to replicate the decision-making process is to express the preference in a sort of ordinal ranking, instead of as a binary choice. Hence, five different levels of willingness to accept UOHD were defined: not at all willing, not too willing, neutral, somewhat willing, and very willing, with the response indicating the receiver's preference (i.e., willingness to do UOHD) given a treatment level.

The success of the experiment, and indeed, the ultimate success of the program, depends on the reliability of the preference data sample studied. The following section presents the methodology followed.

Sample Design and Data Collection

The survey instrument, which targeted receivers, was designed to collect data on deliveries and shipments received, current operations and what flexibility exists within those operations, and the unassisted off-hours delivery (UOHD) scenarios. The deliveries and shipments section included questions about number of deliveries received by the company, typical cost and size of shipment, type of goods received, primary transporter of the goods, carrier access to building when delivering a shipment, and number of vendors. The section on operations and flexibility inquired about hours of operations, number of employees, from whom consent was needed to receive UOHDs, company's interest in consolidating shipments and receiving UOHDs, and if they currently have a vendor they would trust to do UOHDs. The scenario test section used a stated preference (SP) method to allow the respondents to rate their willingness to accept UOHD in six randomly selected scenarios. In each scenario the incentive set that was offered differed, but the question remained the same. The incentive sets were comprised of a one-time incentive ranging from $1,000 to $9,000, a carrier discount ranging from 0% to 50%, public recognition or no public recognition, and business support or no business support. The respondents had the option of selecting "not at all willing," "not too willing," "neutral," "somewhat willing," or "very willing" for each scenario.

To eliminate the potential problem of selectivity bias, the project team used a statistically solid sampling frame to draw the SP sample, the Dun & Bradstreet database (DNB). The SP data was collected using computer-aided telephone interview surveys targeting shippers and receivers. The process followed the outline of previous research projects conducted by the team, consisting of: randomizing the choice scenarios to use during the interviews; drawing a sample of respondents from the DNB database; mailing out invitation letters to participate in the survey; mailing reminder cards to those businesses that have not returned the invitation card; conducting the interviews; and repeating the process until the desired amount of data has been collected.

The survey focuses on industrial sectors that make regular deliveries, including manufacturing, wholesale and retail trade, accommodation and food services, and laundry services. The 3-digit NAICS codes of involved sectors, and the number of establishments within each sector, are listed in Table 11. According to Census, there are a total of 40,531 such business establishments in the study area. These establishments are randomly sampled with a 6.15% sampling rate, resulting in a total of 2,500 business records. All of these 2,500 establishments were first contacted by mail, with a letter that outlined the purpose and scope of this study. The letters were later followed by phone calls for the detailed questionnaire.

Table 11: Sample Selection by Industry Segment

Industry Segment	Establishments in NYC	Sampled establishments
722 Food Services and Drinking Places	8509	524
812 Personal and Laundry Services	4367	269
423 Merchant Wholesalers, Durable Goods	4210	259
424 Merchant Wholesalers, Nondurable Goods	4173	257
711 Performing Arts, Spectator Sports, and Related Industries	3452	213
448 Clothing and Clothing Accessories Stores	3353	207
445 Food and Beverage Stores	2135	132
453 Miscellaneous Store Retailers	1822	112
446 Health and Personal Care Stores	1221	76
425 Wholesale Electronic Markets and Agents and Brokers	878	55
315 Apparel Manufacturing	681	42
451 Sporting Goods, Hobby, Book, and Music Stores	670	42
442 Furniture and Home Furnishings Stores	582	36
454 Nonstore Retailers	581	36
339 Miscellaneous Manufacturing	565	35
811 Repair and Maintenance	560	35
443 Electronics and Appliance Stores	486	30
721 Accommodation	418	26
323 Printing and Related Support Activities	390	25
444 Building Material and Garden Equipment and Supplies Dealers	315	20
311 Food Manufacturing	193	12
452 General Merchandise Stores	151	10
484 Truck Transportation	125	9
313 Textile Mills	81	5
337 Furniture and Related Product Manufacturing	81	5
447 Gasoline Stations	69	5
441 Motor Vehicle and Parts Dealers	67	5
334 Computer and Electronic Product Manufacturing	59	4
314 Textile Product Mills	51	4
316 Leather and Allied Product Manufacturing	45	4
332 Fabricated Metal Product Manufacturing	37	2
493 Warehousing and Storage	35	2
325 Chemical Manufacturing	33	2
622 Hospitals	29	2
331 Primary Metal Manufacturing	23	2
335 Electrical Equipment, Appliance, and Component Manufacturing	18	1
326 Plastics and Rubber Products Manufacturing	15	1
322 Paper Manufacturing	14	1
333 Machinery Manufacturing	13	1
312 Beverage and Tobacco Product Manufacturing	7	1
327 Nonmetallic Mineral Product Manufacturing	6	1
321 Wood Product Manufacturing	5	1
336 Transportation Equipment Manufacturing	5	1
324 Petroleum and Coal Products Manufacturing	1	1

Once the data was collected, the team coded and edited the dataset to ensure that the numerical codes actually represented the responses provided; assessed the quality of the responses and eliminated invalid observations; and produced the dataset to be used in the estimation process. The final dataset contains responses from 254 firms, in most cases covering four different scenarios.

Survey Responses

The main goal of this chapter is to identify how the various industry sectors would react to public sector policies by reporting the findings of the team's attitudinal survey. Analyses reported in this chapter provide important insights into the feasibility and potential of UOHD

Description of the Survey

The survey collected data on: deliveries and shipments received; current operations and what flexibility existed for change; and willingness to participate in UOHD in response to a set of incentives. The delivery section included questions about number of deliveries received, delivery costs, shipment size, type of goods received, primary transporter of the goods, form of access to building, and number of vendors. The section on operations and flexibility inquired about hours of operations, number of employees, who needs to provide consent for the establishment to accept OHD, interest in consolidating shipments, interest in OHD, and if they currently had a vendor they would trust to do OHDs. Respondents were presented with six scenarios and asked to indicate their willingness to accept UOHD. The incentives were a one-time incentive ranging from $1,000 to $9,000, a carrier discount ranging from 0% to 50%, public recognition (or no), and business support (or no). The respondents could answer "not at all willing," "not too willing," "neutral," "somewhat willing," or "very willing," for each scenario.

Data were collected from 263 receivers in Manhattan. The North American Industry Classification System (NAICS) was used to group the companies by industry categories at the 2-digit level. The largest group (40.68%) is in the retail trade (NAICS 44-45); "other services" (NAICS 81) (e.g., laundry and dry cleaning businesses, spas, fitness centers, pet grooming, and pharmacies) comprise 20.91% of the sample; 16.73% are in manufacturing (NAICS 31-33); another 10.65% do wholesale trade (NAICS 42); arts, entertainment, recreation (NAICS 71) represent 5.7%; accommodations and food services (NAICS 72) comprise 3.42%; and 1.90% are in transportation and warehousing (NAICS 48-49), finance and insurance (NAICS 72), and health care and social assistance (NAICS 62).

Descriptive Analyses

This section provides a summary of the most salient features of the data collected, with percentages based on the total of those in the sample that provided an answer. The number of deliveries received in a week ranges from one to 500. An estimate of 39.23% receives one to five deliveries/week, another 22.69% receives six to ten deliveries/week, and 10.77% receives between 11 and 15 deliveries/week. Those receiving between 16 and 20 deliveries, 21 to 25 and 26 to 30 represented 6.54%, 6.15% and 2.31% of the sample, respectively. Those that receive between 31 to 50 deliveries constituted 6.15% of the sample, while only 5.77% receive over fifty deliveries in the average week. In total, the average number of deliveries/week received is 18.96, with standard deviation of 40.14, and median of 10.00. The commodities received were classified into two groups: perishable and nonperishable. Receivers of perishable goods (i.e., agriculture, forestry, fishing, or food) are 13.31% of that total, while 86.69% receive only nonperishable items.

In terms of the average delivery cost, the maximum delivery cost is $1,500.00, and the minimum is zero. Approximately thirty-nine percent (38.60%) of the companies do not pay for deliveries; 38.01% spend between $1 and $50; 8.19% pay between $51 and $100; 23.39% of respondents spend over $50 to receive deliveries; and 5.85% pay over $300. The average delivery cost is $139.60, with a standard deviation of $272.42, and a median of $30.00. An estimated 6.11% of the companies transport their own commodities, 59.96% rely on vendors, and 34.73% use both the company's transportation and vendors. The number of vendors ranges between one and 1,000. The majority (47.37%) has one to five vendors, another 19.43% receives goods from six to ten vendors, 21.05% fall in the range of eleven to thirty vendors, and 12.15% have over thirty vendors. The average total number of vendors is 27.71, with a standard deviation of 88.39, and a median of 6.00 vendors.

The majority (56.27%) of businesses surveyed open between 8:00AM to 10:00AM; 26.62% open between 6:00AM and 8:00AM; 4.18% start operations between 4:00AM to 6:00AM; and 1.14% open between 7:00PM to 12:00AM. A total of 64.64% end operations between 4:00PM and 7:00PM, though a significant portion (25.10%) ends between 7:00PM and 12:00AM, while another 4.18% have 24-hour operations. It should be noted that 32.32% of the sample businesses operate, at some point, during the off-hours period, either in the morning or in the evening/night.

With the data provided about employment, part-time employees were converted to equivalent full-time employees using a conversion factor of 0.45, to estimate total manpower. Total employment (full-time equivalents, or FTE) ranges from one to 422.50. Companies with FTEs between one and five account for 46.31% of the total, 21.16% have six to ten FTEs, another 10.97% have eleven to fifteen FTEs, 15.68% have between sixteen and fifty full-time FTEs, and 5.49% have over fifty FTEs. The average number of FTEs is 16.66, with a standard deviation of 43.74, and a median of 6.00.

In terms of consent to do UOHD work, 48.58% of the respondents indicated that they did not need consent from anyone; 21.05% required consent from the building owner and carriers; 19.43% needed the consent only of the building owner, and 7.29% needed the consent only of the carrier. Since most carriers are inclined to do UOHD because of the cost savings, it should be noted that carrier/vendor consent is forthcoming in most cases. Consolidating shipments is a method used to decrease the number of truck trips. The data indicate that 20.63% of the companies surveyed are interested in consolidating shipments, while 79.37% are not. An estimate of 15.44% of the sample have considered doing OHD, 80.31% have not, while 4.25% are already doing OHD.

The survey asked respondents if they have a vendor they would trust to perform OHD. The data show that 32.02% have one, while 67.98% do not. Figure 17 shows that there is a clear divide, with businesses in some sectors having a sizable number of trusted vendors, while those in other sectors having none. This reflects differences in the economic activities performed.

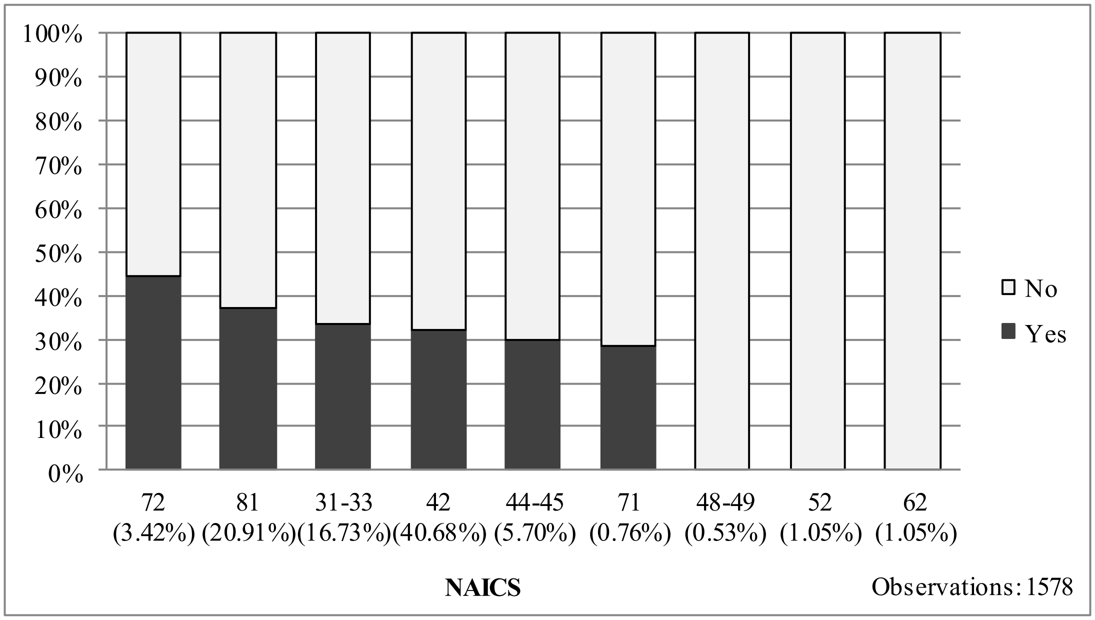


Figure 17: Trusted Vendor versus NAICS Industry Classifications

Note: The codes are: Manufacturing (NAICS 31-33), Wholesale trade (NAICS 42); Retail trade (NAICS 44-45); Arts, entertainment, and recreation (NAICS 71); Transportation and warehousing (NAICS 48-49); Finance and insurance (NAICS 52); Healthcare and social assistance (NAICS 62); Accommodations and food services (NAICS 72); and Other services (NAICS 81).

The companies responded as to what they felt any city agency could do to foster participation in OHD, and the majority (82.46%) believed that there was nothing. However, a solid 17.54% suggested that city agencies could: address parking regulations for freight vehicles (7.02%); provide incentives (5.26%); develop relationships with landlord/building management/company (2.63%); decrease tolls (0.44%); and "others" (2.19%). Other suggestions included: providing a place to conduct OHD, providing more information on the topic, and researching successful OHD projects in other countries. The parking issues mentioned include lack of parking, strict regulations and restrictions, and fines.

Willingness to Participate in Unassisted Off-hours Deliveries (UOHD)

This section discusses the willingness to participate in UOHD in connection with business characteristics and policy variables. In Figure 18, the breakdown of the values or categories is shown on the horizontal axis, where the percentage listed below each category represents the portion of the data for that particular value. The results in the vertical axis are in decreasing order of willingness to participate on UOHD, as the bar progresses upward. To facilitate interpretation, lines have been drawn to separate the results between "willing" ("somewhat willing" and "very willing"), neutral, and "unwilling" ("not too willing", and "not at all willing"). Throughout the paper, when referring to willingness to participate in UOHD, the terms "willing," "neutral," and "unwilling," are used with these defined meanings.

The data show that the willingness to accept UOHD decreases with the number of deliveries received. This is expected, because for a company with a large number of deliveries it would be more complicated to switch operations; these companies are therefore less motivated to switch to UOHD.

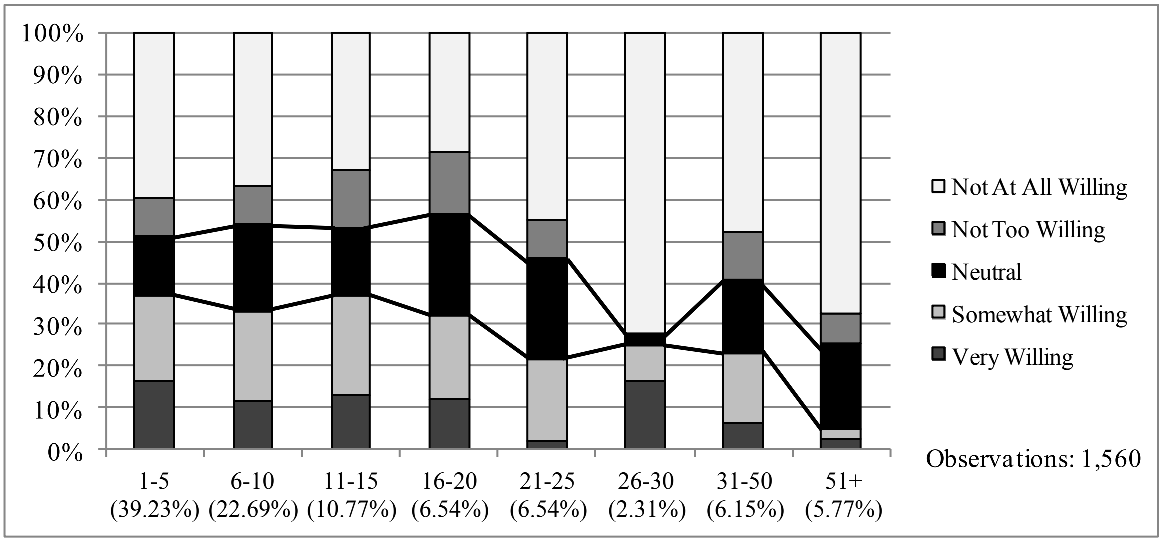


Figure 18: Willingness versus Average Number of Deliveries Received Per Week

The average costs per delivery basis was mapped against willingness in Figure 19. Not surprisingly, companies that do not pay separate delivery costs show low willingness to participate. There is a decrease in willingness level for both $101-200, and the over $300 bins, but that may be similar to the trend noted in Figure 18, where the higher cost may reflect the quantity of goods or shipments received, and the relative complexity of changing operations.

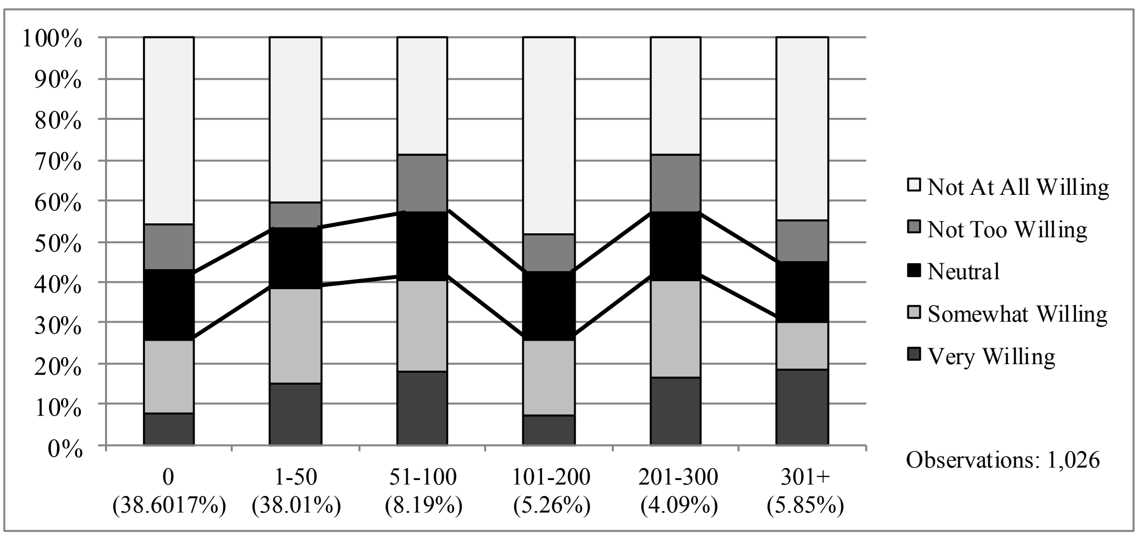


Figure 19: Willingness versus Delivery Costs Incurred for a Typical Delivery Received

Figure 20 displays willingness versus number of vendors. The figure shows that companies with twenty vendors or less are more willing to participate, which may indicate more ease in coordinating deliveries allowing for an easier transition to UOHD. The ranges of 21-25 and 26-30 did not have any respondents who were "very willing" to participate, and those with 26-30 vendors had the greatest percentage (76.44%) of companies who were "not at all willing."

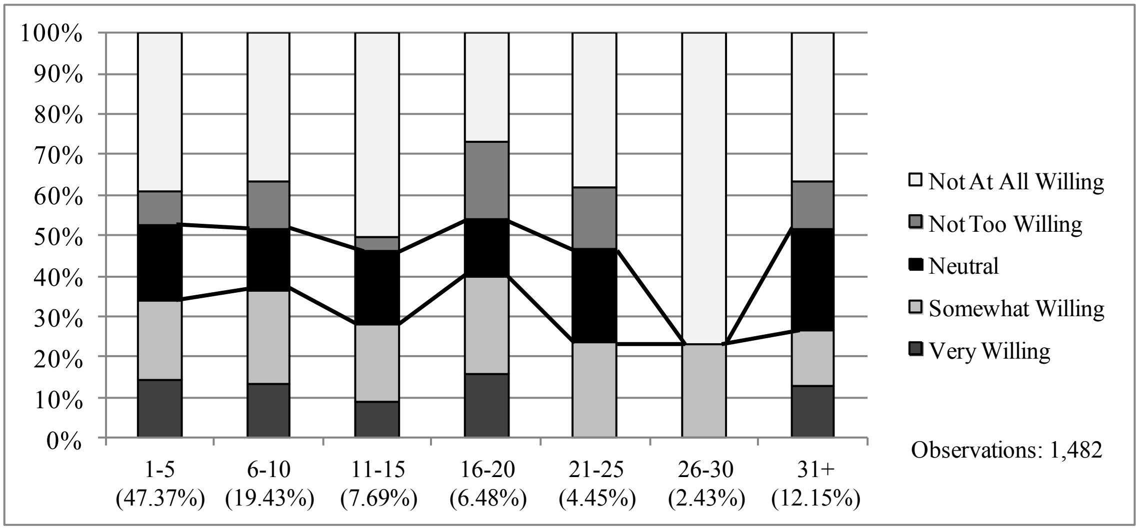


Figure 20: Willingness versus Number of Vendors from Which Deliveries Are Received

As shown in Figure 21, willingness to participate increases with respect to number of employees up to the level of 20 employees or less. Beyond that point, there is a significant decrease in willingness. This is consistent with the results of willingness versus number of deliveries, as the number of employees is also an indicator of business size and complexity of freight/delivery operations. This supports the theory that larger businesses will be less likely to participate in UOHD, because switching operations on a larger scale is more complicated. It is worth noting that those businesses that fall in the 21-50 range have a "very willing" (10.61%) level comparable to those with a smaller number of employees, so these should not be excluded when targeting businesses to do UOHD. However, the willingness to participate for businesses with over 50 employees is significantly smaller than that seen in the other groups. Establishments with over 50 employees had the largest percent (40.48%) of neutrality, which may indicate that there is room to convince businesses of this size to accept UOHD.

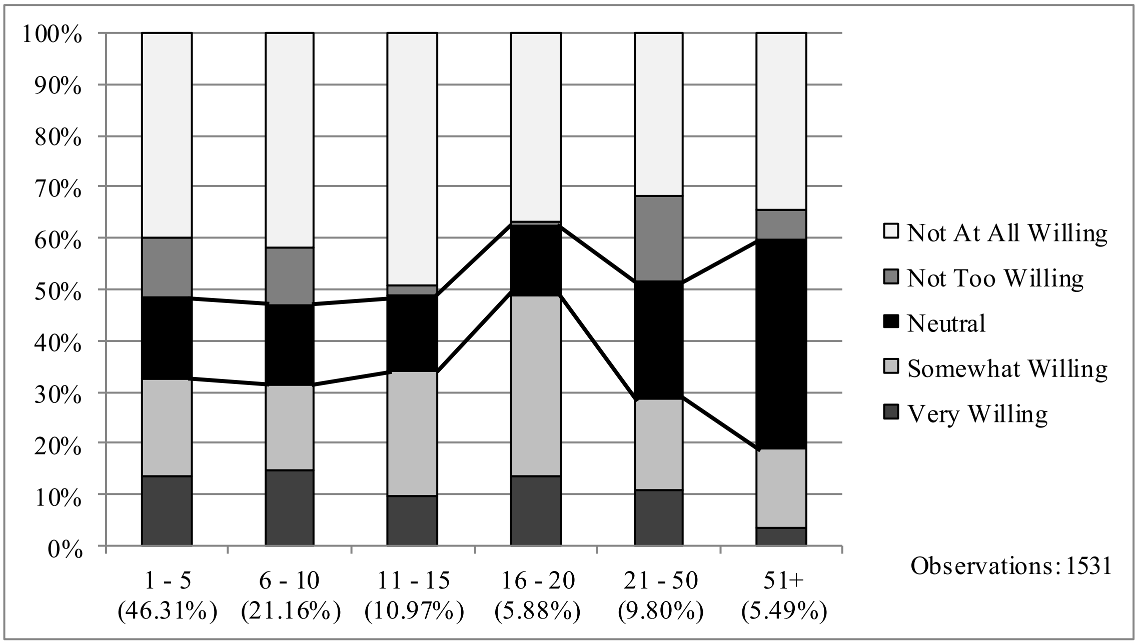


Figure 21: Willingness versus Number of Employees

The willingness to participate was analyzed in connection with the type of commodities received by the businesses, perishables vs. nonperishables. Those that receive perishable goods show a higher willingness to participate (42.19%) than the receivers of nonperishable commodities (30.27%). Receivers of perishables, primarily food stores and restaurants, would like to receive their supplies early in the mornings before the business opens, because that would ensure a more reliable delivery time, with trucks traveling before peak morning traffic.

The breakdown of responses concerning willingness to do UOHD by industry groups is shown in Figure 22. Establishments in "other services" (e.g., laundry and dry cleaning businesses, spas, fitness centers, pet grooming and pharmacies) had the highest willingness (36.21%) to accept UOHD, with accommodations and food services, and retail trade close behind with 35.19% and 34.18%, respectively. Manufacturing (28.04%), wholesale trade (27.54%), and arts, entertainment and recreation industries (25.55%), also showed significant willingness levels. The similarities between the willingness versus NAICS industry group results, and the NAICS industry group versus trusted vendor results, suggest that having trusted vendors influences a company's willingness to participate.

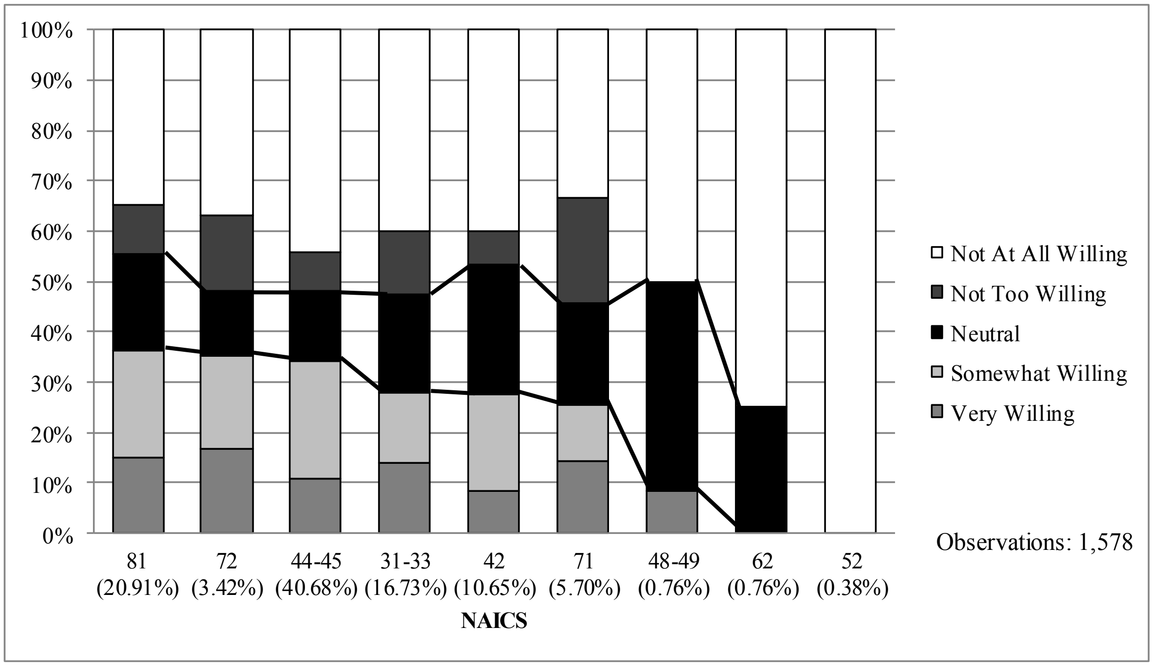


Figure 22: Willingness versus NAICS Industry Groups

Note: The codes are: Manufacturing (NAICS 31-33), Wholesale trade (NAICS 42); Retail trade (NAICS 44-45); Arts, entertainment, and recreation (NAICS 71); Transportation and warehousing (NAICS 48-49); Finance and insurance (NAICS 52); Healthcare and social assistance (NAICS 62); Accommodations and food services (NAICS 72); and, Other services (NAICS 81).

The working hours data indicate that those companies that are open during off-hours are slightly more willing to accept UOHD than those that are not, 33.20% compared to 30.77%. Companies with long operating hours, such as those that overlap with morning and evening/night off-hour periods, and those that have 24-hour operations, are very willing to do UOHD. More specifically, businesses that have both morning and evening/night off-hours operations (4.56% of the sample), including 24-hour operations, have the highest willingness (43.94%) to do UOHD, another 17.24% are neutral, compared with those that have off-hours operations in only one period (morning or evening/night), or no off-hours operations.

The data for willingness to participate in relation to the availability of a trusted vendor revealed that businesses with a trusted vendor are more willing (39.17% willingness, with 17.10% being "very willing") to accept UOHD, than those that do not have a trusted vendor (27.30% willingness, with 9.52% being "very willing"). A sizable 58.74% of those without a trusted vendor were not willing to accept UOHD, with 50.00% expressing that they were "not at all willing." Obviously, trust is one of the most important factors related to willingness to accept UOHD, because receivers would need to allow vendors access to their property, leaving them vulnerable to possible loss or damage of property.

Figure 23 shows willingness versus the one-time financial incentive. As shown, there is a steady increase in willingness in relation to a $1,000 incentive (willingness of 20.11%) up to a $4,000 incentive (willingness of 36.46%), at which point the willingness evens out. As expected, the incentive of $9,000 produces the largest willingness, 38.10%. These results indicate that a one-time incentive increases willingness to participate in UOHD up to $4,000, and that beyond that point, the willingness to participate does not change significantly.

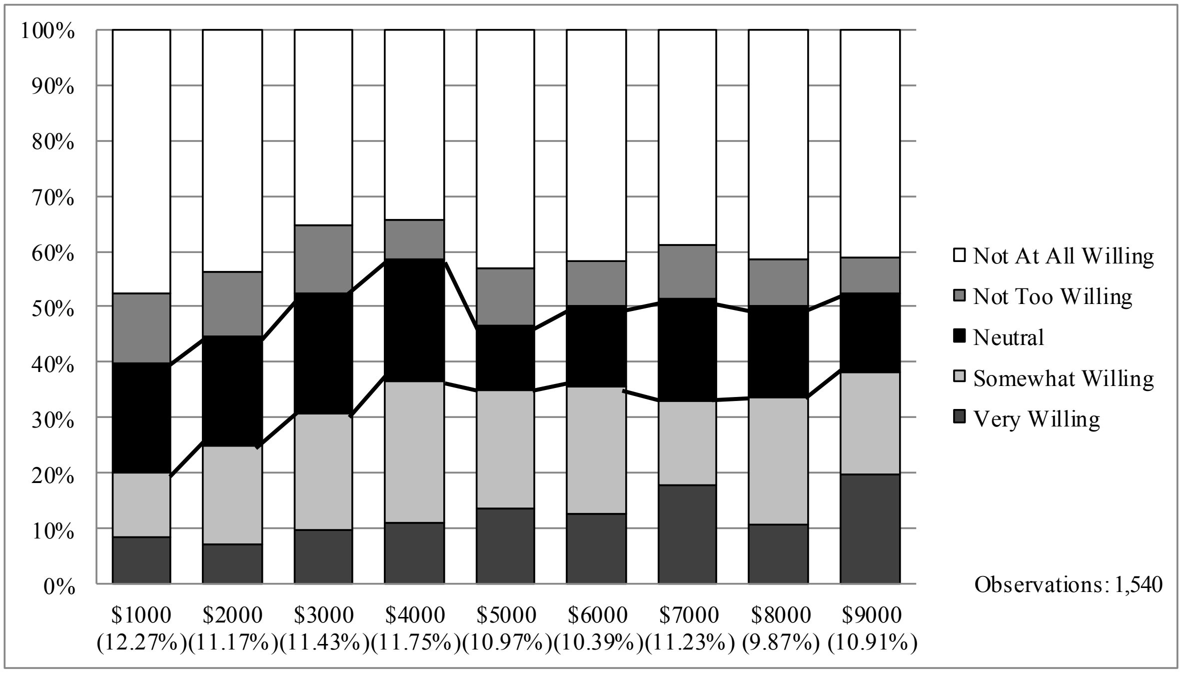


Figure 23: Willingness versus One-time Incentive to Influence Switch to UOHD

Another form of incentive for the receivers is discounts in shipping costs that carriers/vendors could provide to them if they accept UOHD. The scenarios considered include discount rates ranging from 0% to 50%. The results, shown in Figure 24, indicate that the largest increase in willingness takes place in the range from zero to 10% discount (9.53% increase). Beyond that level, the willingness gradually increases up to the 50% discount (willingness of 41.05%).

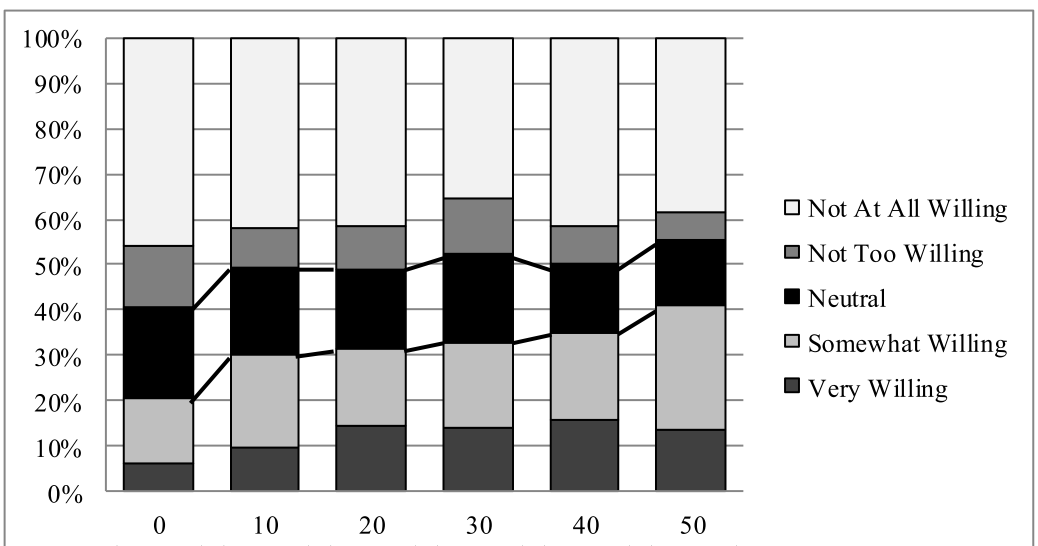


Figure 24: Willingness versus Carrier Discount

The provisions of public recognition (PR) and business support (BS) are non-monetary incentives that were tested in the survey. Public recognition refers to the use of awards, a branding logo, and other mechanisms to certify that the receiver is participating in sustainability efforts that are beneficial to the community. Among other things, this public recognition would help businesses raise their profile among environmentally sensitive customers, and enable such customers to identify and patronize those businesses that participate in environmentally friendly practices. The results show that receivers value public recognition; the willingness to participate in UOHD increases to 33.33% from the base value of 30.11% when no public recognition is offered. In essence, public recognition increased willingness by 3.22%. Business support programs provide a service whereby receivers can seek assistance and advice on issues relating to their operations, such as tax preparation. A member of the project's Industry Advisory Group suggested this idea, indicating that many small businesses are in need of such support services. The inclusion of business support as incentive also increased the willingness to participate to 34.09%, from its base value of 29.56%. Therefore, business support increases willingness by 4.53%.

The relationship between interest in consolidating shipments and willingness to accept UOHD was analyzed. The results show that 46.44% of those that said they are interested in consolidation (20.63% of the sample) were also willing to do UOHD, with 24.22% being "very willing." In contrast, only 26.61% of those that were not interested in consolidation (79.37% of the sample) were willing to do UOHD, 8.39% of which were "very willing." This suggests the possibility that there are some common factors that explain the propensity of these businesses to participate in innovative delivery practices.

Survey Results Implications

In general terms, the results of these analyses clearly indicate the potential of UOHD, and implicitly, of other TDM measures. It is important to note that about 17.54% of respondents think that the public sector could influence business behavior by either: using parking regulations (7.02%), providing incentives (5.26%), or developing relations with the private sector (2.63%). Such findings are consistent with practices at NYCDOT, where such tools have been used to foster participation in OHD.

The data show that businesses that have a trusted vendor are about 1.4 times more inclined to participate in UOHD (39.17% vs. 27.30%). This finding—together with the estimate that 32.02% of establishments feel that they have a trusted vendor they would allow to do UOHD—has tremendous implications; it indicates that a sizable number of establishments could do UOHD with minimal inconvenience. There is also the intriguing possibility of developing, in collaboration with trade organizations such as trucking associations, a "trusted vendor certification program" that would certify vendors that have completed training on how to conduct UOHD safely and in compliance with all appropriate regulations. This, together with the finding that 48.58% of establishments do not need the consent of anyone else to implement UOHD, suggests that a trusted vendor program could play a key role at fostering UOHD. Moreover, since 15.44% of establishments have considered UOHD—most notably, without any incentive—there is a real possibility of inducing large numbers of receivers to participate in UOHD.

When deliveries are consolidated, and a carrier is designated to do the final leg of deliveries on behalf of others, receivers reduce the amount of disruption they experience receiving deliveries, which enables them to use their staff for more productive pursuits. It is worth noting that 20.63% of receivers surveyed are willing to consolidate deliveries. By doing so, receivers contribute to reduce truck traffic and congestion, and to improve operational efficiency of the carriers that serve them. Although there are coordination issues and transfer costs that could impact financial viability, receiver-led consolidation schemes have great potential. If the receivers that are willing to try this concept manage to reduce their deliveries by 50%, a 10% reduction in total truck traffic could be within reach. The idea of using receivers to push the carriers toward consolidation is at the heart of the successful Binnerstag service in The Netherlands. The public sector should pursue fostering similar programs.

The changes in willingness to participate in UOHD in connection with business characteristics and policy variables reveal important findings. Willingness to participate in UOHD increases with business size up to a point (16-20 employees), and then decreases (similar behavior was found in such related attributes as number of deliveries). This makes sense: if the establishment is too small, there may not be a need for UOHD; while if the establishment is too large, the coordination effort and risk involved in switching may render UOHD unfeasible. However, this is not a problem for TDM efforts, as small establishments produce the bulk of the freight traffic in urban areas. A second important finding of these analyses is that different industry sectors exhibit different levels of willingness to accept UOHD (in descending order): other services (NAICS 81); accommodations and food services (NAICS 72); retail trade (NAICS 44-45); manufacturing (NAICS 31-33); wholesale trade (NAICS 42); and, arts, entertainment, and recreation (NAICS 71). Small businesses in these segments are the ideal target for UOHD programs.

The research also studied the effectiveness of these measures in increasing a business's willingness to participate: a one-time financial incentive provided by the public sector, shipping discounts provided by carriers, public recognition and business support services, and the availability of a trusted vendor. The one-time incentive proved to be a key component, as without it, receivers are less likely to take the risk to try UOHD. However, the data show that the one-time incentive has a limit in effectiveness; it increases willingness to participate to 36.46% from 20.11% (for no incentive), but only up to $4,000. Beyond that point, financial increases do not translate into greater willingness to participate (for the range of values studied in the research).

The shipping discounts provided by the carriers play an important role as well, increasing willingness by 20.62% (from 20.43% to 41.05%, if a 50% discount is provided). In contrast to the one-time incentive, the discount consistently increases willingness for the range of values considered. Obviously, securing an ongoing discount is bound to be more enticing than a one-time incentive.

The availability of a trusted vendor significantly impacts willingness to participate in UOHD, increasing it by 11.87%. This result highlights the importance of creating "trusted vendor" certification programs that would train carriers to do UOHD safely and in compliance with best community-sensitive practices. Part of the training could include how to perform low-noise UOHD, and require that carriers use low noise equipment during the UOHD work. Such programs, which could go a long way in ameliorating receivers' concerns about UOHD, could be managed by local trucking associations, business groups, and the like.

Business support services and public recognition programs do provide modest, but meaningful increases in willingness to participate, in the range of 4.53% and 3.22%, respectively. In addition, these programs have other benefits, as they could help transform the nature of the relations between public and private sectors, and create a more collaborative and business-friendly environment.

Discrete Choice Models

Building on insights gained from the descriptive analyses, the team used the stated preference data to estimate a set of behavioral models. These models allow for a formal assessment of the role played by company attributes, the characteristics of the alternatives being considered, and policy variables. They can also be used to obtain estimates of market responses to the various combinations of policy variables; to study the econometric interactions between independent variables; and to provide a solid foundation for the estimation of market elasticities. The insight gained from these models is extremely useful for policy making.

The dataset assembled consists of panel data gathered by the stated preference survey. The dependent variable is an ordinal variable that measures the willingness to receive UOHD, while the independent variables are the attributes of the receivers and the incentives offered. Given the ordinal nature of the dependent variable, ordered choice models must be used to estimate the outcome probabilities. The willingness level is represented by a numerical scale, ranging from one to five, with one being the least willing, and five being the most willing. The descriptors used were “not at all willing,” “not too willing,” “neutral,” “somewhat willing,” and “very willing.”

In ordered choice models, the dependent variable (which is an ordinal scale) is modeled through the joint estimate of a score function—which is a linear combination of independent variables—and a set of parameters, μ, (thresholds) that split the domain of the score function to replicate the original choice probabilities. The log-likelihood function is used to determine the efficiency of the ordered discrete model; this function is maximized to arrive at the best model.

The models belong to the family of Random Utility Models (RUM), which postulates that rational individuals try to maximize their utility (Domencich and McFadden, 1975). In the case of ordered discrete choice modeling, the choice (*y*), is estimated by defining a utility (*U*), that depends on the attributes of the individuals and the alternatives. The utility is specified using a linear function, as follows:

$$U = \boldsymbol{\beta}\mathbf{X} + \varepsilon \tag{1}$$

Where,

X: A vector of variables or attributes proper to the observation

β: A vector of estimable parameters

ε: A random disturbance

The threshold parameters, $\mu(i)$, are derived along with the dependent variable during the modeling process. These parameters also referred to as thresholds, are used to define the dependent variable by using the utility value to determine willingness; therefore, providing a numerical range that indicates the level of willingness, as shown in the following equations:

$$\begin{aligned} y&=1, &&\text{if} && U \le 0 \\ y&=2, &&\text{if} && 0 < U \le \mu(1) \\ y&=3, &&\text{if} && \mu(1) < U \le \mu(2) \\ y&=4, &&\text{if} && \mu(2) < U \le \mu(3) \\ y&=5, &&\text{if} && U > \mu(3) \end{aligned} \tag{2}$$

To determine the probability for each willingness level, the random disturbance (ε) is assumed to follow a Gumble distribution. Therefore, the probability that *U* corresponds to a willingness level can be described by the following equations:

$$P(Y=1) = \frac{1}{1+\exp(U-0)} \tag{3}$$

$$P(Y=i) = \frac{1}{1+\exp(U-\mu(i-1))} - \frac{1}{1+\exp(U-\mu(i-2))} \tag{4}$$

$$P(Y=5) = 1 - \frac{1}{1+\exp(U-\mu(3))} \tag{5}$$

The analysis of the utility function's specification is based both on statistical significance, and conceptual validity; any variable that does not meet these criteria is excluded from the analysis. Once the final models are obtained, the elasticities of the key variables are calculated. The direct elasticities can be computed using equation (6). Based on the estimates for each individual, it is possible to compute the market elasticity in order to assess the overall effects of incentives (or attributes) on the willingness to accept UOHD.

$$\eta_{x_{nk}}^{P_n(j)} = \frac{\partial P_n(j)}{P_n(j)} / \frac{\partial x_{nk}}{x_{nk}} = \frac{\partial P_n(j)}{\partial x_{nk}} * \frac{x_{nk}}{P_n(j)} \qquad \forall j \in W, n \in N, k \in K \tag{6}$$

Where:

$P_n(j)$ is the probability that an individual *n* presents a willingness level *j*

X_{nk} is the variable *k* for the individual *n* and alternative *j*

$\eta_{x_{jnk}}^{P_n(j)}$ is the individual direct elasticity of choosing *j* with respect to variable *k*

Given the panel structure of the data (a single company providing multiple responses), there is a high risk of correlation between the unobserved characteristics of each company. This correlation between disturbances will lead to incorrect estimates of the model parameters. This issue is accounted for using a random effects model that includes an error term for each individual, along with the traditional error term. The next section introduces and discusses the results of the model estimation process.

Modeling Results

According to the analysis presented in the former section, the team studied more than 1,000 models to define a systematic relation between attributes of the firms, incentives offered, and the willingness of a firm to accept off-hour deliveries. Based on the descriptive statistics presented previously, the attributes of the firm considered for the econometric analysis are: industry segment, commodity type, employment, sales, number of vendors (linear and non-linear models), area (linear and non-linear models), transportation costs, and direct access to the establishment. However, some of these were discarded on the final model because they do not represent a statistical valid relationship, or because the effect on willingness to do UOHD is not conceptually valid. The main reasons explaining this lack of statistical or conceptual relationship are measurement errors (e.g., area is not properly measured), and the correlations between independent variables (e.g., employment and deliveries).

The trusted vendor variable is a special case. Although the variable was initially considered an attribute of the firm, an analysis of the concept of trust led the team to consider the variable as a potential incentive. In essence, building trust in the relationship between receiver and vendor can be considered as an external stimulus to foster UOHD. Moreover, this incentive does not need to be provided by the Public Sector, a trusted vendor program could be managed instead by truckers' associations. In this way, different agents benefiting from UOHD would be contributing to the program's implementation, instead of the burden being left exclusively with the Public Sector.

After significant modeling efforts, a basic model was obtained. However, it was observed that when industry segments with few observations (i.e., firms) were included, there were some unexpected effects on parameter estimates. Therefore, an initial step was included to do a sensitivity analysis to determine how the number of establishment in each industry segment affects the robustness of these parameters. The number of observations to reach the stability of the coefficients was determined to be six. Beyond this level the coefficients remain stable, and the model is more reliable. Table 12 presents the two models selected. As shown, the models are relatively similar, with the primary distinction that model 2 has a generic parameter for the trusted vendor, while model 1 only has sector-specific parameters.

The results presented in Table 12 show the coefficients affecting the utility of each firm. Different industry segments have different utilities, and therefore different responses. As expected, every incentive is statistically significant. On one hand, business support and public recognition have the same effect on utility for every industry segment (though not a monetary value, as will be shown later on this section). On the other hand, one-time incentive, carrier discount, and trusted vendor affect utility in a different way depending on the industry segment targeted. As shown in Table 12, the model includes three parameters, Mu(1), Mu(2) and Mu(3), estimated jointly with the other parameters. These parameters are thresholds that define the willingness level corresponding to an estimated utility. Since the thresholds are free parameters, the unit distance between the set of observed data does not have any significance, "they merely provide the coding" (Washington et al., 2009). In fact, this model is not linear, and an elasticity analysis is required to understand the net effects of each independent variable on willingness to accept UOHD.

Table 12: Ordered Logit Model Using Random Effects. Dependent Variable: Willingness to Accept Off-Hour Deliveries

Model	Model 1		Model 2	
Independent variables	**Parameter**	**t-stat**	**Parameter**	**t-stat**
Constant	0.61	(2.78)	0.22	(1.00)
Number of deliveries	-0.07	(-9.17)	-0.08	(-11.66)
Incentives				
One time incentive in $1000 (OTI)	0.18	(6.95)	0.17	(6.76)
Carrier discount in percent (CDR*100)	3.00	(6.81)	3.10	(7.12)
Business Support (BS)	0.55	(3.82)	0.51	(3.52)
Public Recognition (PR)	0.34	(2.24)	0.38	(2.48)
Trusted Vendor (TV)			0.94	(4.29)
NAICS				
Clothing stores, binary variable	-2.73	(-4.57)	-2.46	(-4.32)
Performing arts, binary variable	-1.96	(-5.69)	-4.80	(-12.38)
Interaction terms: OTI and NAICS				
OTI for food and beverage stores	0.12	(2.56)	0.20	(4.24)
OTI for apparel manufacture stores	0.23	(1.72)	0.11	(1.88)
OTI for clothing stores	0.24	(3.18)	0.25	(3.40)
OTI for nondurable wholesalers	0.33	(6.83)	0.37	(7.62)
Interaction terms: CDR and NAICS				
CDR for personal laundry	-2.11	(-2.98)	-2.08	(-3.25)
Interaction terms: Trusted vendor and NAICS				
TV for food and beverage stores	4.35	(7.29)	2.02	(3.17)
TV for performing arts	4.65	(2.56)	13.49	(11.16)
TV for clothing stores	5.06	(8.28)	2.24	(4.06)
TV for miscellaneous stores retailers	6.59	(13.63)	3.17	(5.86)
Parameters				
μ(1)	1.88	(21.54)	1.91	(21.36)
μ(2)	4.56	(34.64)	4.56	(34.14)
μ(3)	7.63	(40.45)	7.55	(40.51)
Sigma	4.58	(27.64)	4.74	(25.83)
n	1522		1522	
Log likelihood	-1390.89		-1388.50	

Table 13 shows that willingness to accept UOHD is a function of the number of deliveries received, the policy incentives offered (one-time incentive, carrier discounts, Business Support, Public Recognition, and availability of a trusted vendor), and industry sectors that, in most cases, interact with other variables. The one-time incentive, carrier discount, and trusted vendor affect utility in a different way depending on the industry segment targeted. The models show that the number of deliveries has a negative relation with willingness to accept UOHD, as it is more difficult to switch a large number of deliveries to UOHD than to switch only a few. The analysis shows that firms have different attitudes to UOHD depending on the industry segments they belong to. Nondurable wholesalers and clothing stores seem to be particularly willing to accept UOHD. Moreover, the interaction terms between incentives and industry segments enable researchers to study what segments are more sensitive to a given incentive. The model reveals that retail establishments (e.g., clothing, food and beverages stores) are particularly willing to participate in UOHD. This suggests that the retail segment should be considered as a specific target of UOHD programs.

Table 13 presents the market elasticities for the each type of incentive and interaction with industry sectors.

Table 13: Summary of Elasticity Values for Incentives

Variable	Not at all willing	Not too willing	Neutral	Somewhat willing	Very willing
Trusted vendor (*)	0.983	0.941	0.936	0.930	0.910
Trusted vendor for miscellaneous retailers (TRUST453)	8.372	6.858	6.767	6.416	4.537
Trusted for clothing stores (TRUST448)	6.187	5.203	5.120	4.897	3.893
Trusted vendor for performing arts (TRUST711)	5.616	4.768	4.691	4.501	3.674
Trusted vendor for food & beverage (TRUST445)	5.206	4.450	4.378	4.211	3.505
One-time incentive (OTI)	0.888	0.881	0.879	0.878	0.875
OTI for nondurable goods wholesalers (OTIN424)	1.589	1.563	1.559	1.556	1.543
OTI for apparel manufactures stores (OTIN315)	1.197	1.188	1.182	1.180	1.173
OTI for clothing stores (OTIN448)	1.186	1.172	1.170	1.168	1.162
OTI for food and beverage (OTIN445)	0.600	0.596	0.596	0.595	0.593
Carrier discount	0.865	0.864	0.864	0.863	0.863
Carrier discount for personal and laundry (CDRN812)	-0.591	-0.592	-0.592	-0.592	-0.593
Business support	0.566	0.550	0.549	0.546	0.539
Public recognition	0.346	0.342	0.339	0.339	0.336

The elasticities show that the most potent policy variables are, in descending order of importance, the trusted vendor program, the one-time incentive, carrier discount, business support, public recognition. In terms of response to incentives, the elasticities are positive, meaning that an increase in the incentive would increase the willingness to accept UOHD. It should be mentioned that there are instances where there are both a generic (that apply to all industry segments) and industry-specific parameter that impact the same variable. In these cases, the total effect is the summation of both effects, generic plus industry-specific. It is worth noting that participation in UOHD is particularly elastic to the presence of a trusted vendor program: in some cases the elasticity can be as high as 8.372, which is sixteen times higher than the two other binary incentives (Business Support and Public Recognition).

Subjective Monetary Value of the Non-monetary Incentives

As shown in Table 12, the models include both monetary and non-monetary incentives, which provides an opportunity to estimate the subjective monetary value of the non-monetary incentives. The monetary value of each incentive is the marginal rate of substitution of the incentive with respect to the one-time-incentive:

$$MV_{I,j} = \left(\frac{\partial U}{\partial I} / \frac{\partial U}{\partial OTI} \right) \quad \textbf{(7)}$$

Where:

$MV_{I,j}$: monetary value of incentive I for segment j

I: incentive

j is the industry segment

U: utility function specified in the model

OTI: one time incentive offered (US$)

The resulting estimates are listed in Table 14. As shown, the various policy incentives have a sizable monetary value, though the valuation varies with industry segment. The results reveal that offering business support has the same effect on the utility as a $1,078 to $3,049 one-time incentive; though it would also require public-sector investment, which needs to be factored in for implementation. Providing public recognition is equivalent to a one-time incentive ranging from $666 to $1,885. While this range is lower than the one for business support, public recognition is an attractive alternative because it does not involve large expenditures. Having a trusted vendor offered the most surprising result, with a subjective monetary value ranging from $1,741 to $36,538, which confirms the importance given to this factor by some industry segments. These results provide an indication of the important role that trusted vendor certification programs could play to foster UOHD.

Table 14: Subjective Monetary Values of Incentives for each Industry Segment

NAICS	315	424	445	448	453	711	812		
Descrip-tion	Apparel manufacturing	Non durable wholesaler	Food and beverages	Clothing stores	Miscellaneous store retail	Performing arts	Personal & laundry services	Other Segments	Range
Business Support	$1,340	$1,078	$1,831	$1,308	$3,049	$3,049	$3,049	$3,049	$1,078 - $3,049
Public Recognition	$829	$666	$1,132	$809	$1,885	$1,885	$1,885	$1,885	$666 - $1,885
Trusted Vendor*	$3,357	$1,741	$14,483	$12,037	$36,538	$25,782	$5,529	$5,529	$1,741 - $36,538

Notes: The estimates for NAICS 315, 424, 812, and others were estimated using Model 2

Table 15 and Table 16 show the UOHD market shares for different combinations of incentives for all industry segments, and retail establishments, respectively. The top of the tables show the percentage of firms that would be willing to accept UOHD when no business support is offered, for each one-time incentive, for each carrier discount, and when public recognition is provided (or not). To study the efficacy of a trusted vendor program, two scenarios were developed. On the left side of the tables, the market shares are shown for the original sample (30.31% of establishments with a trusted vendor, and 28.16% for retail establishments), while market shares on the right correspond to a simulated scenario where 50% of the firms have a trusted vendor. Since it is not possible to define which firms are likely to enter the trusted vendor program, the latter scenario is created using a Monte Carlo simulation to randomly select the firms. The market shares presented in the tables are the average of ten independent simulations.

Table 15: Market Shares Summary for All Industry Segments

No Business Support																								
	Actual Trusted Vendors: 30.30%												Simulated Trusted Vendors: 50.00%											
Carrier Discount	0%		10%		20%		30%		40%		50%		0%		10%		20%		30%		40%		50%	
One-Time	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR
$0	3.9	4.5	4.3	5.0	4.9	5.7	5.5	6.5	6.3	7.4	7.2	8.6	5.7	6.5	6.4	7.4	7.2	8.3	8.1	9.4	9.2	10.6	10.4	12.1
$1,000	4.3	5.0	4.8	5.7	5.5	6.4	6.2	7.4	7.1	8.5	8.2	9.8	6.4	7.4	7.2	8.3	8.1	9.4	9.1	10.6	10.3	12.0	11.7	13.6
$2,000	4.8	5.6	5.5	6.4	6.2	7.3	7.1	8.4	8.2	9.7	9.4	11.3	7.2	8.3	8.1	9.4	9.2	10.6	10.3	12.0	11.7	13.6	13.3	15.4
$3,000	5.5	6.4	6.2	7.4	7.1	8.4	8.2	9.7	9.4	11.3	10.9	13.1	8.2	9.5	9.2	10.7	10.4	12.1	11.7	13.6	13.3	15.4	15.0	17.5
$4,000	6.3	7.4	7.2	8.5	8.2	9.8	9.4	11.3	10.9	13.1	12.7	15.2	9.3	10.8	10.5	12.2	11.8	13.7	13.4	15.5	15.1	17.5	17.0	19.8
$5,000	7.3	8.6	8.3	9.9	9.5	11.4	11.0	13.1	12.7	15.2	14.7	17.6	10.6	12.3	12.0	13.8	13.5	15.6	15.2	17.5	17.1	19.8	19.3	22.3
$6,000	8.4	10.0	9.7	11.5	11.1	13.2	12.8	15.3	14.8	17.6	17.0	20.3	12.1	14.0	13.6	15.7	15.3	17.7	17.2	19.8	19.3	22.3	21.7	25.0
$7,000	9.9	11.7	11.3	13.4	13.0	15.4	14.9	17.6	17.1	20.2	19.6	23.1	13.9	16.0	15.5	17.9	17.4	20.0	19.4	22.3	21.7	24.9	24.3	27.8
$8,000	11.5	13.6	13.2	15.6	15.0	17.7	17.2	20.2	19.6	23.0	22.3	26.2	15.8	18.1	17.6	20.1	19.6	22.4	21.8	24.9	24.3	27.7	27.0	30.8
$9,000	13.4	15.8	15.2	17.9	17.3	20.3	19.6	22.9	22.2	26.0	25.2	29.3	17.9	20.3	19.8	22.5	21.9	24.9	24.3	27.6	26.9	30.5	29.8	33.7

Business Support																								
	Actual Trusted Vendors: 30.30%												Simulated Trusted Vendors: 50.00%											
Carrier Discount	0%		10%		20%		30%		40%		50%		0%		10%		20%		30%		40%		50%	
One-Time	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR
$0	4.9	5.7	5.5	6.5	6.3	7.5	7.2	8.6	8.3	9.9	9.6	11.6	7.2	8.3	8.1	9.4	9.1	10.6	10.3	12.1	11.7	13.7	13.3	15.6
$1,000	5.5	6.5	6.3	7.4	7.1	8.5	8.2	9.8	9.5	11.4	11.0	13.3	8.1	9.4	9.1	10.6	10.3	12.0	11.7	13.6	13.3	15.5	15.1	17.6
$2,000	6.3	7.4	7.1	8.5	8.2	9.8	9.4	11.3	10.9	13.2	12.7	15.4	9.2	10.7	10.3	12.0	11.7	13.6	13.2	15.4	15.0	17.5	17.0	19.9
$3,000	7.2	8.5	8.2	9.8	9.4	11.3	10.9	13.1	12.7	15.3	14.8	17.8	10.4	12.1	11.7	13.7	13.3	15.5	15.0	17.5	17.0	19.8	19.3	22.5
$4,000	8.3	9.9	9.5	11.4	10.9	13.1	12.7	15.3	14.7	17.7	17.1	20.6	11.8	13.8	13.4	15.5	15.1	17.5	17.0	19.8	19.2	22.4	21.8	25.3
$5,000	9.6	11.5	11.0	13.2	12.7	15.3	14.7	17.7	17.0	20.4	19.7	23.6	13.5	15.7	15.2	17.6	17.1	19.9	19.3	22.4	21.7	25.2	24.5	28.3
$6,000	11.2	13.4	12.9	15.4	14.8	17.7	17.1	20.4	19.7	23.4	22.6	26.8	15.4	17.8	17.3	20.0	19.4	22.4	21.7	25.1	24.4	28.1	27.4	31.5
$7,000	13.1	15.5	15.0	17.8	17.1	20.4	19.6	23.3	22.5	26.5	25.7	30.2	17.5	20.1	19.5	22.5	21.8	25.1	24.4	28.0	27.2	31.2	30.3	34.7
$8,000	15.2	17.9	17.3	20.4	19.7	23.2	22.4	26.4	25.5	29.8	28.9	33.7	19.7	22.6	21.9	25.1	24.4	27.9	27.1	31.0	30.1	34.3	33.4	38.0
$9,000	17.5	20.5	19.8	23.2	22.4	26.2	25.3	29.6	28.6	33.3	32.2	37.3	22.1	25.2	24.5	27.9	27.1	30.8	29.9	34.0	33.1	37.6	36.5	41.4

Notes: (1) PR: Public Recognition (2) Values indicate market shares in %

Table 16: Market Shares Summary for Retail Establishments

No Business Support																								
	Actual Trusted Vendors: 28.2%												Simulated Trusted Vendors: 50%											
Carrier Discount	0%		10%		20%		30%		40%		50%		0%		10%		20%		30%		40%		50%	
One-Time	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR
$0	7.9	8.8	8.7	9.6	9.5	10.6	10.4	11.6	11.5	12.9	12.7	14.3	12.2	13.6	13.4	14.9	14.7	16.4	16.2	18.0	17.8	19.8	19.5	21.8
$1,000	8.6	9.6	9.4	10.5	10.4	11.6	11.4	12.8	12.6	14.2	14.0	15.8	13.4	15.0	14.8	16.4	16.2	18.1	17.8	19.8	19.6	21.8	21.5	24.0
$2,000	9.4	10.4	10.3	11.5	11.3	12.7	12.5	14.0	13.8	15.6	15.4	17.4	14.8	16.5	16.3	18.1	17.9	19.9	19.7	21.8	21.6	24.0	23.7	26.2
$3,000	10.3	11.4	11.3	12.6	12.4	13.9	13.7	15.4	15.2	17.1	16.9	19.1	16.4	18.3	18.1	20.0	19.8	21.9	21.7	24.0	23.7	26.2	25.9	28.6
$4,000	11.3	12.6	12.4	13.8	13.6	15.2	15.0	16.9	16.7	18.8	18.5	21.0	18.2	20.2	19.9	22.0	21.8	24.0	23.7	26.1	25.8	28.4	28.1	30.9
$5,000	12.4	13.8	13.6	15.1	14.9	16.7	16.5	18.5	18.2	20.6	20.3	23.1	20.1	22.1	21.9	24.0	23.8	26.1	25.8	28.2	27.9	30.6	30.3	33.2
$6,000	13.6	15.0	14.9	16.5	16.3	18.2	18.0	20.2	19.9	22.6	22.3	25.4	22.0	24.1	23.9	26.0	25.8	28.1	27.8	30.3	30.0	32.8	32.4	35.6
$7,000	14.8	16.4	16.2	18.0	17.8	19.9	19.6	22.2	21.8	24.8	24.4	28.0	24.0	26.1	25.8	28.0	27.7	30.1	29.8	32.4	32.1	35.1	34.7	38.0
$8,000	16.1	17.8	17.6	19.6	19.4	21.8	21.5	24.3	24.0	27.3	26.9	30.9	25.8	27.9	27.7	29.9	29.6	32.1	31.8	34.6	34.3	37.4	37.0	40.7
$9,000	17.5	19.4	19.2	21.5	21.2	23.9	23.6	26.8	26.4	30.2	29.7	34.2	27.6	29.8	29.5	31.8	31.6	34.2	33.9	36.9	36.5	40.0	39.5	43.5

Business Support																								
	Actual Trusted Vendors: 28.2%												Simulated Trusted Vendors: 50%											
Carrier Discount	0%		10%		20%		30%		40%		50%		0%		10%		20%		30%		40%		50%	
One-Time	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR	No PR	PR
$0	9.4	10.4	10.3	11.5	11.3	12.7	12.5	14.1	13.9	15.8	15.5	17.7	14.5	16.1	15.9	17.7	17.5	19.5	19.3	21.5	21.2	23.7	23.4	26.1
$1,000	10.2	11.4	11.2	12.6	12.4	13.9	13.7	15.5	15.3	17.4	17.1	19.6	16.0	17.8	17.6	19.6	19.3	21.5	21.2	23.6	23.3	26.0	25.7	28.6
$2,000	11.2	12.5	12.3	13.8	13.6	15.3	15.1	17.1	16.8	19.2	18.9	21.6	17.7	19.6	19.4	21.5	21.3	23.6	23.3	25.9	25.6	28.4	28.0	31.1
$3,000	12.3	13.7	13.5	15.1	14.9	16.8	16.6	18.8	18.5	21.1	20.8	23.8	19.5	21.6	21.4	23.6	23.4	25.8	25.5	28.2	27.8	30.8	30.4	33.7
$4,000	13.4	15.0	14.8	16.6	16.4	18.5	18.2	20.6	20.3	23.2	22.8	26.2	21.5	23.7	23.4	25.8	25.5	28.0	27.7	30.5	30.1	33.2	32.8	36.2
$5,000	14.7	16.4	16.2	18.2	17.9	20.2	20.0	22.7	22.3	25.5	25.1	28.9	23.5	25.7	25.5	27.9	27.6	30.2	29.9	32.8	32.4	35.6	35.2	38.9
$6,000	16.1	18.0	17.7	19.9	19.6	22.2	21.9	24.9	24.5	28.1	27.7	31.8	25.5	27.8	27.5	30.0	29.7	32.4	32.1	35.1	34.7	38.2	37.8	41.7
$7,000	17.5	19.6	19.3	21.8	21.5	24.4	24.0	27.4	27.0	31.0	30.5	35.2	27.4	29.8	29.5	32.1	31.7	34.6	34.3	37.5	37.1	40.9	40.4	44.6
$8,000	19.1	21.4	21.1	23.9	23.6	26.8	26.4	30.3	29.8	34.3	33.8	38.8	29.3	31.8	31.5	34.2	33.9	37.0	36.6	40.1	39.7	43.7	43.2	47.7
$9,000	20.8	23.5	23.2	26.3	25.9	29.7	29.2	33.5	33.0	38.0	37.4	42.9	31.2	33.8	33.5	36.4	36.1	39.5	39.1	42.9	42.4	46.8	46.3	51.1

Notes: (1) PR: Public Recognition (2) Values indicate market shares in %

As shown in Table 15 and Table 16, the market share of UOHD for all industry segments ranges from 3.9% to 37.3% for the current proportion of trusted vendors (30.31%); and from 5.7% to 41.4% if the proportion of trusted vendors increases to 50%. The larger increases in market shares are produced by the one-time incentive (OTI). However, a market share responding to a given value of OTI can be reached by offering a combination of a smaller OTI, and other incentives. As expected from the model structure, the values are not linear. This non-linearity reflects the heterogeneity of receiver behavior, and has to be considered to find the optimum combination of incentives to obtain the desired outcome, in terms of UOHD market share.

A similar analysis focused on the retail sector. The results shown in Table 16 confirm the findings from the elasticity analysis; the higher market shares reveal that retail establishments are inclined to participate in the program. For this segment, the UOHD market share ranges from 7.9% to 42.9%, with the current proportion of trusted vendors (28.16%); and from 12.2% to 51.1% if the proportion increases to 50%. Targeting retail establishments and implementing strategies to raise the proportion of trusted vendors would boost UOHD. Clearly, multi-layered, multi-stakeholder collaborative approaches are crucial to achieve the desired behavior change most efficiently.

Summary of Findings for the Assessment of the Effectiveness of Proposed Policies and Programs

The first component of this chapter presented the approach followed to assess the effectiveness of a set of policies aimed at fostering the Unassisted Off-Hour Deliveries (UOHD) Program. A data collection effort was implemented to study receivers' responses to the different policies. Using the resulting dataset, Ordered Logit models were implemented to study: how firms' attributes affect their willingness to participate in the program; which market segments are most inclined to enter the program; the effectiveness of each policy; and to estimate potential participation.

The survey targeted receivers from different industry segments, and inquired about the firms' attributes and willingness to accept UOHD given a set of policies. The scenario test section used a stated preference (SP) method to allow the respondents to rate their willingness in each scenario. The incentive sets were comprised of a one-time incentive, a carrier discount, public recognition, and business support. In general terms, the results clearly confirm the potential of UOHD. The data show that a significant proportion of establishments are in some way(s) willing to participate in UOHD. Moreover, businesses that have a trusted vendor are about 1.4 times more inclined to participate in the program (39.17% vs. 27.30%). This finding—together with the estimate that 32.02% of establishments have a trusted vendor they would allow to do UOHD—has tremendous implications, demonstrating that a sizable number of establishments could do UOHD with minimal inconvenience. Furthermore, since 15.44% of establishments have considered UOHD—and most notably, without any incentive—there is a real possibility of inducing large numbers of receivers to participate in UOHD. Based on these results, a set of discrete choice models was estimated to assess the market potential of UOHD, and the effectiveness of each policy in fostering the program.

The analyses of willingness to participate in relation to business characteristics revealed that willingness increases with business size up to a point (16-20 employees), and then decreases. This is logical given that if the establishment is small, there may not be a need for UOHD, while if the establishment is very large, the coordination effort and risk may render UOHD not feasible. A second important finding is that industry sectors exhibit different levels of willingness to accept UOHD, with, in descending order of willingness: other services (NAICS 81), accommodations and food services (NAICS 72); retail trade (NAICS 44-45), manufacturing (NAICS 31-33), wholesale trade (NAICS 42); and, arts, entertainment, and recreation (NAICS 71). Small businesses in these segments are the ideal target for UOHD programs.

The behavioral models confirm that willingness to accept UOHD can be influenced by the factors studied: one-time incentive, carrier discount, business support, public recognition, and the availability of trusted vendors. The most effective policies in terms of influence are the one-time-incentive and carrier discount, followed by public recognition and business support. The availability of a trusted vendor is highly valued by certain specific industry segments. Without a one-time incentive many receivers are less likely to try UOHD, but the data show a limit to its effectiveness. The one-time incentive increases willingness to participate to 36.46% from 20.11% (for no incentive), but only up to $4,000. Beyond that point, a larger incentive does not translate into increased willingness to participate (for the range of values studied in the research).

The shipping discounts provided by carriers increase willingness by 20.62% (from 20.43% to 41.05%, if a 50% discount is provided). Unlike the one-time incentive, the carrier discount consistently increases willingness for the range of values considered. Securing an ongoing discount is clearly more enticing than getting a one-time incentive.

The availability of a trusted vendor increases willingness by 11.87%. These results highlight the potential of creating "trusted vendor" certification programs that would train carriers to do UOHD safely and in ways that would not impact local communities, such as using low noise equipment. Such programs could help address receiver concerns about OHD, and could conceivably be managed by local trucking associations, or other suitable private-sector stakeholders.

Business support services and public recognition provide more modest, but still meaningful increases in willingness, in the range of 4.53% and 3.22%, respectively. These programs could also increase goodwill between the public and private sector, creating a more collaborative and business-friendly environment.

The behavioral models suggest that market participation in UOHD would range between 3.9% and 37.3%, with the current proportion of trusted vendors (30.31%), and between 5.7% and 41.4% if that proportion increases to 50%. For retail establishments, the estimated UOHD market share ranges from 7.9% to 42.9% with the current proportion of trusted vendors (28%), and from 12.2% to 51.1% if the proportion increases to 50%. In essence, targeting retail establishments, and implementing strategies to raise the proportion of trusted vendors are two key strategies to reach significant shifts to UOHD.

Behavioral Micro-Simulation

This section assesses incentives designed to foster off-hour deliveries (OHD) using an enhanced behavioral micro-simulation (BMS). The BMS reproduces the main characteristics of freight industry in an urban environment by explicitly considering the relationship between carriers and receivers, matching the freight-trip generation pattern, and considering the characteristics of each industry segment. The behavioral foundation is the way the behavior of both carriers and receivers is modeled. For receivers, an econometric model describes the response to incentives. Each receiver decides whether or not to accept doing OHD according its industry segment, and the incentive structure offered. The behavior of carriers is ruled by the economic evaluation of the scenario, whereby a fraction (or all) receivers will switch to OHD, while others will decide to stay in the regular hours. This process requires considering all of the carrier cost components: the savings realized by driving at night, and the cost of having to make more than one delivery tour.

This part of the chapter shows in detail the BMS, and its implementation for the New York City OHD Program. The incentives considered are one-time incentive (OTI), business support (BS), and public recognition (PR), and the first set of analyses looks at the relative influence of each in fostering OHD. The main finding is that the highest impact is reached when all three incentives are offered to receivers. The latter shows that even though OTI and BS do not represent monetary benefits for receivers, they can influence the final decision towards OHD. Also considered was the possibility of giving incentives to some receivers based on either geographic location or industry segment. The results clearly show the benefits of giving incentives to receivers located in the most congested parts of the city, which supports previous theoretical work in the field. In terms of offering incentives according to industry segment, the analysis was focused on retail, where incentives rapidly generate 6% of change in the industry segment, which in turn represents around 2% of the total freight-trip generation in Manhattan. Moreover, larger incentives to the retail industry segment increases the market share of OHD by approximately 0.2% per each $1,000 of OTI.

Also presented are methodology, results and analyses related to incentives to foster OHD. The findings shed light on the implementation of OHD programs in urban environments, and support previous theoretical research in the field.

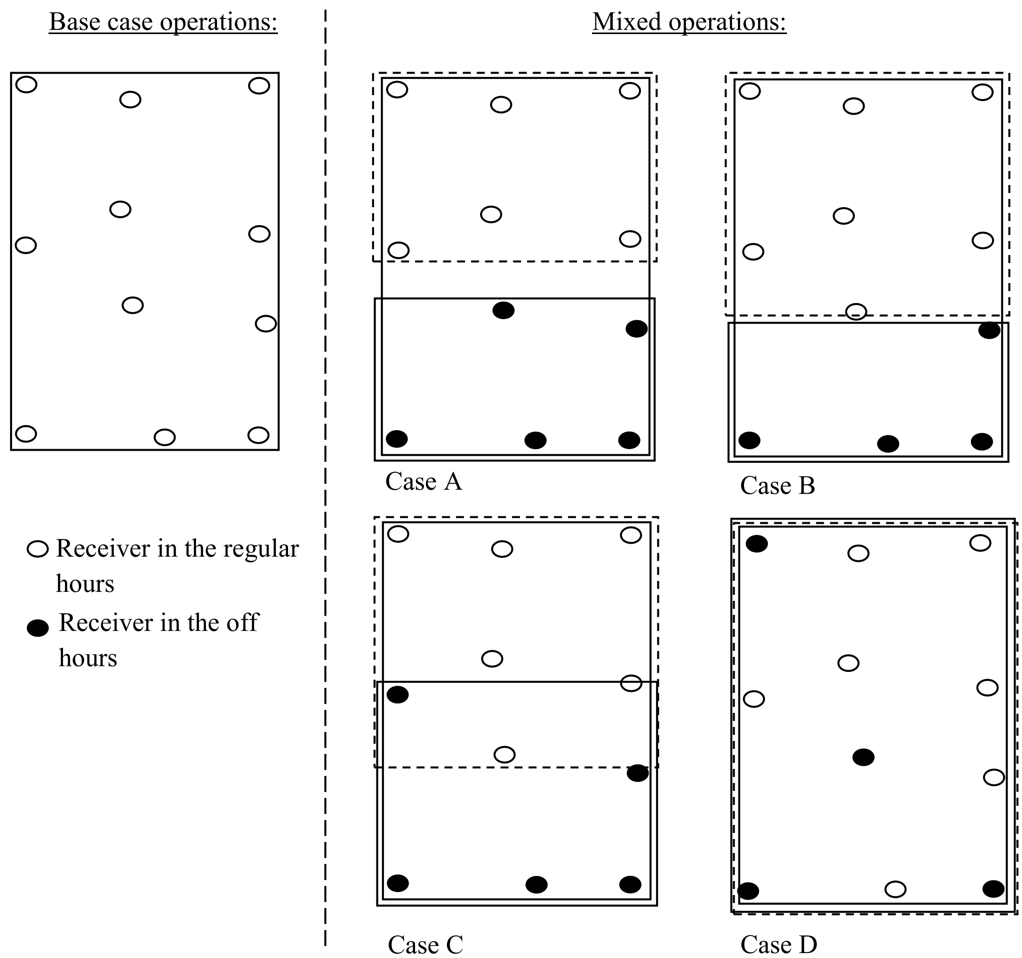
Literature Review

Originally formulated by Pigou (1920) and mathematically formalized by Walters (1961), road pricing appeared to be a good alternative to reduce the congestion generated by freight traffic in large metropolitan areas. However, experiences in both New York City and London clearly showed that toll increases during peak hours failed to reduce the corresponding freight traffic (Holguín-Veras et al., 2006b). Carrier responses to surveys made by Holguín-Veras et al. (2005a) revealed that almost 70% of them simply could not change their operations because their clients would not accept delivery time changes. In fact, only 9% of the carriers were able to pass the toll on to the receiver. In the rest of the cases, the carrier had to absorb the costs imposed by the toll of delivering during peak hours. Holguín-Veras et al. (2006b) proved that this is explained by the fact that the trucking industry is a competitive market where the price is equal to the marginal cost of producing the service. Since the cost imposed by the toll represents a fixed operational cost, carriers simply cannot pass the toll on to their clients. If no price signal reaches the receivers they have no incentive to switch their delivery times. The receiver decision to receive goods during regular daytime hours essentially forces the carrier to travel in congestion. The rationale for the OHD program is to induce receivers to accept OHD by providing them with incentives. This concept was pilot-tested in New York City with great success (Brom et al., 2011). One of the key challenges is determining the amount of incentive required to achieve a certain amount of OHD. This is a challenging endeavor because the actual market share of OHD depends on the joint response of carriers and receivers, as both of them have to agree.

A number of approaches have been developed to estimate the joint response of carriers and receivers to OHD initiatives. The first entailed the use of discrete choice models to estimate the percent of receivers that would agree to participate in OHD given an incentive, and then use these results to estimate the percent of carriers that would agree to OHD given the receivers' response (Holguín-Veras et al., 2008b). The second approach, the predecessor of the method used in this chapter, consisted of the development of a BMS by Silas and Holguín-Veras (2009). The third approach is based on a numerical approximation that provides lower bounds of the expected market share of OHD. Since the publications of these approaches, significant developments have taken place. A successful pilot test of OHD, which validated the overall concept, took place; and more importantly to the purposes herein, the pilot test revealed that a significant portion of the receivers could be induced to switch to the off-hours by means of a one-time incentive (OTI) (as opposed to an ongoing incentive). The latter finding is extremely important for the public sector since providing an OTI is significantly easier than an ongoing incentive. However, important questions remain concerning the amount of the shift to the off-hours that an OTI could produce, the ideal amount of the OTI, and the industry segments and geographies that should be the focus of the program. Answering these questions required a significant redesign of the BMS, that expanded its capabilities beyond what was feasible to consider before (Silas and Holguín-Veras, 2009). The question of whether or not the incentives to receivers should be provided on the basis of a geographic focus is very important because previous research (Holguín-Veras, 2011) has suggested that doing so could enhance the market share of OHD.

Another important consideration is the geographic location and distribution of the receivers, and how such characteristics can be used to foster OHD. Using mathematical models, Holguín-Veras (2011) described the decision process of the carrier in terms of the area where receivers are located. Naturally, the area is the largest for the base-case operation, where all receivers are in the regular hours (Figure 25). For a mixed operation, where a fraction of receivers decide to accept OHD, the situation is different. Figure 25 shows the base case and the mixed operation. It can be seen that cases A and B present a clear geographic segmentation for receivers in regular and off-hours. A different situation appears for cases C and D, where little or no segmentation is produced. In essence, Holguín-Veras (2011) supports the idea of geographic- oriented incentives because the segmentation produced could significantly benefit the carrier, and therefore, foster OHD.

Figure 25: Area for Receivers and the Scenarios for Regular and Off-hours



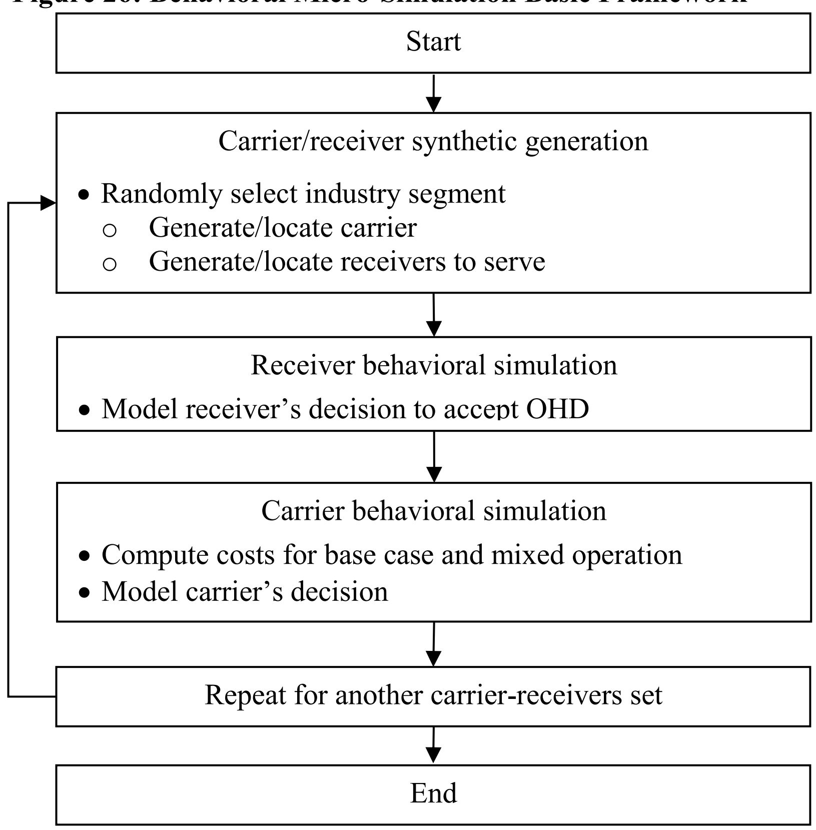
Methodology

The methodology developed determines the effect that incentives will have on carriers and receivers. The root of the complexity is that, in response to an incentive, the receivers in a delivery tour may react differently: some receivers may decide to accept OHD, while others may reject the idea. Once the receivers decide how they would react to an incentive, the carriers have to decide what to do. If only a handful of receivers want OHD, the additional delivery tour that is required is likely to increase carrier costs and cause them to reject OHD. Conversely, if a large number of receivers agree to accept OHD, the carrier is likely to go along with their request, as doing so will lead to cost savings. The main goal of the BMS is to model the decision of the receivers in response to incentives; and then model the decision of the carriers using the receivers' choices as an input. The results of the BMS are the market shares of trucks and deliveries moving to the off-hours. This section provides an overview of the BMS, its main components, and the most relevant implementation considerations.

The basic framework of the BMS is shown in Figure 26 (Silas and Holguín-Veras, 2009). As shown, the BMS has three main components: Carrier/Receiver Synthetic Generation, and the Behavioral Simulation of Receivers and Carriers. The "Carrier/Receiver Synthetic Generation" is the process of generating and geo-locating carriers and receivers, input that will be considered in the simulations.

Essentially, this procedure produces a geo-located assignment of carriers and receivers that matches: the control totals of the number of establishments by industry segment by ZIP code; the freight-trip generation by industry segment and ZIP code; and the tour length distributions (number of stops per tour) by industry segment. The creation of the synthetic populations, subject to such constraints, provides assurances that they represent the realities on the ground. The next two modules focus on modeling the behavior of receivers and carriers. The behavior of receivers is modeled using the ordered logit model described in Part One of this chapter, while the behavior of carriers is explained in detail later in this section. The process is repeated for a large number of replications and policy scenarios to ensure convergence.

Figure 26: Behavioral Micro-Simulation Basic Framework



Carrier Behavior

The carrier decision regarding participation in OHD depends on the impacts produced by the OHD operation. Assessing the impacts on the carrier requires computation of the generalized costs associated with a mixed operation with both regular-hour deliveries (RHD) and OHD. This must include: travel time, travel distance, tolls, and operational costs, as well as parking fees, and parking fines. The chief complexity of modeling the carrier's decision regarding OHD is that, in response to the public sector incentives, the receivers served by the carrier are likely to be split in their decisions. While some may decide to accept OHD, others may not. As exemplified in Figure 27, the net effect of this is to split the population of receivers into two delivery networks (one in the RHD and the other in the OHD). The BMS simulates the routes used by the carrier by performing consecutive 2-opt and 3-opt heuristic procedures.

Once the routes have been obtained, the corresponding costs are computed. If the total costs for the mixed operation are smaller than for the base case, the carrier will agree to OHD. Thus, the carrier and the subset of receivers that want the service will move to the OHD, otherwise the entire operation will remain in the RHD.

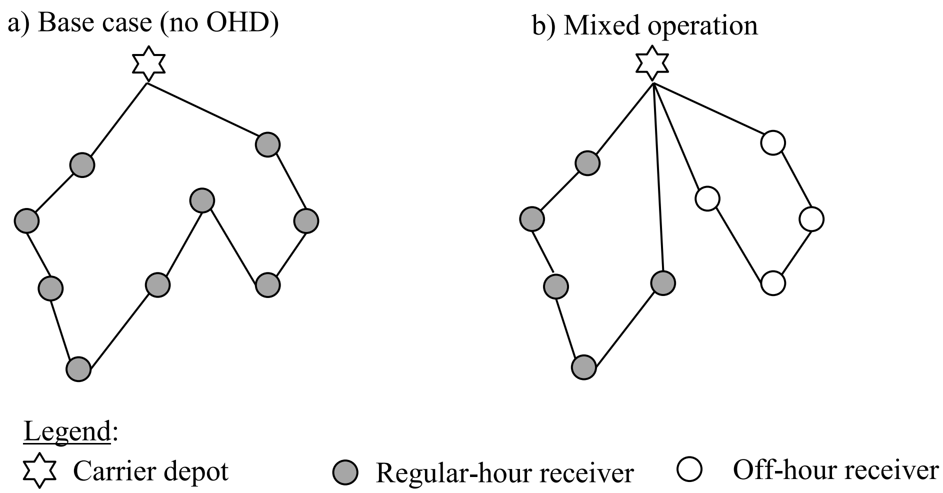


Figure 27: Receivers networks emerging for the evaluation

Implementation Considerations

Each iteration of the BMS includes the generation of a carrier, receivers and their geo-locations, and the evaluation of the impacts on the carrier. This process has to be repeated for a large number of cases to ensure robustness of the results. Figure 4 shows the market shares estimated by the BMS as a function of the number of carriers simulated. As shown, estimating market shares using a few iterations produce rather unreliable results. This is obvious in the case of only 100 replications that, as shown, estimates market share that are not monotonic which does not make sense as there is no valid reason why an increase in OTI could lead to a reduction in market share (as it happens between $4,000 and $5,000). As shown, increasing the number of replications leads to increasingly monotonic results as those for 100,000 replications.

The tradeoff between robustness of results and number of replications is the execution time. While doing 100 iterations takes a few seconds, generating 50,000 carriers takes between 2 and 3 hours depending on the incentives under analysis. Also, the number of applications of 2 and 3-opt heuristic procedure for computing routes impacts the execution times. For the results shown in Figure 28, a 2-opt procedure was applied 10 times and a 3-opt procedure only once. Although the highest impact is increasing the number of applications of 3-opt, more applications of either procedure considerably increases execution times.

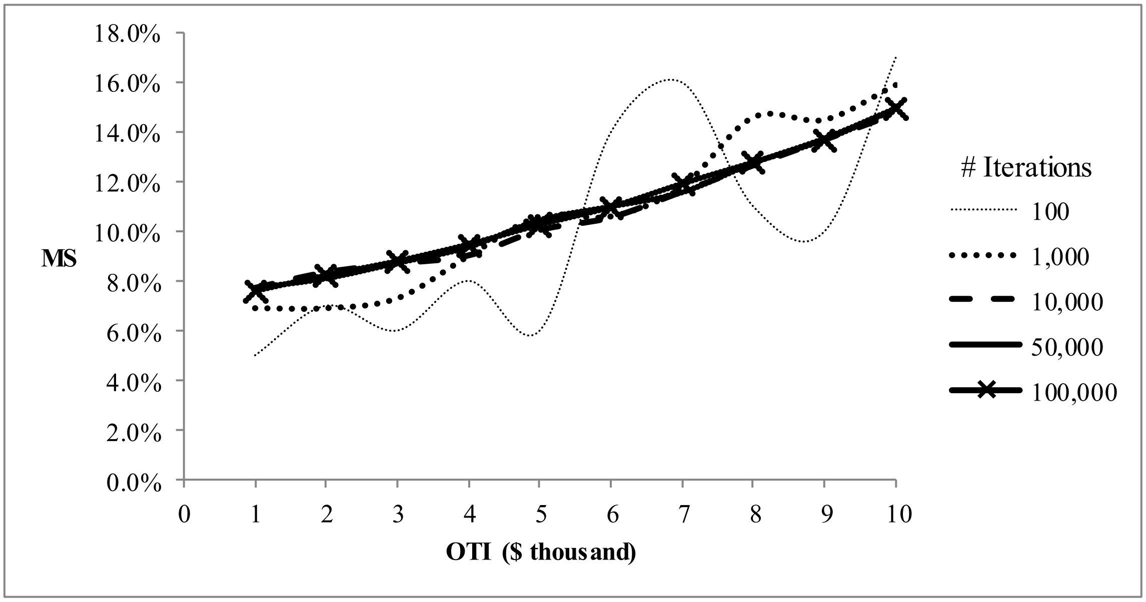


Figure 28: Market Share Results in Function with the Number of Replications

Application to Manhattan

The BMS was used to assess different structures of incentives; this section discusses the results of the application of the BMS to assess different structures of incentives offered to receivers in Manhattan to foster OHD. Manhattan has more than 103,000 establishments that attract, on average, 115,000 freight deliveries per day. Half of these establishments are located in Midtown Manhattan, which is the most congested part of the city.

The island of Manhattan is the economic center of a large metropolitan area with a total population of 20 million; NYC, has eight million residents. Although there are no recent data that could provide solid estimates of the amount of freight that enters NYC, the figures available in the literature are impressive. Using data from a comprehensive freight origin-destination survey, Wood (1970) estimated that for every resident in the NYC metropolitan area, about 625kg of water (all uses), 20kg of fuel (heating, transportation and electricity generation), 3kg of food (including container weight), and 12kg of other raw and semi-manufactured consumer goods are transported every single day. This translates into 35kg/day of freight per person, or 280,000t per day. Because of its primarily consumer orientation, Manhattan is, in practice, the terminus of most supply chains. In contrast, other boroughs like Brooklyn and Queens have large manufacturing centers that serve Manhattan and other parts of the city. Impressive as this amount of cargo is, it is tiny in comparison to the number of deliveries. Table 17 shows the freight-trip generation estimates for NYC.

Table 17: Number of establishments and freight-trip generation by borough

County	Population	Establish-ments	Employ-ment	FTA (trips/day)	FTP (trips/day)	FTG (trips/day)	%
Bronx	1,332,650	15,528	224,179	26,320	26,838	53,157	7.45%
Brooklyn	2,465,326	44,043	521,992	75,865	73,431	149,295	20.92%
Manhattan	1,537,195	102,597	2,062,079	182,427	161,144	343,571	48.14%
Queens	2,229,379	41,551	518,953	71,447	68,883	140,330	19.66%
Staten Island	443,728	8,376	100,975	14,464	12,910	27,374	3.84%
Grand Total	8,008,278	212,095	3,428,177	370,522	343,206	713,728	100.00%

Note: FTA: Freight trip attractions, FTP: Freight trip productions, FTG: Freight trip generation, FTG = FTA+FTP

As shown, Manhattan represents 48% of the total establishments, and 60% of employment for NYC, even though it accounts for less than 20% of the total population. These numbers reflect the concentration of economic activity in Manhattan. It is not surprising that a large proportion of freight-trip attraction (FTA) and production (FTP) are generated in the island. These truck trips create major stress on already congested networks, and represent a huge challenge to transportation agencies.

The congestion and other externalities produced by pick-up and delivery activity are tremendous because the freight vehicles originate in warehouses and distribution centers that could be 20 or more miles away in Northern New Jersey and New York State. Since these regional networks are chronically congested, the freight traffic destined for NYC produces large amounts of externalities. Conversely, a switch to the off-hours is bound to produce significant benefits throughout the region. In fact, the results of the economic analyses conducted clearly indicate that the bulk of the economic benefits of OHD are accrued in the regional networks (Holguín-Veras et al., 2011b).

In terms of geographic level of detail, the BMS was designed to use the transportation analysis zones (TAZs) embedded in the transportation demand model developed by the New York Metropolitan Transportation Council, the metropolitan planning organization in the area. This zoning system considers 317 TAZs in Manhattan, which could be the locations of receivers, as well as 100 possible locations for carriers in Northern New Jersey and New York State. A schematic is shown in Figure 29.

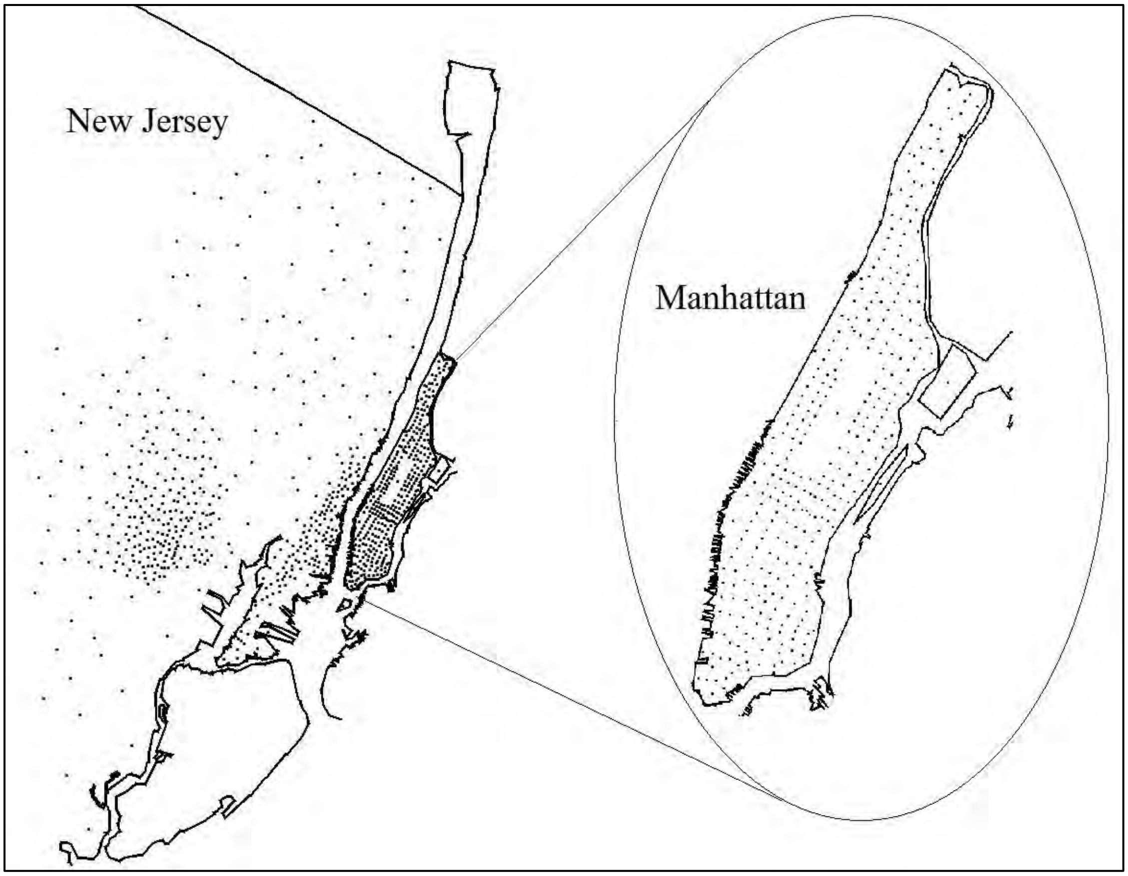


Figure 29: Transportation Analysis Zones

The BMS uses a synthetic population of carriers and receivers, which was generated using the data collected in previous stages of the research (Holguín-Veras, 2006a; Holguín-Veras et al., 2007; 2008b; Holguín Veras et al., 2014). The synthetic populations generated match the geographic distribution of receiving establishments, and the freight-trip generation estimated at the ZIP code level. Such estimates are shown in Figure 30. The control totals for the numbers of receivers at the ZIP code level were obtained from the ZIP Code Business Patterns (U.S. Census Bureau, 2011), while the estimates of freight-trip generation were obtained by the application of the models estimated by (Holguín-Veras et al., 2012a). As shown, the distributions of establishments and the number of deliveries they receive are mainly concentrated in lower and Midtown Manhattan (south of Central Park). As expected, FTG is determined largely by the number of establishments. In Figure 30, the centroids in Midtown Manhattan to the south of Central Park concentrate 42% of establishments, and 45% of deliveries in the city.

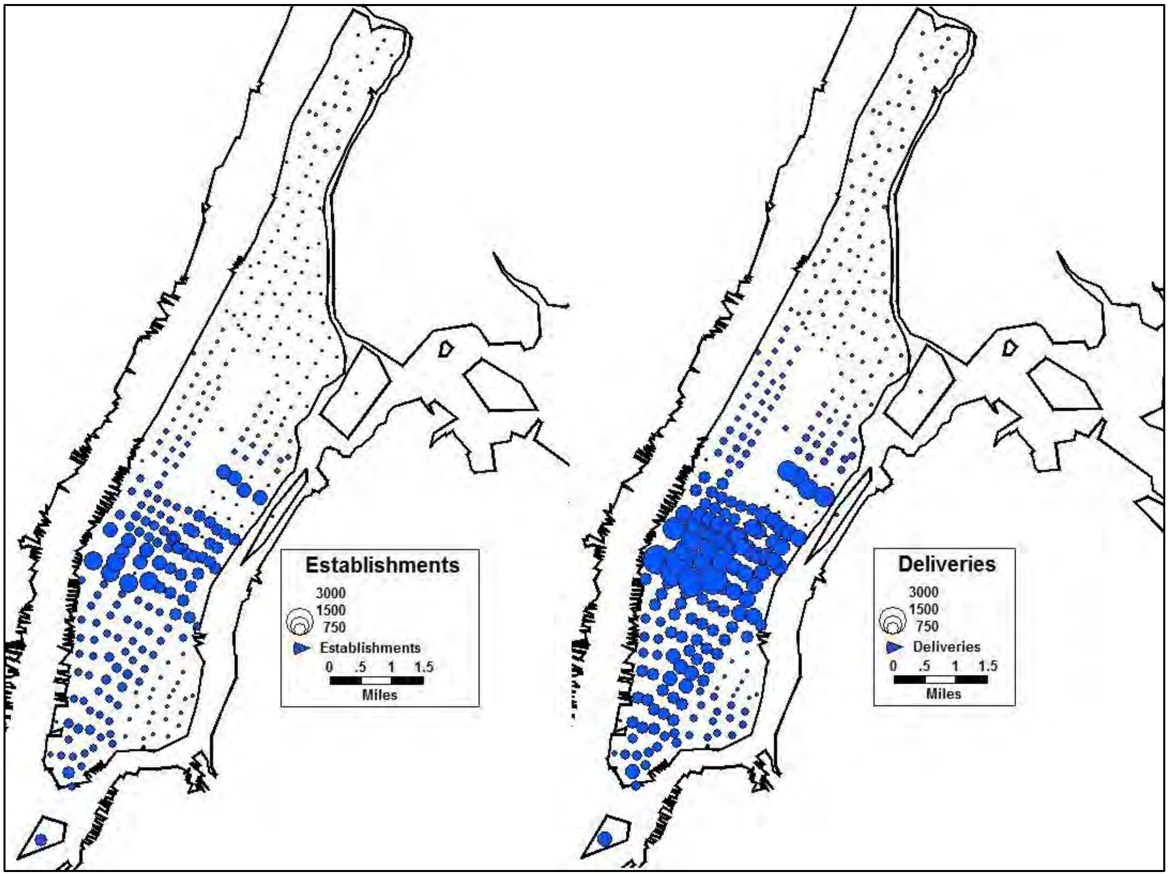


Figure 30: Distribution of Establishments and Deliveries Received in Manhattan

Three main structures of incentives are considered: incentives to all of Manhattan, incentives according to industry segment, and incentives according to geographic location. Each of these structures is analyzed according to three performance measurements: (1) the percentage of trucks switching to OHD, termed joint market share (JMS) since it is the result of a joint decision by carriers and receivers; (2) the percentage of deliveries switching to OHD, termed receivers market share (RMS); and (3) the budget required to provide the incentives to receivers. All three performance measurements allow the assessment and comparison of the different incentive structures. The information regarding travel time, distance, and tolls was obtained from the New York Metropolitan Transportation Council (NYMTC) Best Practice Model (BPM) (12). Receivers in Manhattan are located in any of the 317 centroids established by the NYMTC BPM. As mentioned, the BMS takes into consideration the business pattern and freight-trip attraction of New York City (13).

Impact of Incentives to Manhattan

This subsection discusses the results of an OHD program in Manhattan. Analyses include assessing the effect of: (1) OTI, (2) OTI plus BS, (3) OTI plus PR, and (4) OTI plus BS and PR (see Table 18). JMS and RMS increase monotonically with OTI in all cases, and as expected, the largest JMS and RMS appears for the highest value of OTI in addition to BS and PR. BS and PR play an important role in the OHD programs as they clearly increase the impact of the OTI measure. The budget required for implementing the OHD program ranges from $2.42 to $70 million, producing JMS=15% and RMS=7%. These numbers must be contrasted with the savings realized in terms of decreased congestion.

Table 18: Results of incentives to all receivers in Manhattan

	OTI			OTI+BS			OTI+PR			OTI+BS+PR		
OTI ($K)	JMS (%)	RMS (%)	Budget ($M)	JMS (%)	RMS (%)	Budget ($M)	JMS (%)	RMS (%)	Budget ($M)	JMS (%)	RMS (%)	Budget ($M)
0	5.1	1.3		6.2	1.7		5.8	1.6		7.0	2.1	
1	5.1	1.3	1.27	6.3	1.8	1.81	5.9	1.6	1.62	7.7	2.4	2.42
2	5.5	1.4	2.83	6.6	1.9	3.74	6.1	1.7	3.44	8.1	2.7	5.45
3	5.5	1.5	4.40	6.9	2.0	6.12	6.4	1.8	5.54	8.7	3.0	9.14
4	5.7	1.5	5.87	7.3	2.2	8.67	6.7	2.0	7.82	9.4	3.4	13.58
5	6.0	1.7	8.62	7.3	2.2	11.18	6.8	2.0	9.75	10.5	4.0	19.77
6	6.2	1.8	10.55	7.7	2.5	14.82	7.0	2.1	12.68	11.0	4.4	26.49
7	6.5	1.8	12.94	8.0	2.6	18.34	7.1	2.2	15.19	11.6	4.7	32.93
8	6.9	2.0	15.78	8.3	2.7	21.82	7.7	2.4	19.53	12.8	5.5	44.09
9	6.9	2.0	18.18	8.7	2.9	26.22	7.8	2.5	22.64	13.7	6.2	55.99
10	7.2	2.2	21.86	8.8	3.1	30.82	8.3	2.8	28.17	15.0	7.0	70.08

Impact of Incentives According to Geographic Location

The idea of providing incentives to receivers according to geographic location is motivated by the heterogeneous distribution of establishments in Manhattan, as shown in Figure 31. In fact, 50% of establishments are located in Midtown Manhattan, which is a destination for 52% of the incoming freight trips to the city (without considering service trips). Moreover, a theoretical argument suggests that geographically-focused incentives could boost participation in OHD because they lower the threshold of participation required for carriers to benefit from OHD. It is important to assess whether or not this argument is correct, because it would have profound policy implications.

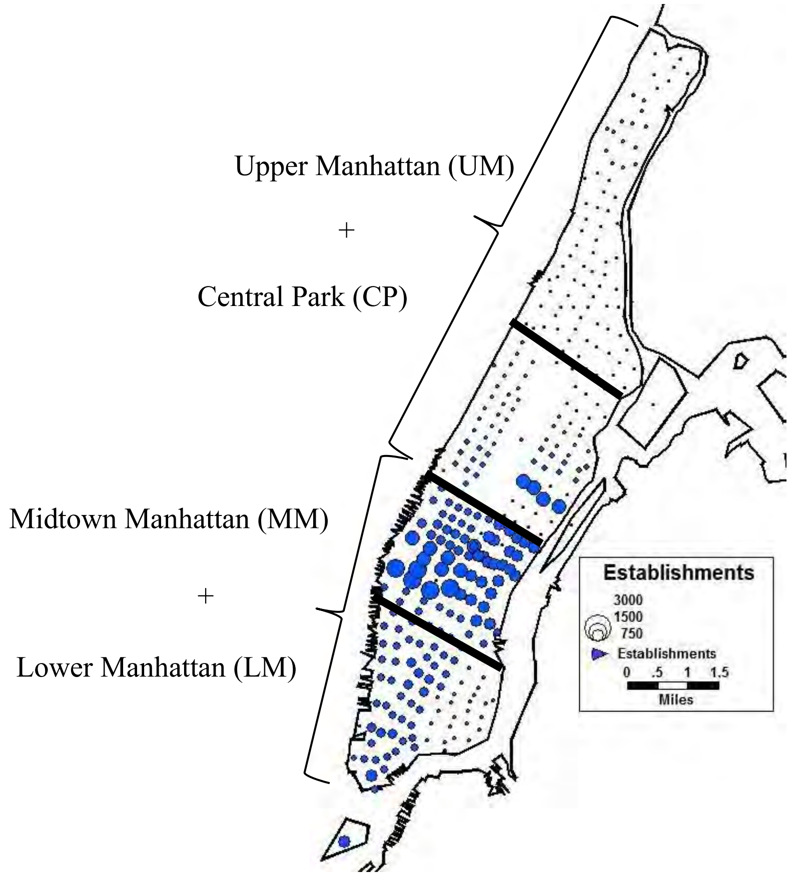


Figure 31: Geographic Distribution of Manhattan and Establishments

Two scenarios have been considered, incentives to (1) Lower and Midtown Manhattan, and (2) Central Park and Upper Manhattan (Table 19). As shown in the table, the results exhibit little difference between JMS and RMS for each level of OTI. However, the major difference is that the budget for Lower and Midtown Manhattan is considerably larger than the one needed for Central Park and Upper Manhattan. The high concentration of businesses in Midtown Manhattan, even for a small percentage of establishments, would lead to large incentive expenditure. However, because Midtown Manhattan is the most congested part of the city, moving deliveries away from the daytime hours would have dramatic positive effects on traffic.

Table 19: Results of Incentives According to Geographic Location

	Lower and Midtown Manhattan			Central Park and Upper Manhattan		
OTI ($K)	JMS (%)	RMS (%)	Budget ($M)	JMS (%)	RMS (%)	Budget ($M)
1	6.5	1.7	1.4	6.7	1.8	0.4
2	7.0	1.9	3.4	7.0	1.9	0.8
3	7.4	2.1	5.5	7.0	1.9	1.2
4	7.8	2.3	8.5	7.5	2.2	2.1
5	8.0	2.4	11.2	8.2	2.4	2.8
6	8.6	2.7	15.2	8.4	2.6	3.7
7	8.9	2.7	19.2	8.6	2.7	4.5
8	9.7	3.2	26.1	9.1	2.9	5.9
9	9.6	3.3	29.7	9.7	3.3	7.3
10	10.3	3.6	36.2	9.9	3.4	8.8

The results in Table 19 indicate that, from the standpoint of the JMS, the geographic focus of the OHD incentives does not matter much. As predicted in Holguín-Veras (2011), as long as the study area is segmented, participation in OHD could increase. However, in terms of congestion reductions—which provide the rationale for the incentives—it does not make sense to offer incentives to the upper part of Manhattan as that area is considerably less congested than from Midtown to Lower Manhattan.

Impact of Incentives According to Industry Segment

Table 20 shows the results of giving incentives to receivers in Manhattan to NAICS 44 and 45, both associated with retail activity. NAICS 44 and 45 account for 30% and 31%, respectively, of the total freight-trip attraction to the city. These percentages are important for interpretation purposes, as seen in Table 20, showing the difference between the CMS in the particular industry segment and the respective impact on the total industry in the city. That is why, for example, a CMS of 6.5% for $1,000 in NAICS 44 represents a 1.9% of the total freight traffic in the city. A similar situation occurs for NAICS 45.

The results show that RMS, JMS, and the budget for each level of incentive are similar in all cases. This is explained by the similarities between these two industry segments. Both account for a third of the freight-trip generation, and have on average, 4 stops per delivery tour. As can be seen, around 2% of CMS can be reached by offering the minimum incentive analyzed and, unfortunately, none of the industry segments is influenced by increases of the OTI. For practical purposes, the authority can take into consideration segregation by industry segment, but the marginal impact of increasing the incentive is not substantial.

Table 20: Results of Incentives According to Industry Segment

	NAICS 44 - Retail (e.g. food and beverage, building materials)			NAICS 45 - Retail (e.g. general merchandise, sporting goods)		
OTI ($M)	CMS (%)	RMS (%)	Budget ($MM)	CMS (%)	RMS (%)	Budget ($MM)
0	6.5	1.6	2.19	6.1	1.5	2.04
1	6.5	1.5	1.82	6.1	1.5	1.80
2	6.5	1.5	1.89	6.5	1.6	1.87
3	6.7	1.7	1.91	6.7	1.7	2.00
4	7.0	1.7	2.02	6.8	1.7	2.08
5	7.4	2.0	2.23	7.6	2.0	2.24
6	7.4	2.0	2.28	7.6	2.0	2.24
7	7.8	2.1	2.29	7.6	2.0	2.25
8	7.8	2.1	2.30	7.9	2.1	2.27
9	8.4	2.3	2.49	8.0	2.3	2.37
10	8.4	2.4	2.48	8.7	2.6	2.60

Self-Supported Freight Demand Management

A self-supported freight-demand management system (SS-FDM) is one that generates the funds required for a continuing improvement towards sustainability. In the terms considered in this chapter, the incentives handed out to the receivers of UOHD would be generated by a toll surcharge to the vehicles that travel in the regular hours. The chapter considers two possibilities: applying the surcharge to only freight vehicles, or to all vehicles traveling in the regular hours. A key feature of the SS-FDM is that the incentives modify the demand for deliveries in the regular hours, thus increasing the flexibility of the industry to accept OHD. This has multiple benefits: if a sufficient number of receivers accept OHD, the carriers switch to the off-hours, which reduces congestion during the regular hours of the day. As a result, all regular-hour travelers benefit from the congestion reductions; the carriers that do OHD benefit from lower costs and increased productivity; while the receivers benefit from the increased reliability and the incentive provided.

The SS-FDM has a number of notable advantages. The toll surcharge—which is primarily intended to raise the funds for incentives—does not have to be large, as its primary role is not related to fostering behavior change. Needless to say, this increases the political acceptability of the concept. Second, since the incentives are used to increase (voluntary) participation in OHD, their main effect is to change the underlying demand for deliveries, making it easier for the private sector to participate. In essence, the regular-hour users pay to incentivize the businesses that can do UOHD. Thus, both groups are better off. Third, in light of the NYC experience where receivers that tried UOHD stayed with the program long after the incentive ended, over time, a gradual shift out of the regular hours would take place as successive rounds of incentives would, permanently or quasi-permanently, reduce the number of deliveries during the regular hours. In this context, the toll revenues collected during the first round of the SS-FDM could be used to incentivize a first set of receivers to operate in the off-hours. If these receivers behave in the same way as those in the NYC pilot, they would remain in the off-hours for a long time. Then, in a second round, the toll revenues would be available to incentivize a second set of receivers, and so on. It is expected that over time, the magnitude of the incentive would increase as those receivers willing to participate at a low incentive level gradually switch to the off-hours. At this point, a toll increase could be considered to expand the OHD program; otherwise, the toll revenues could be used for other purposes, or phased out. This concept builds on Holguín-Veras (2006a) and Silas et al. (2012).

When interpreting the results, it is important to keep in mind that the incentive budget to be distributed among receivers would only be disbursed once. In contrast, the toll revenues produced by the toll surcharge would accrue every year for as long as the surcharge is in place. As a result, the toll revenues of multiple years could be used to fund a staggered implementation of UOHD in the NYC metropolitan area. A staggered implementation would: (1) provide ample time to design the compliance verification mechanisms to prevent fraud; (2) enable the private sector to transition to UOHD in an orderly manner; and (3) allow business managers who may have doubts about UOHD time to observe the experience of those who have tried it. For purposes of this chapter, the authors assume an implementation period of three years, which is in line with the time it has taken for the USDOT-funded implementation project to start switching businesses to the off-hours.

Table 21 and Table 22 show the results obtained for the SS-FDM in which the toll revenues that finance the incentives are raised solely from the freight traffic that crosses the bridges and tunnels in the NYC metropolitan area. The tables show, for various levels of incentives, the market share that UOHD is expected to generate, and the number of delivery tours and receivers that would be involved in UOHD. The five rightmost columns contain the toll revenues for different values of a surcharge per truck axle. As a benchmark, Table 21 shows the results assuming that the efficiency of toll collection is 100%, which implies no toll evasion and toll collection costs. Table 22 considers a more realistic scenario where the efficiency of toll collection (75%) is in-line with the observed performance of toll agencies in the United States.

Table 21: Financial Estimates (Toll collection efficiency = 100%)

One-time-incentive	% OHD	OHD tours (year)	Total incentive budget	Yearly incentive budget	Yearly toll revenues (car surcharge = $0)				
					Freight vehicle surcharge per axle:				
					$1	$2	$5	$8	$10
$0	7.1%	8,467	$0.00	$0.00	$58.08	$116.16	$290.40	$464.63	$580.79
$1,000	7.6%	9,031	$5.65	$1.88	$57.78	$115.56	$288.91	$462.26	$577.82
$2,000	8.2%	9,783	$26.32	$8.77	$57.39	$114.77	$286.93	$459.10	$573.87
$3,000	8.8%	10,463	$59.89	$19.96	$57.03	$114.06	$285.15	$456.23	$570.29
$4,000	9.5%	11,265	$111.95	$37.32	$56.61	$113.21	$283.04	$452.86	$566.07
$5,000	10.3%	12,209	$187.14	$62.38	$56.11	$112.22	$280.55	$448.89	$561.11
$6,000	11.0%	13,058	$275.51	$91.84	$55.66	$111.33	$278.32	$445.31	$556.64
$7,000	11.9%	14,175	$399.58	$133.19	$55.08	$110.15	$275.38	$440.62	$550.77
$8,000	12.8%	15,200	$538.65	$179.55	$54.54	$109.08	$272.69	$436.30	$545.38
$9,000	13.7%	16,279	$703.14	$234.38	$53.97	$107.94	$269.85	$431.76	$539.70
$10,000	14.9%	17,754	$928.70	$309.57	$53.19	$106.39	$265.97	$425.56	$531.95

Note: The shaded cells represent non-feasible combinations of financial incentives to receivers and tolls.

Table 22: Financial Estimates (Toll collection efficiency = 75%)

One-time-incentive	% OHD	OHD tours (year)	Total incentive budget	Yearly incentive budget	Yearly toll revenues (car surcharge = $0)				
					Freight vehicle surcharge per axle:				
					$1	$2	$5	$8	$10
$0	7.1%	8,467	$0.00	$0.00	$58.08	$116.16	$290.40	$464.63	$580.79
$1,000	7.6%	9,031	$5.65	$1.88	$57.78	$115.56	$288.91	$462.26	$577.82
$2,000	8.2%	9,783	$26.32	$8.77	$57.39	$114.77	$286.93	$459.10	$573.87
$3,000	8.8%	10,463	$59.89	$19.96	$57.03	$114.06	$285.15	$456.23	$570.29
$4,000	9.5%	11,265	$111.95	$37.32	$56.61	$113.21	$283.04	$452.86	$566.07
$5,000	10.3%	12,209	$187.14	$62.38	$56.11	$112.22	$280.55	$448.89	$561.11
$6,000	11.0%	13,058	$275.51	$91.84	$55.66	$111.33	$278.32	$445.31	$556.64
$7,000	11.9%	14,175	$399.58	$133.19	$55.08	$110.15	$275.38	$440.62	$550.77
$8,000	12.8%	15,200	$538.65	$179.55	$54.54	$109.08	$272.69	$436.30	$545.38
$9,000	13.7%	16,279	$703.14	$234.38	$53.97	$107.94	$269.85	$431.76	$539.70
$10,000	14.9%	17,754	$928.70	$309.57	$53.19	$106.39	$265.97	$425.56	$531.95

Note: The shaded cells represent non-feasible combinations of financial incentives to receivers and tolls.

The estimates show that incentive amounts less than $3,000 would not attract a sufficient number of receivers, and the base-case participation in OHD remains stable at 3.9%. However, as the incentive increases, the level of participation picks up, and with it, the total incentive budget to be handed out to the receivers. The tables also show that the incentives lead to a reduction of the commercial traffic in the regular hours, and toll revenues. The table makes clear that, if funded solely on the basis of a toll surcharge to freight vehicles, the SS-FDM would necessitate politically unacceptable toll surcharges (larger than $5/axle) to achieve a level of participation larger than 10%. Small toll surcharges in the range of $1/axle and $2/axle would lead to small, though meaningful, increases in UOHD participation that would reach 6.3% and 7.1% respectively. (Using the leftover funds to increase the incentive would increase participation above these numbers.)

Table 23 and Table 24 consider the scenario in which a small toll surcharge of $1 per vehicle is applied to passenger car vehicles. There are multiple reasons to apply a surcharge to passenger cars. First, they stand to benefit from the reductions in travel time produced by reduced delivery traffic. According to the estimates produced, regular-hour travelers would experience a reduction in travel times of about five minutes per trip (Holguín-Veras et al., 2011b). Second, the surcharge may act as a deterrent—albeit a small one—to the induced demands that would be generated by the travel time reductions. The data from the Port Authority of New York and New Jersey (Ozbay et al., 2006) indicate that about 85 million passenger cars use their facilities any given year, and that about 245 million/year use the Metropolitan Transportation Authority bridges and tunnels. In both cases, truck traffic is in the vicinity of 9% of the total.

Table 23: Financial Estimates (Toll collection efficiency = 100%)

One-time-incentive	% OHD	OHD tours (year)	Total incentive budget	Yearly incentive budget	Yearly toll revenues (car surcharge = $1) Freight vehicle surcharge per axle:				
					$1	$2	$5	$8	$10
$0	7.1%	8,467	$0.00	$0.00	$382.94	$460.38	$692.69	$925.01	$1,079.89
$1,000	7.6%	9,031	$5.65	$1.88	$382.54	$459.59	$690.71	$921.84	$1,075.93
$2,000	8.2%	9,783	$26.32	$8.77	$382.02	$458.53	$688.08	$917.63	$1,070.66
$3,000	8.8%	10,463	$59.89	$19.96	$381.54	$457.58	$685.69	$913.81	$1,065.89
$4,000	9.5%	11,265	$111.95	$37.32	$380.98	$456.45	$682.88	$909.31	$1,060.26
$5,000	10.3%	12,209	$187.14	$62.38	$380.31	$455.13	$679.57	$904.01	$1,053.64
$6,000	11.0%	13,058	$275.51	$91.84	$379.72	$453.94	$676.59	$899.25	$1,047.69
$7,000	11.9%	14,175	$399.58	$133.19	$378.94	$452.37	$672.68	$892.99	$1,039.86
$8,000	12.8%	15,200	$538.65	$179.55	$378.22	$450.93	$669.09	$887.24	$1,032.67
$9,000	13.7%	16,279	$703.14	$234.38	$377.46	$449.42	$665.30	$881.18	$1,025.10
$10,000	14.9%	17,754	$928.70	$309.57	$376.43	$447.35	$660.13	$872.91	$1,014.76

Note: The shaded cells represent non-feasible combinations of financial incentives to receivers and tolls.

Table 24: Financial Estimates (Toll collection efficiency = 75%)

One-time-incentive	% OHD	OHD tours (year)	Total incentive budget	Yearly incentive budget	Yearly toll revenues (car surcharge = $1) Freight vehicle surcharge per axle:				
					$1	$2	$5	$8	$10
$0	7.1%	8,467	$0.00	$0.00	$363.58	$421.66	$595.90	$770.13	$886.29
$1,000	7.6%	9,031	$5.65	$1.88	$363.28	$421.06	$594.41	$767.76	$883.32
$2,000	8.2%	9,783	$26.32	$8.77	$362.89	$420.27	$592.43	$764.60	$879.37
$3,000	8.8%	10,463	$59.89	$19.96	$362.53	$419.56	$590.65	$761.73	$875.79
$4,000	9.5%	11,265	$111.95	$37.32	$362.11	$418.71	$588.54	$758.36	$871.57
$5,000	10.3%	12,209	$187.14	$62.38	$361.61	$417.72	$586.05	$754.39	$866.61
$6,000	11.0%	13,058	$275.51	$91.84	$361.16	$416.83	$583.82	$750.81	$862.14
$7,000	11.9%	14,175	$399.58	$133.19	$360.58	$415.65	$580.88	$746.12	$856.27
$8,000	12.8%	15,200	$538.65	$179.55	$360.04	$414.58	$578.19	$741.80	$850.88
$9,000	13.7%	16,279	$703.14	$234.38	$359.47	$413.44	$575.35	$737.26	$845.20
$10,000	14.9%	17,754	$928.70	$309.57	$358.69	$411.89	$571.47	$731.06	$837.45

Note: The shaded cells represent non-feasible combinations of financial incentives to receivers and tolls.

The addition of the toll surcharge to passenger cars could have significant effects on fostering UOHD, as the results in Table 24 clearly show. Table 23 and Table 24 show that it is possible to induce a shift of in excess of 13% of the total delivery traffic to the off-hours, a change that would have a significant impact on congestion and pollution. The tables also reveal the increasing cost of inducing that desired switch to the off-hours. While $197.11 million are needed to increase the participation in UOHD from 3.9% to 6.7%, at a unit cost of $70.40 million per 1% increase; an additional $772.69 million would be needed to increase the market share of OHD from 6.7% to 13.0%, at a cost of $122.65 million per 1% increase.

Summary of Findings

In the first component of the chapter, the picture that emerges from the analysis of the effectiveness of a set of policies aimed at fostering the Unassisted Off-Hour Deliveries (UOHD) Program is that, although there is no single policy that in itself could accomplish a large shift to UOHD, there are a number of tools available to transportation agencies and cities seeking to foster UOHD. These tools are most effectively used as part of a multi-layered, multi-stakeholder collaborative approach that would include: (1) the public sector provision of a one-time incentive, a public recognition program, and business support services for participants; (2) shipping discounts provided by the carriers to receivers of UOHD; and (3) trusted vendor certification programs, to be managed by trucking or local business groups, to ensure that participating carriers know how to do UOHD safely and with minimal disturbance to local communities. These findings were incorporated into the Behavioral Micro-Simulation (BMS) and described in that section of this chapter.

The second component of this chapter focuses on the design and application of the BMS to the Manhattan case study. This provides significant insight into the potential benefits, and limitations of incentives: to all Manhattan, to the most congested part of the city, or to specific industry sectors. Finally, the analysis of a self-supported freight demand management (SS-FDM) system shows the viability of imposing a small toll to either trucks or trucks and cars.

With respect to geographically-oriented incentives, the results presented confirmed the conjectures made in Holguín-Veras (4). The chief advantage of such an incentive structure is its superior effectiveness. The authors analyzed the ratio of the incentive budget and the JMS. This ratio provides an idea about the amount of resources required to achieve a 1% JMS. The ratio increases with the incentive amount, reflecting that it becomes increasingly difficult to recruit new participants to OHD. The results also show that geographically-focused incentives would require between 71% and 75% less expenditures than incentives spread over Manhattan. The possibility of providing incentives according to industry segment appears less attractive than geographically-oriented incentives. In fact, the gains by targeting retail—which accounts for 60% of freight-trip generation in the city—do not appear to be as effective as those targeted to the most congested parts of the city.

The analyses show that in order to have a noticeable impact on participation in unassisted off-hour deliveries (UOHD), the one-time incentive should be larger than $4,000 per establishment. Incentive values below that amount would not attract a significant number of receivers. The analyses also revealed that a SS-FDM solely supported by a toll surcharge on freight vehicles would foster UOHD on a limited, though still meaningful basis. The authors estimate that a toll surcharge of $1/axle could increase participation in UOHD to 6.3% (from a base-case share of 3.9%); while a $2/axle surcharge would increase participation to 7.1% during the implementation period of three years. (If the leftover budget is used to increase the incentives, these market shares would increase accordingly.) Obviously, extending the surcharge and the UOHD incentive program beyond these three years would also increase participation. In contrast, applying a small surcharge of $1 to all passenger cars that travel in the regular hours would significantly increase toll revenues and the incentive budget. The effects of this extension are notable; such a surcharge could produce a deep transformation in urban delivery patterns. The estimates are that a $1 toll surcharge to the passenger cars that use the bridges and tunnels in the NYC area, combined with a toll surcharge in the range of $1-2/axle to freight vehicles, could switch in excess of 13% of the truck traffic to the off-hours. This in turn could be expected to bring about significant economic savings in terms of congestion and pollution reductions.

These findings make clear: (1) the benefits of targeting receivers in the most congested parts of the city, and (2) that a combination of small toll increases, combined with targeted incentives, could have a dramatic effect on economic welfare as they would lead to reductions in travel times. Moreover, the reliance on a small toll surcharge significantly increases the political acceptability of the proposal. In the opinion of the authors, this is the way to go.

CHAPTER 5: URBAN FREIGHT PERFORMANCE EVALUATION USING GLOBAL POSITIONING SYSTEMS (GPS) DATA

Urban freight transportation is crucial to the quality of life in urban areas, though at the same time produces significant negative externalities. Despite the relatively small proportion of freight to the entire traffic system, it is now understood that urban freight movements significantly impact the efficiency and robustness of the urban transportation system. The volume and vehicle miles travelled (VMT) of commercial vehicles are growing faster compared with passenger vehicles in most metropolitan areas. Holguin-Veras et al. (2008) also pointed out that the value of travel time for commercial trucks can reach \$50-70/h, which is 2-6 times greater than that for passenger cars(Holguín-Veras and Brom, 2008). According to the US Environmental Protection Agency (EPA), the emission rates (e.g., carbon dioxide produced per mile driven) of light-duty trucks are much higher than passenger cars. Such effects become more salient as truck size increases. It is therefore imperative to measure the performances, including mobility, fuel consumption, and emissions, of urban freight activities.

Characterizing urban freight activity is challenging due to its complex and multifaceted nature. In general, freight modeling methods can be categorized into two groups: commodity-based modeling and vehicle-trip based modeling (Holguín-Veras and Thorson, 2003; Raothanachonkun et al., 2007). The former targets the value of the goods and the amount of goods transported, which are direct reflections of the economic characteristics. The latter depicts the activities of commodity vehicles (e.g., the number of trips and deliveries made), which can be easily obtained via field counts and traffic monitoring data (e.g., GPS). This research focuses on vehicle-trip-based modeling methods by using GPS data for urban freight performance measurement.

Unlike such traditional tools as loop detectors and traffic cameras, which can only gather data (e.g., flow and occupancy) from a limited number of network locations, GPS units are more portable and less expensive, and can be deployed to capture detailed trajectories of vehicles for wide areas. GPS trajectories are direct reflections of traffic states, which can be further processed and exploited to acquire more information (e.g., location, speed, acceleration/ deceleration, stops, duration of stops, etc.). Such information is very useful for measuring urban freight performances.

However, the use of GPS for urban freight performance measurement also poses some challenges. One challenge is that the fraction of vehicles sampled (penetration rate) is usually quite small. Whereas a loop detector or traffic camera can collect data from every vehicle that passes a location, currently only a handful of vehicles in the traffic network may be equipped to record data via GPS. To address this issue, Sun and Ban (2013) proposed a trajectory reconstruction method to infer the un-sampled vehicle trajectories at signalized arterials using sampled trajectories/travel times (Sun and Ban, 2013). In this project, since the GPS data is too sparse and the related traffic flow information (e.g., traffic flow rate and density) unknown, it is difficult to apply the trajectory reconstruction method for the entire traffic flow, and the system-wide freight performance measures cannot be acquired. As a compromise, we only focus on individual commercial vehicles equipped with GPS devices. Another challenge is the signal interference/loss in urban environments (e.g., tall buildings, tunnels, highway overpass, etc.), which can degrade the quality of the data. We apply data-cleaning processes and use robust tour/stop identification methods to relieve this problem.

While most existing studies are primarily concerned with the mobility performance of commercial vehicles, little effort has been made to quantify the externalities (e.g., emissions) generated by these vehicles. In this research, the focus is on using GPS data for performance evaluation of urban freight activities, including mobility, fuel consumption, and emissions. The mobility measures are primarily concerned with the efficiency of urban freight movements, e.g., travel time of a delivery tour, number of delivery stops, and service times at delivery stops. Fuel consumption and emissions are used to quantify the expenses and the environmental externalities of urban freight activities. The measures can help design and evaluate freight policies, and enable more informative decision-making. For example, one of the recent innovative freight policies is to provide incentives to businesses that agree to accept deliveries during the off-hours (Holguín-Veras, 2008; Silas and Holguín-Veras, 2009). This off-hour delivery (OHD) policy can be evaluated from two aspects: the participation rate of businesses within an urban area; or the improvement in freight performances under such a policy. The GPS-based performance measurement methods proposed here can help evaluate the OHD policy and other freight policies from the second perspective, i.e., in terms of the mobility, fuel consumption, and emissions of urban freight activities.

This chapter is comprised of 6 sections. The next section provides a description of the data sources used in this project, collected from industry partners who are currently participating in the OHD program in New York City. Followed by an introduction to the definitions of urban freight delivery performance measurements and proposes the general research methodology and procedure. The next section presents the methods to calibrate the performance measures. Urban freight performance measurement results and analyses are provided in the "Results and Analyses" section. Then the chapter is concluded by a summary of the major research findings.

Data Description

This section provides a description of the data used in this project. The data were collected from vehicle-equipped GPS devices provided by a few logistics companies (i.e., industry partners) that are currently participating in the OHD program in New York City. Some of these companies also provided other datasets, including the locations of their truck centers, warehouses, and stores, as well as the delivery logs recorded by the truck drivers. These company-specific datasets were mainly used for algorithm development and cross-validation purposes, which also helped filter out some spurious delivery stops.

Data Collection Effort and Procedures

During the course of the project, the team worked closely with various shippers and receivers to gain access to data related to their fleets. Each company records data in different ways and maintains varying degrees of data about their deliveries and shipments. Once discussions with the companies about shifting their deliveries to the off-hours (defined as 10 pm to 6 am) were underway, the team questioned the companies to learn what kinds of data each collects about its fleet. Some companies collect and maintain virtually no records, while others collect very detailed logs and records. The team worked with the companies to sign non-disclosure agreements (NDAs) to protect their data and privacy.

Once the NDAs were signed and in place, the team gained access to the companies' current delivery records. Some companies even supplied historical records. The records varied from handwritten notes to detailed computer-generated logs.

One of the key pieces of data the team was interested in gaining access to, was GPS data. Some companies have GPS systems, while others do not. The companies that have GPS systems each have various levels of reporting and granularity. Some GPS systems are set to collect data at predefined time intervals (2 or 5 minute intervals are common) or when a specific event (e.g., travel start, travel stop, ignition on/off) happens; other systems only collect data when the vehicle passes predefined landmarks such as their warehouse, customer locations, or landmarks (such as bridges and tunnels). Data at this granularity was difficult to use for travel time analysis purposes because the vehicle route was not known.

Three main alternatives were offered to companies for the purpose of gaining access to their GPS data: (i) providing the company with portable GPS loggers, which plug into the auxiliary 12v plug typically found in a vehicle and collect position data every second; (ii) direct access to the company's GPS system (typically online); or (iii) periodically (and manually) downloading GPS data and running reports for delivery logs. For some fleets, the team was not able to collect GPS data. This was typically due to a company's GPS service provider being unwilling to provide fine-grained GPS data to the company or the team.

The portable GPS loggers were typically mailed to the fleet manager several weeks before they would switch deliveries to the off-hours so that before and after impacts could be measured. This had to be done carefully because the fleets typically did not simply shift an entire route from day to night; instead, they modified routes based on which customers switched to OHD. These data loggers are capable of storing several months' worth of GPS data. The team typically tried to download the data at monthly intervals to ensure that the loggers were working properly, and the data was not being lost. Although these devices add a layer of complexity because the fleet manager assigns them to a vehicle, and drivers must plug them in, there are many benefits to using these devices. The benefits include: breakage or loss are not serious problems, since the devices are low cost; they are durable; they collect GPS data every second; and once plugged in, they automatically turn on. Another benefit is that the data is uniform; therefore, data analysis is much more straightforward than when using a GPS system already integrated into a vehicle. There were some fleet managers, however, who opposed the use of these GPS devices because of the extra steps involved in tracking the units on a daily basis, or because they thought the drivers might behave differently if they knew they were being monitored.

GPS Data

The GPS datasets used in the analyses include three types of formats with different temporal resolutions. The *event-based* GPS data record the time and location information (latitude and longitude) of a GPS unit every few minutes (at 5-minute intervals, in this project) or when a specific event (e.g., travel start, travel stop, ignition on/off) happens. The s*top-based* GPS data provide information at each vehicle stop, including the arrival and departure time, number of cargos delivered, duration of a stop, location information, and so on. The data can be considered as a combination of GPS data and delivery logs. Therefore, no company-specific data are available for stop-based GPS data. The *second-by-second* GPS data provide fine-grained information (e.g., time, location, speed, heading, etc.) regarding the delivery vehicles equipped with GPS units every few seconds (every 1 second, in this project). Detailed utilization descriptions of the three types of GPS data are as follows. The event-based and stop-based GPS data are for logistics companies that have been doing OHD for the last a few years (as part of the OHD Phase I project); the second-by-second GPS data are for logistics companies that just switched to OHD in the midst of the data collection (therefore, data for both before and after the switch were collected).

Event-based GPS data

The event-based GPS data were provided by a logistics company that serves the New York metropolitan area. An example of event-based GPS data is illustrated in Table 25. "Event-based" means that the time and location information of the vehicle-equipped GPS devices are recorded whenever a particular event happens (or every 5 minutes, if no event happens). For example, the "geofence out" or "geofence in" events represent the points outside or inside some pre-defined geographical boundaries; the "ignition on" or "ignition off" events indicate that the vehicle engine is turned on or turned off; and the "travel start" or "travel stop" events correspond to when the vehicle begins to move or comes to a stop. The event-based GPS data were provided for the period of January 1, 2012 to December 31, 2012. Since the log data from the company were only provided for the period of January 1, 2012 to June 30, 2012 (see Section 2.3 below), to be consistent, event-based GPS data for this period (January 1, 2012 – June 30, 2012) was used for the performance analysis in this project. Note that the vehicle labels, and the latitudes and longitudes from the data are purposely removed from Table 25 to protect the privacy of the truck drivers and the logistics company.

The "ignition on" and "ignition off" events can be used to directly identify vehicle stops. When combined with the company-based data (e.g., the locations of truck centers/warehouses/stores), the delivery stop information can be further inferred, which are later used for mobility evaluation. However, due to the poor temporal resolution, the fuel consumption/emission measures cannot be accurately estimated from this type of GPS data.

Table 25: Event-based GPS data

Date / Time	Address	Event
4/10/2012 5:35	56th St, New York, NY, 11378	Geofence Out
4/10/2012 5:35	56th St, New York, NY, 11378	Geofence In
4/10/2012 5:37	56th St, New York, NY, 11378	Travel Stop
4/10/2012 5:42	56th St, New York, NY, 11378	Ignition Off
4/10/2012 7:11	56th St, New York, NY, 11378	Ignition On
4/10/2012 7:12	56th Rd, New York, NY, 11378	Travel Start
4/10/2012 7:13	56th Rd, New York, NY, 11378	Travel Stop
4/10/2012 7:13	56th Rd, New York, NY, 11378	Ignition Off
4/10/2012 9:27	56th Rd, New York, NY, 11378	Ignition On
4/10/2012 9:34	50th St, New York, NY, 11378	Travel Start

Stop-based GPS data

The stop-based GPS data were collected from another logistics company in the form of route files, which provide information related to each vehicle stop, including vehicle ID, driver ID, route ID, stop location ID, arrival date and time, departure date and time, duration of a stop, delivery quantity/weight, latitude and longitude, etc. The dataset used in our project was collected during the half-year time period from Jan 1, 2013 to June 30, 2013. Samples of the stop-based data are provided in Table 26. The latitude and longitude information are removed from the table to protect privacy. Note that the locations ID provide information on the type of stop location, which can be used to infer the purpose of a vehicle stop. In particular, number "1" refers to the warehouse, small one-digit integers such as "3" and "4" represent truck centers, and multi-digit integers stand for delivery stores. The other columns in the table are mostly self-explanatory. Based on this type of GPS data, complete tours and delivery stops can be easily identified for mobility evaluation. Similar to the event-based data, the stop-based data cannot be applied for fuel consumption/emission estimations due to the poor temporal resolution.

Table 26: Samples of the Stop-based GPS Data

Vehicle ID	Driver ID	Route ID	Location ID	Odo-meter	Arrival Date	Arrival Time	Departure Date	Departure Time	Time from last stop	Miles from last stop	Stop time minutes	Delivery quantity
1009	84249	6WATW	3	348686			41275	0.7243056			0	0
1009	84249	6WATW	1	348763	41275	0.78472			0.06042	76.9	3	0
1009	84249	60SWB	1	348764			41275	0.9854167			0	0
1009	84249	60SWB	4	348898	41276	0.08681			0.10139	133.9	4	0
1039	2094	53001	1	127864			41275	0.9951389			0	0
1039	2094	53001		127869	41276	0.00486	41276	0.0083333	0.00972	4.3	5	0
1039	2094	53001	670638	127876	41276	0.025	41276	0.4069444	0.01667	6	550	75
1039	2094	53001	720656	127877	41276	0.42083	41276	0.4597222	0.01389	0.9	56	62
1039	2094	53001	819359	127877	41276	0.46042	41276	0.4625	0.00069	0.1	3	28
1039	2094	53001	561704	127877	41276	0.4625	41276	0.5458333	0	0	120	73
1039	2094	53001	757682	127878	41276	0.55	41276	0.56875	0.00417	0.8	27	47
1039	2094	53001	549352	127878	41276	0.57153	41276	0.5722222	0.00278	0.5	1	26
1039	2094	53001	614537	127882	41276	0.57986	41276	0.5805556	0.00764	3.7	1	25
1039	2094	53001	BREAK	127885	41276	0.59722	41276	0.5972222	0.01667	3.6	0	0
1039	2094	53001	1	127886	41276	0.59861			0.00139	0	17	0
1039	22075	11003	1	172153			41276	0.0152778			0	0
1039	22075	11003		172153	41276	0.01528			0	0	10	0

Second-by-second GPS data

The second-by-second GPS data were collected from a logistic company making freight deliveries from truck centers/warehouses to grocery stores in New York City. Most stores are within the borough of Manhattan (including Roosevelt Island), except one store in Brooklyn and one in Scarsdale. Examples of the second-by-second GPS data are provided in Table 27. Each data point includes information on date, time, latitude, longitude, height, speed, and heading. Again, the vehicle latitude and longitude information is removed to protect privacy. Such fine-grained GPS data can be used to identify vehicle stops. However, these identified stops may include not only deliveries, but also stops due to other purposes (traffic stops and traffic incidents, among others). Therefore, robust methods need to be developed to correctly identify delivery stops. In addition, due to the refined temporal resolution of the second-by-second GPS data, they can be used to calculate not only mobility measures, but also fuel consumption and emission measures of urban freight delivery activities.

Table 27: Second-by-Second GPS Dataset

Index	Tag	Date	Time	Height	Speed (km/h	Heading
54	T	130227	205402	136	6	0
55	T	130227	205403	136	7	0
56	T	130227	205404	136	10	147
57	T	130227	205405	135	10	149
58	T	130227	205406	134	10	149
59	T	130227	205407	134	12	154

Company-based Data (optional)

Besides the GPS data, some company-based datasets were provided by some of the logistics companies, mainly for validation purposes. These company-based datasets were available only for event-based GPS data and second-by-second GPS data, and not for stop-based GPS data.

Driver's Delivery Logs

The delivery logs were recorded by the freight vehicle drivers, which can be considered as the "ground truth" of delivery activities. Such information is available for the event-based GPS data (see Table 28), and the second-by-second GPS data (see Table 29). Since the stop-based GPS data already included delivery information (if any), there is no need to have dedicated delivery logs for this type of data.

Table 28: Driver's Delivery Log (Event-based GPS Data)

No. of Carts	No. of Dollies	Store scheduled delivery time	Store arrival time	Store unload start time	Store departure time	Travel time to store	Travel time to distribution center	Total unload time	Total turn time of truck
5	8	8:00	7:55	8:24	8:59	0:30	1:31	0:35	3:05
		7:30					0:00	0:00	0:00
4	8	8:00	8:25	8:30	9:15	2:35	4:16	0:45	7:41
3	6	7:30	8:00	8:05	8:40	1:55	2:30	0:35	5:05
5	8	8:00	9:15	9:20	9:35	0:10	3:29	0:15	5:39

Table 29: Driver's Delivery Log (Second-by-Second GPS Data)

Date	PC	Commit time	Time in	Time out	Pieces	Weight	Time at store	OK/Early /Late
2/27/2013	PC	5p-11p	6:15 PM	7:00 PM	250	5017	0:45	ok
	0	5p-11p	7:30 PM	8:00 PM	307	5349	0:30	ok
	0	5p-11p	8:30 PM	9:00 PM	463	8513	0:30	ok
	0	5p-11p	9:30 PM	10:00 PM	278	5202	0:30	ok

The delivery logs provide information on the date, starting and ending times of each tour, the arrival time, departure time and service time/waiting time at each delivery stop, as well as other information. Some information in the tables is purposely removed to protect privacy. Note that the time recorded in the delivery logs that correspond to the second-by-second GPS data (Table 29) is based on a 5-minute resolution. Therefore, certain errors should be expected with respect to the travel times and service times derived from this type of data. Moreover, the delivery logs were manually recorded by the drivers, which may lead to errors during the data collection process. These issues may lead to some discrepancies between the performance measures calculated via the GPS data and the delivery log data. Such discrepancies will be discussed in more detail in later chapters.

Store, Truck Center and Warehouse Locations

In addition to the log data, the location information for some of the grocery stores/truck centers/warehouses was also provided by the logistic companies participating in the OHD program. This provides additional information of the freight delivery activities. For example, if a truck stops at a place in the neighborhood of one (or multiple) stores, this is more likely to be a delivery stop. Similarly, if a truck stop is found at a warehouse or truck center with no store nearby, the most probable explanation is that this is the starting/ending point (if at a warehouse) or intermediate point for repair (if at a truck center) of a delivery tour.

An example of a store list, which includes the store number, location, and business hours, can be found in Table 30. The warehouses and truck centers share similar data formats and details are omitted here. The locations of the grocery stores/truck centers/warehouses can be used as reference points for validating the delivery stop identification algorithm, which will be presented in the "Results and Analyses" section of this chapter.

Table 30: A List of Grocery Store Locations

Store No.	Borough	Store M-Th, F, Sat, Sun
101	MANHATTAN	7:00-9:00/9:00-6:00/10:00-5:00
102	MANHATTAN	7:00-12:00/9:00-8:00/10:00-6:00
104	MANHATTAN	24 Hours
108	MANHATTAN	24 Hours
110	MANHATTAN	7:00-9:00/9:00-6:00/10:00-5:00
111	MANHATTAN	24 Hours

Definitions of Urban Freight Performance Measures

Since delivery-related freight activities are the key components of urban freight transportation, the main focus of this research is to assess the performance of urban deliveries using GPS and other related datasets. Urban freight delivery-related performance measures and their corresponding definitions are provided in this section.

Table 31 is a summary of the performance measures considered in this research. These stop/tour-centric measures are mainly from the perspectives of the private sectors (e.g., logistics companies). Note that freight activities can also be evaluated with respect to network-wide performances such as average speed, route travel times, route travel time reliability, etc., which indicate the overall performances of freight activities from a system perspective. These measures will not be discussed in the report, mainly due to the small sample size and low penetration of the available GPS data. Network-wide freight performance measures will be discussed in Chapter 6.

Table 31: Freight Performance Measures and Definitions

Performance Measures			Definition	Notes
Mobility	Delivery stop analysis	Service time	$S_{i,j} = t_{i,j}^{end} - t_{i,j}^{start}$	$t_{i,j}^{start}, t_{i,j}^{end}$: the starting and ending time of stop *i* during tour *j*
		Average service time	$\bar{S} = \frac{\sum_i \sum_j S_{i,j}}{\sum_j N_j}$	N_j: the total number of delivery stops during tour *j*
	Tour analysis	Travel time between delivery stops	$T_{i,j} = t_{i+1,j}^{start} - t_{i,j}^{end}$	$T_{i,j}$: the travel time between delivery stop *i* and delivery stop *i+1* during tour *j*
		Average travel time between delivery stops	$\bar{T} = \frac{\sum_i \sum_j T_{i,j}}{\sum_j N_j}$	N_j: the total number of trip segments between delivery stops during tour *j*
		Travel time between delivery stops and warehouse	$TT_j^1 = t_{1,j}^{start} - T_j^{start}$ $TT_j^2 = T_j^{end} - t_{N_j,j}^{end}$	$t_{1,j}^{start}$: the starting time of the first delivery stop during tour *j* $t_{N_j,j}^{end}$: the ending time of the last delivery stop during tour *j* T_j^{start}, T_j^{end}: the starting and ending time of tour *j*
		Average travel time between delivery stops and warehouse	$\overline{TT} = \frac{\sum_j (TT_j^1 + TT_j^2)}{2N_T}$	N_T: the total number of tours
		Miles traveled per tour	$M_x = \sum_{i=2}^{n} v_{i-1} * (t_i - t_{i-1})$	M_x: the total miles traveled by tour *x*; n: the total number of records during tour *x*; v_{i-1}: the speed of record *i-1*; t_i, t_{i-1}: the time for record *i-1* and *i*;
		Average speed	$V_x = \frac{M_x}{T_x}$	V_x: the average speed of tour *x*; T_x: the total traveling time of tour *x* excluding the stopping time
Fuel Consumption	Fuel consumption rate		*FR*	*FR:* fuel consumption rate; only applicable to second-by-second GPS data
Emissions	Emission rate		ER_{CO_2}, ER_{CO} ER_{HC}, ER_{NOX}	$ER_{CO_2}, ER_{CO}, ER_{HC}, ER_{NOX}$: the tailpipe out emission rates of CO2, CO, HC, NOx; only applicable to second-by-second GPS data

In Table 31, a *tour* is defined as an entire trip that starts at a warehouse, makes deliveries in the middle, and finally ends at the same warehouse. There could be multiple *stops* within a tour, including delivery stops and non-delivery stops. A *delivery stop* is defined as a stop for the purpose of making deliveries or pickups at stores; a *non-delivery stop* is defined as a stop for another purpose, such as stops due to traffic congestion/traffic signals, waiting for ferry or paying tolls, etc. Service time is defined as the duration of a delivery stop.

In this report, the delivery stop analysis, trip segment analysis, and tour analysis are conducted for mobility evaluation. The delivery stop analysis targets the service times of delivery stops. The tour analysis targets the miles/times traveled by each tour, and the average travel speed for each tour. The trip segment analysis looks at the travel times between delivery stops, and between delivery stops and the warehouse. For second-by-second GPS data, fuel consumption and emissions of selected trip segments and entire tours can also be estimated using micro-scale emission models. For event-based and stop-based GPS data, however, these estimations are not applicable, mainly due to the poor time resolution of these two datasets. Comparisons are also made to evaluate the performances of urban freight deliveries conducted during off-hours and regular hours.

Figure 32 depicts the procedure developed in this project for urban freight delivery performance measurement. The input data are comprised of event-based, stop-based, or second-by-second GPS data; company-based data (i.e., delivery logs, store/warehouse/truck center locations), which are optional; and the network geometry information. The input data are further processed and exploited to identify tours, stops/delivery stops, and trip segments between delivery stops and between delivery stops and the warehouse.

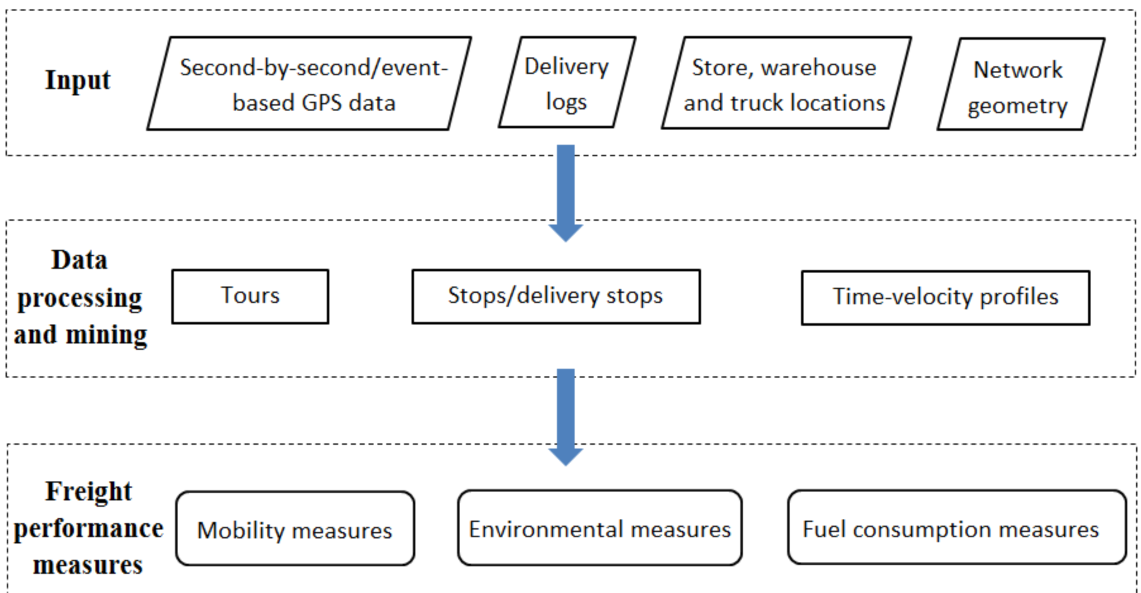


Figure 32: Freight performance measurement flowchart

Since each second-by-second GPS file corresponds to one tour, it is trivial to conduct tour identification for this type of data. However, for event-based and stop-based data, warehouse locations/stops need to be considered. That is, a tour is defined as an entire trip that starts and ends at the same warehouse. In terms of stop identification, the purpose of stops can be directly inferred from the stop-based GPS data. For event-based and second-by-second GPS data, however, a vehicle stop needs to be further identified as a delivery or non-delivery stop using additional information. In particular, for event-based data, a stop will be labeled as a delivery stop only when the stop is in the neighborhood of one or multiple grocery stores. For second-by-second GPS data, a robust learning method, called the Support Vector Machine (SVM), is applied. Three features are considered in the SVM model, including the duration of the stop, the distance from the stop location to the city center, and the distance from the stop location to key bottlenecks (e.g., bridges, tunnels, toll booths, etc.). Calculations of these features need additional information such as the network geometry. The SVM model is trained using the "ground truth" delivery stops offered by the delivery logs (details will be presented in Section 4). Based on the identified tours and delivery stops, the trip segments between delivery stops and the corresponding time-velocity profiles (if applicable) can be acquired. The mobility measures, fuel consumption, and environmental measures can then be calculated.

Identification of Tours and Delivery Stops

A unique feature of urban freight deliveries is "tour-centric." Correctly identifying tours and delivery stops is essential to characterize urban freight deliveries, such as tour durations, delivery times, number of delivery stops, among others. In this chapter, we show how the tours and delivery stops can be identified using the three aforementioned GPS datasets. Due to the distinct differences of the data formats, these three types of data were treated and analyzed separately.

Event-based GPS Data

For event-based data, the engine status (i.e., "ignition off" and "ignition on") can be used to indicate the start or end of a stop. A simple string-search script was developed to automatically identify the stops. The duration and location information of these stops can then be easily acquired. The major challenge is to further identify delivery stops and tours from these pre-acquired stops. The detailed procedures and algorithms are presented as follows.

Identification of Delivery Stops

There are many possible reasons for vehicle stops in addition to making deliveries, such as stops due to traffic signals and congestion. These stops are referred to as non-delivery stops, and are distinguished from delivery stops. To this end, the locations of grocery stores must be considered because the location of a delivery stop is usually quite close to the store location. Therefore, we can calculate the distance from a stop to its closest store location, and then compare this distance to a pre-defined threshold. If this distance is smaller than the threshold, the stop will be identified as a delivery stop. Otherwise, it will be identified as a non-delivery stop.

It is noteworthy that, given the longitudes and latitudes of two locations, the distance in between can be approximated by the *great-circle distance* as in Equation (8).

$$d = r\Delta\hat{\sigma} \tag{8}$$

Here r is the earth radius (6,371,009 meters) and is the central angle between the two points which can be calculated using the equation below:

$$\Delta\hat{\sigma} = \arctan\left(\frac{\sqrt{(\cos\phi_f \sin\Delta\lambda)^2 + (\cos\phi_s \sin\phi_f - \sin\phi_s \cos\phi_f \cos\Delta\lambda)^2}}{\sin\phi_s \sin\phi_f + \cos\phi_s \cos\phi_f \cos\Delta\lambda}\right) \tag{9}$$

Here $\emptyset_s, \lambda_s, \emptyset_f, \lambda_f$ are the geographical latitudes and longitudes of the two points (s and f stands for the two locations, such as the location of a stop and a grocery store); $\Delta\phi, \Delta\lambda$ represents the absolute differences. In this project, it is found that the threshold of 200 meters (by trial-and-error) provides the best identification results.

Identification of Tours

A simple rule was applied for tour identification. That is, a tour starts with a stop whose distance to the warehouse is less than 1km (an average size of the warehouses), and ends with a stop whose distance to the (same) warehouse is less than 1km. To obtain more robust results, several issues need to be properly addressed, which are indicated as follows.

- Vehicles might stop at the warehouse without "ignition off". Therefore for these vehicles, we cannot simply use "ignition on" and 'ignition off' at the warehouse to mark the start or end of tours. Instead we use the following rules. If the distance between a GPS record and the warehouse is less than 1 km followed by a record with distance to the warehouse more than 1 km, then this record marks the start of a tour. Similarly, if the distance between a GPS record and warehouse is more than 1km following a record with distance to the warehouse less than 1 km, this record marks the end of a tour.
- Tours that are shorter than 30 minutes are not considered in the analyses. These tours usually represent the non-delivery activities around the warehouses.
- If a tour stops at any truck center, this tour will be excluded. This is because trucks usually stop at truck centers due to mechanical problems.
- If there is no delivery stop within a tour, this tour will not be considered as a delivery tour and will be excluded from our analyses.
- If a tour includes some irregular stops (e.g., stop duration is longer than 5 hours), this tour is excluded. This 5-hour threshold is obtained from delivery logs, as there is no single stop in the logs that is 5 hours or longer.

Identification of Warehouses and Truck Centers

In this project, the location information of warehouses and truck centers is available. However, in the event that this information is not available in real-world problems, we propose a method to identify warehouses (or truck centers) based on the number of stops (or long stops) during a given period of time: the larger the number corresponding to number of stops (or the duration of a stop), the more likely the stop is at a warehouse (or truck center). The rationale of the method is that the warehouses usually have large numbers of stops, and the truck centers usually have long-duration stops (for truck maintenance or repair).

In particular, one can first find the number of stops for each location (address) using the event-based GPS data as presented earlier in this section. The locations with large numbers of stops are labeled as possible warehouse locations. Manual checking (e.g. using digital maps) is then required to further confirm this. In cases when some possible warehouse locations essentially belong to the same warehouse, these locations are clustered as one warehouse. In this project, we use 1,000 as the threshold (for data collected for a year) to tag stops as potential warehouse or truck center locations. There were eight locations with over 1,000 stops in 2012 (as shown in Table 32), and seven of them are within the same warehouse, as shown in Figure 33. The remaining one proved to be a truck center, using the method introduced next.

Table 32: Locations with Over 1000 Stops in 2012

Event	Number of Stops
Ignition Off	12654
Ignition Off	10083
Ignition Off	4100
Ignition Off	1881
Ignition Off	1773
Ignition Off	1325
Ignition Off	1311
Ignition Off	1162

Figure 33: The Geographical Distribution of Stop Locations with Over 1000 Stops in 2012

To identify the truck centers, the locations with large numbers of long-duration stops need to be investigated. The threshold for a long-duration stop is defined in this project as one (1) hour. If there are more than a certain number (three, in this project) of long-duration stops at one location, this location will be treated as a possible truck center location. A similar manual checking procedure is also applied to confirm whether the identified location is indeed a truck center. In this project, it has been found that the proposed methods are fairly effective. The identification results of warehouse and truck centers are identical to the ground truth information provided by the logistics company.

Note that the actual thresholds defined here for warehouse or truck center identifications may be site-specific (e.g., depending upon the city in which the deliveries are made) and company-specific (e.g., which commodities they are delivering). Therefore, the initial investigation of the data and manual checking are crucial. However, since there are usually only a handful of warehouses or truck centers for a logistics company, confirming their locations manually should not be a huge undertaking.

Stop-based GPS Data

The stop-based GPS data record all vehicle stops and their corresponding location IDs. Therefore, tours and delivery stops can be identified easily from this type of data. With respect to tour identification, since a tour starts and ends at the same warehouse and is completed by the same driver, we developed a simple algorithm to identify each tour by using the location ID "1" to mark the start and the end of a tour. It should also be ensured that the driver's ID at the starting point remains the same at the ending point. Travel time and distance checks were also applied to filter out those spurious tours with very short total travel time (e.g., less than 10 minutes), or short distance traveled (e.g., the odometer does not change over different stops), or with one or more abnormally long delivery stops (e.g., longer than five hours). In terms of delivery stop identification, since the type of stop is revealed by the location ID, we can simply identify the stops with multi-digit integral location IDs and with non-zero delivery quantities as delivery stops.

Second-by-Second GPS Data

It has proven challenging to distinguish urban delivery stops from non-delivery stops using second-by-second GPS data only. One of the first attempts to discuss such a stop identification issue was conducted by Du and Altman-Hall (2007), who analyzed the GPS data from a subset of travelers in Lexington, KY between March 2002 and July 2003, and calibrated this data with manual travel logs provided by the participants. Using the two datasets, they identified the heading change (compass direction); dwell time (time elapsed while vehicle speed drops below a certain level); distance between the GPS points; and the network geometry as the main parameters for trip end prediction. It was found that the proper benchmarks for detecting trip ends were a heading change of 180 degrees, and/or a dwell time between 20 and 140 seconds (Du and Aultman-Hall, 2007). This study, however, focused on passenger cars. Since passenger cars typically take less time to park, it is very likely that a lower threshold for vehicle dwell times is acceptable for identifying a trip end of passenger cars. This may not be the case for commercial vehicles.

Recently, Greaves and Figliozzi (2008) developed an algorithm to identify the stops for commercial vehicles. The algorithm analyzed the time difference between GPS-to-satellite communications to determine if the vehicle was stopped. By investigating different thresholds between 120 seconds and 300 seconds, it was found that 240 seconds was an adequate threshold to indicate a stop. In addition to the time threshold, the geographic distance between the locations of a vehicle at consecutive communications was also considered. If the vehicle had moved more than the accuracy rating of the device (e.g., 6 meters), it was determined that the signal had been lost. They also tagged any points where the vehicle position changed less than 6 meters regardless of the time elapsed to identify short stops by manual inspection. The limitation of their algorithm is that it heavily relies on manual inspections, which may be biased and also time-consuming for a large dataset. Their algorithm becomes further distressed in urban areas such as New York City where a commercial vehicle may have to move several times for the same delivery due to the extremely demanding spatial constraints of the traffic network (e.g., numerous one-way streets, tall buildings, and pedestrian traffic). Since the algorithm needs to flag such short trips for manual inspection, it may end up manually checking almost every delivery site within an urban area (Greaves and Figliozzi, 2008).

More recently, McCormack et al. (2010) analyzed data from the Seattle, Washington metropolitan area using an algorithm that recorded delivery stops when the vehicle's dwell time (i.e. time that the vehicle engine is off or idle) exceeded 3 minutes (180 seconds). It was pointed out that in addition to insignificant truck movement, the GPS points tend to fluctuate when a truck idles (McCormack et al., 2010). To deal with this issue, if the distance between two consecutive data points was less than 65 feet, this instance will be removed. While this algorithm is effective in filtering spurious trips, it also removes data that could be significant for other freight performance measures such as service times (i.e., how long it takes for the truck to unload and start the next trip).

In this project, a three-stage algorithm was developed for delivery stop identification based on a linear SVM with nested K-fold cross-validation. The first stage is to identify all the stops based on speeds, as recorded in the second-by-second GPS data. In the second stage, three features are extracted, including the duration of a stop, distance of the stop to the center of the city, and a binary distance of the stop to the closest key bottleneck such as bridge, tunnel, toll booth, etc. The third stage is the implementation of the linear SVM with nested K-fold cross-validation to classify all stops as either delivery stops or non-delivery stops.

Identification of Stops and Tours

For second-by-second GPS data, since each data file represents a complete tour, it is trivial to identify tours. The data used in this project cover 11 complete tours that start and end at the same warehouse. These 11 tours are quite similar with respect to the tour duration and the number of delivery stops per tour, as shown later in Table 40.

With respect to stop identification, the stops are indicated by the data points under a certain speed threshold (14km/h in this research). The reason why 14km/h (instead of zero) was adopted as the threshold is because there may be some insignificant (minor) movement during the unloading process. It is found that the differences between the durations of stops obtained using zero and 14km/h threshold are less than 30 seconds, which is negligible compared with a minimum duration of at least 10 minutes for a delivery stop, according to the delivery logs.

Feature Extraction

The next step is to extract the features (of the stops) so that the stops can be further classified as delivery or non-delivery stops. Here *features* represent salient characteristics of the data samples that can help divide the data into multiple groups. In this context, features mean certain unique characteristics of the stops. Three features of a stop are found to be effective in this classification: the duration of a stop, the distance from the stop to the center of the city, and the binary distance from the stop to the closest key bottleneck. *Key bottlenecks* are defined as bridges, tunnels, toll booths, ferries; these represent the major “choking points” of the city in which the deliveries are made. In this project, three key bottlenecks are identified: the two ends of the Lincoln Tunnel and a toll booth, as shown in Table 33. Obviously, those key bottlenecks are problem-specific, and need to be manually identified, possibly with the help of local traffic experts.

Table 33: The Longitude and Latitude of bottlenecks

Faciltity	Latitude	Longitude
Tolling Booth	40.76486	-74.023606
Lincoln Tunnel (the NJ side)	40.766485	-74.022728
Lincoln Tunnel (the Manhattan side)	40.760196	-74.003202

The scatter plot of the stops (in terms of these three features) is shown in Figure 34. It can be observed from the figure that: (i) samples with longer duration of stops are more likely to be delivery stops; (ii) stops that are closer to the central city are more likely to be delivery stops; and (iii) stops that are far away from the key bottlenecks are more likely to be delivery stops. However, the data cannot be well-separated using any single feature. The combinations of the three features, on the other hand, can serve as a very effective classifier for delivery stops or non-delivery stops, which leads to more robust classification results.

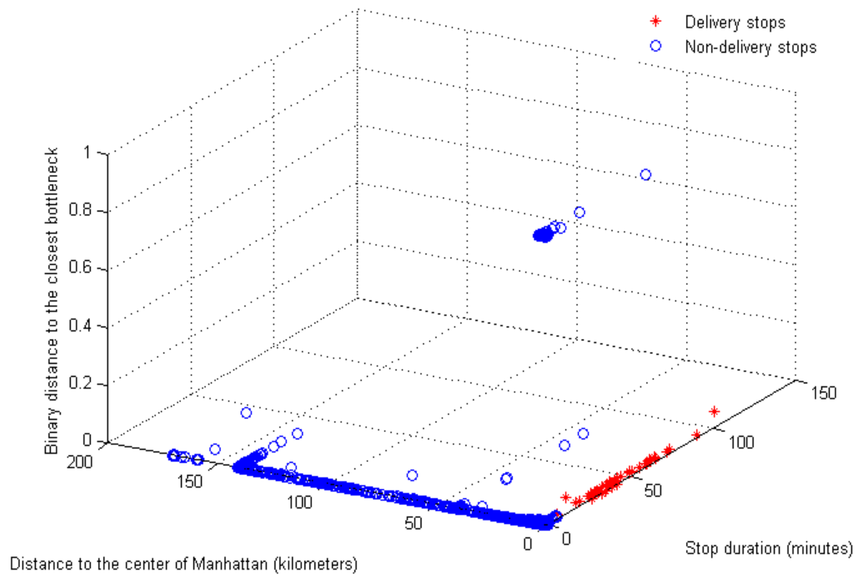


Figure 34: Stop Duration, Distance to the Center of Manhattan and Distance to the Closest Key Bottleneck of all Stops

Identification of Delivery Stops Using SVM

SVM is a recently developed pattern classifier (Vapnik, 1995; Bishop, 2006) that can be used for two-group or multi-group classification. In transportation, SVM has been used for incident detection, signal timing estimation, vehicle classification, regression analysis, and so on (Cortes and Vapnik, 1995; Yuan and Cheu, 2003; Hao et al., 2012; Sun and Ban, 2013).

The application of SVM usually involves two major steps: training and testing. In the training step, a classifier is learned from the training data, which can separate the training samples by maximizing the margin between two or multiple classes. In the testing step, the classifier is applied to classify the testing samples. Kernel methods can be integrated into the SVM models to capture the non-linear effects of the data. In this project, it is found that a linear SVM is sufficient for the delivery stop identification problem. Therefore, complex kernel functions are not considered here.

To implement the linear SVM model, data from the delivery logs are first processed to obtain the true labels of the stops (in terms of delivery stops and non-delivery stops). Among a total number of 2,249 stops detected from the second-by-second GPS data (from Step 1), it is found that only 42 are delivery stops and the rest are non-delivery stops. Nested K-fold cross validation procedures is applied to parameterize and validate the SVM model. The procedures are summarized below.

SVM with nested K-fold cross-validation:

1. Repeat K times;
   - Training set ←*K-1* subsets;
   - Testing set ← remaining set;

   1.1 Repeat for i=*1, 2, …, m*:

   a. Repeat for *j=1, 2, .., K-1* (for samples only in the training set):

   Training validation set ←*K-2* subsets;

   Testing validation set ←the remaining subsets;

   Train a classifier on the training validation set using parameter 'α_i';

   Test the classifier on the testing validation set.

   b. Record $p(i)$ the average performance over *K-1* testing validation sets.

   1.2 Determine $\alpha_{\hat{p}}$, where $\hat{p} = argmax(p(i))$for *i=1,2,..,m;*

   1.3 Train the classifier on the training set using parameter $\alpha_{\hat{p}}$.

   - Test the classifier using in step 1.3 on the testing set.
2. Return $\bar{p}$, the average performance over K testing sets.

Notice that the outer loop is for performance evaluation of the SVM model. We first randomly divide the sample data into *K* subsets. Among all the *K* sets, *K*-1 sets are used for training and the other ones are used for testing. The model parameters are calibrated using the training dataset and evaluated using the testing dataset. The average performance of the testing results is recorded as the final performance of the model. The inner loop is used for model selection (using the current testing data). The inner loop has similar data-splitting strategies, except that it attempts to find the best parameters that can lead to the best average performance over the testing datasets in the inner loop. Since the outer loop is repeated for *K* times, this procedure can guarantee unbiased estimation results. *K* is set to 10 in this project.

Results and Analyses

Using the aforementioned methods, the performance of urban freight delivery activities can be assessed with respect to mobility, fuel consumption, and emissions. The performance measures are then used to evaluate the effectiveness of the OHD policy.

Mobility measures using event-based data

Delivery Stop Analysis

Based on the delivery log data from 57 trucks for the period of January 01 – June 30, 2012, 9,132 delivery stops were identified. The longest stop duration from the log file is less than 5 hours. From the log data, the results of the number of cargos delivered, waiting time before unloading, unloading time, and service time at each delivery stop can be acquired. The aggregated statistics are illustrated in Table 34. Compared with the delivery during regular hours, the results show that an off-hour delivery usually has a slightly longer service time and waiting time (mostly less than 3 minutes), almost the same unloading time, and a slightly lower number of cargos delivered.

Table 34: Delivery stop analysis using delivery logs for event-based GPS data

		All time period	Off-hour	Regular-hour
No. of delivery stops		9132	4654	4478
Service time at delivery stop (minutes)	Average	**52.8**	**52.8**	**49.8**
	Standard deviation	26.4	26.4	21
	Maximum	277.8	277.8	244.8
	Minimum	1.2	1.2	4.8
Waiting time before unloading at a delivery stop (minutes)	Average	**12.6**	**12.6**	**9.6**
	Standard deviation	15.6	15.6	11.4
	Maximum	175.2	175.2	139.8
	Minimum	0	0	0
Unloading time at a delivery stop (minutes)	Average	**40.2**	**40.2**	**40.2**
	Standard deviation	19.8	19.8	16.8
	Maximum	180	180	235.2
	Minimum	1.2	1.2	1.8
Number of cargos delivered at a delivery stop	Average	**7.1**	**7.1**	**7.2**
	Standard deviation	2.5	2.5	2.5
	Maximum	22	22	24
	Minimum	1	1	1

Based on the method described earlier, 7,882 delivery stops were identified from the GPS data for the time period between January 01 and June 30, 2012. Among the 7,882 delivery stops, 2,403 are during off-hours and the rest 5,479 are during regular hours. Stops with irregularly long durations (i.e., longer than 5 hours as shown in the log data) were excluded from the analysis. The service times at delivery stops are provided in Table 35. Notice that other measures, such as waiting times, or number of cargos delivered, are not available from event-based GPS data. The table illustrates that the average service time during off-hours is longer than that of regular hours. This is consistent with the results obtained using delivery logs. However, the average value from GPS data (for all time periods, or regular or off-hours) is about 10-15 minutes less than that from delivery log data. This is because the delivery stops identified from the event-based GPS data are marked with the "ignition off" status, which may not represent the vehicle's actual arrival time (at a store). For example, without turning the engine off, a driver may stay in the truck to finish things up, or while waiting for the store employees. As a result, the service time calculated based on GPS data will not include this in-vehicle time, while the delivery log data may very well include it as part of the service time. This generates discrepancies for the results calculated based on GPS data and based on delivery logs (i.e., the "ground truth").

Table 35: Service time analysis using event-based GPS data

	All time period	Off-hour	Regular-hour
Average (minutes)	**35.9**	**43.3**	**32.6**
Standard deviation (minutes)	26.5	31.9	23.1
Maximum (minutes)	291	290	291
Minimum (minutes)	1	10	1

Tour Analysis

Delivery logs only provide information at delivery stops; they do not provide delivery tour-related information. Therefore, the tour analysis here is only based on event-based GPS data. The results show that there are 4,521 tours that do not pass any truck centers. As shown in Table 36, among the 4,521 tours, 896 are during off-hours and 3,625 are during regular hours. The average tour duration for off-hour tours is 122.6 minutes, which is much lower than the average tour duration (204.4 minutes) during regular hours. Note from Table 35 that the average service time per stop for off-hours is about 43.3 minutes (54 minutes for 1.3 stops), which is slightly higher than that for the regular hours (32.9 minutes). This is consistent with the stop analysis results shown previously.

Table 36: Tour Analysis Using Event-based GPS Data

		All time period	Off-hour	Regular-hour
Number of tours		4521	896	3625
Tour duration	Average	**187.2**	**122.6**	**204.4**
	Standard deviation	128.3	57.8	136.2
	Maximum	1762	1131	1762
	Minimum	36	36	51
Total service time during a tour (minutes)	Average	**66.5**	**54**	**69.8**
	Standard deviation	41.5	33.5	42.8
	Maximum	407	282	407
	Minimum	1	1	1
The number of delivery stops during a tour	Average	**1.9**	**1.3**	**2**
	Standard deviation	1.1	0.6	1.1
	Maximum	10	8	10
	Minimum	1	1	1

The results in Table 34 and Table 35 indicate that the average service time at delivery stops during off-hours is slightly greater (usually by a few minutes) than that for regular hours. This is consistent between results from log data and from GPS data. Follow-up interviews/surveys with logistics company managers and truck drivers reveal several possible reasons for this. First, during off-hours, a truck driver often (i) must lock/unlock the truck each time a delivery is made; (ii) must open the gate and turn the security system off in case of unassisted deliveries (which seem to be the form that the receivers like the most); and (iii) seems to be unrushed and less stressed, compared with regular hours, about being late to the next stop or getting a parking ticket. All of these can result in a slight increase in the service time at a store. More importantly, as mentioned, the logistics company that provided the event-based GPS data has implemented OHD for certain stores for the last few years. It turns out that the company has already made changes to the tours and deliveries during regular hours and off-hours, which implies that the delivery activities during regular hours and off-hours can be very different. For example, during regular hours, a driver may simply stop and pick up empty carts at a store, which usually requires very short service time. This however, is not the case for off-hours.

The above findings indicate that in the long-term, OHD may have a much more profound impact to a logistics company's operations compared with its short-term impact. In future research, therefore, such long-term impacts should be further investigated and systematically evaluated. On the other hand, OHD obviously provides more options to a logistics company regarding when to make the deliveries. It is thus reasonable to assume that such OHD-induced delivery changes are a result of the company's exploration of these newly realized OHD options. Since the logistics company best understands its own operations, we can safely assume that after such changes, the overall operational efficiency of the company (including both regular hours and off-hours) is further improved.

Trip Segment Analysis

Based on the identified delivery stops and the warehouse (at the beginning and ending of the tours), 42,382 trip segments were identified, among which 31,719 segments are between delivery stops and 10,664 segments are between warehouse and delivery stops. The segment travel time, distance traveled, average speed, and total duration of stops on these segments are summarized in Table 37– Table 39. In general, it can be observed that OHD leads to shorter segment travel time, shorter duration of non-delivery stops (due to traffic lights or congestion), and much higher travel speed (except for the segments between delivery stops, wherein the speed during off-hours is slightly lower than that during regular hours). Notice that the logistics company that provided the stop-based GPS data has also implemented OHD for a few years and very likely has changed the tours and deliveries during off-hours compared with regular hours. So the results here do not necessarily reflect the most direct comparisons between OHD and regular hour deliveries.

Table 37: All trip segment analysis using stop-based GPS data

		All time period	**Off-hour**	**Regular-hour**
Total number of segments		42382	5856	36526
Segment travel time (minutes)	Average	**37.4**	**31.3**	**38.4**
	Standard Deviation	74	24.9	79
	Maximum	864	347	864
	Minimum	1	1	1
Distance traveled (miles)	Average	**9.9**	**13.3**	**9.4**
	Standard Deviation	15.6	14.3	15.7
	Maximum	247.6	93.3	247.6
	Minimum	0.1	0.1	0.1
Average travel speed (miles/hour)	Average	**16**	**20.6**	**15.3**
	Standard Deviation	11.3	12.4	10.9
	Maximum	90	72	90
	Minimum	0.1	0.8	0.1
Average total stop time (minutes)	Average	**7.9**	**2.5**	**8.8**
	Standard Deviation	43.2	12.1	46.2
	Maximum	690	312	690
	Minimum	0	0	0

Table 38: Type 1 trip segment analysis using stop-based GPS data

		All time period	Off-hour	Regular-hour
Number of segments between the warehouse and delivery stops		10664	3540	7124
Segment travel time (minutes)	Average	**97.6**	**45**	**123.8**
	Standard Deviation	121.4	21.9	140.6
	Maximum	864	347	864
	Minimum	2	5	2
Distance traveled (miles)	Average	**27.6**	**20.6**	**31.1**
	Standard Deviation	20.7	14	22.6
	Maximum	247.6	93.3	247.6
	Minimum	0.1	0.6	0.1
Average travel speed (miles/hour)	Average	**24.2**	**26.8**	**22.8**
	Standard Deviation	13.1	11.3	13.7
	Maximum	54.7	54.4	54.7
	Minimum	0.1	2.2	0.1
Average total stop time (minutes)	Average	**21.2**	**3.6**	**29.9**
	Standard Deviation	77.2	14.6	92.7
	Maximum	690	312	690
	Minimum	0	0	0

Table 39: Type 2 trip segment analysis using stop-based GPS data

		All time period	Off-hour	Regular-hour
Number of segments between delivery stops		31719	2317	29402
Segment travel time (minutes)	Average	**17.2**	**10.4**	**18**
	Standard Deviation	27	10.4	18.3
	Maximum	609	126	28.3
	Minimum	1	1	469
Distance traveled (miles)	Average	**4**	**2.2**	**4.1**
	Standard Deviation	6.2	3.9	4.1
	Maximum	152.3	75.6	6.2
	Minimum	0.1	0.1	135.3
Average travel speed (miles/hour)	Average	**13.2**	**11**	**14.1**
	Standard Deviation	9	6.7	12.9
	Maximum	90	72	8.8
	Minimum	0.1	0.8	84
Average total stop time (minutes)	Average	**3.5**	**0.8**	**4**
	Standard Deviation	20.3	5.9	3.9
	Maximum	538	107	21.2
	Minimum	0	0	416

Mobility Measures Using Second-by-Second Data

The logistics company that provided the second-by-second GPS data switched to OHD in the middle of the data collection. Therefore, data for both "before" and "after" the switch were collected, mostly for identical or very similar tours, and for deliveries made during off-hours and regular hours. Therefore, the most direct impact (in terms of mobility, fuel consumption, and emissions) of OHD can be evaluated in this section.

Tour Analysis

Since delivery logs do not contain tour-related information, the tour analysis here is done based on GPS data. Eleven (11) complete tours are analyzed for the second-by-second GPS data. Among these 11 tours, 6 tours are during regular hours, while the remaining 5 are tours after the implementation of the OHD program on March 12, 2013. It is worth mentioning that these 5 tours are (roughly) treated as off-hour tours since part of their travel time between the last stores to the warehouse is during regular hours. The aggregated tour-related statistics are shown in Table 40. In spite of the slightly longer distance traveled (per tour), the results indicate that OHD leads to reduced total tour duration and total service time compared with regular hours.

Table 40: Tour Analysis Using Second-by-Second GPS Data

		All time period	Off-hour	Regular-hour
Number of tours		11	5	6
Tour duration(minutes)	Average	**564**	**554.4**	**571.8**
	Standard deviation	85.2	22.8	118.2
	Maximum	773.4	577.8	773.4
	Minimum	447	521.4	447
Number of delivery stops	Average	**3.7**	**4**	**3.5**
	Standard deviation	0.8	0	1.1
	Maximum	5	4	5
	Minimum	2	4	2
Total service time (minutes)	Average	**178.2**	**175.2**	**180.6**
	Standard deviation	47.4	33	60
	Maximum	217.2	203.4	217.2
	Minimum	61.8	131.4	61.8
Tour-based average service time per delivery stop (minutes)	Average	**48.6**	**43.8**	**48.6**
	Standard deviation	13.2	8.4	15.6
	Maximum	72.6	51	72.6
	Minimum	31.2	33	31.2
Distance traveled per tour (miles)	Average	**219**	**223.9**	**213.1**
	Standard deviation	19.2	25.3	6.6
	Maximum	272.6	272.6	219.9
	Minimum	199.3	199.3	199.3

Delivery Stop Analysis

Using the three-stage method proposed in Section 4, we were able to identify 2,249 stops from the second-by-second GPS data, of which 42 stops were further identified as delivery stops using the SVM model. Compared with the ground truth (delivery log), only 3 of them were misclassified. Table 41 summarizes the results for service times calculated using GPS data, including the average, standard deviation, and maximum and minimum service times. The results are presented for regular hours (defined as 6 AM to 10 PM), off-hours (defined as 10 PM to 6 AM), and all time periods of the day. To compare, the same results calculated using delivery log data are also presented in Table 42. It is found that the patterns of the average service times estimated using GPS data are in general consistent with the ones recorded in the delivery logs.

One noticeable discrepancy in the results is that the average service times obtained from the GPS data are about 10 minutes larger than those obtained from the delivery logs. There are at least two possible reasons for this discrepancy. First, as mentioned, the time recorded in the delivery logs is based on a 5-minute resolution, while the GPS time is highly accurate. In this regard, the measures estimated using GPS data might be more reliable than those from log data. Second, the definition of a "delivery stop" is a bit different using GPS data or delivery log data. The starting time, ending time, and the duration of a stop using GPS data are inferred based on vehicle speed. That is, if the vehicle speed is less than a pre-defined threshold, a stop will be tagged. If the speed exceeds the threshold again, the stop ends. The duration in between is the stop time, i.e., the service time if the stop is further identified as a delivery stop. For delivery log data, however, the delivery start and end times are recorded manually by the driver, and, therefore, may involve clerical errors. More importantly, a driver may finish a delivery (say at 8:00 am) and sit in the vehicle for a few minutes or longer (perhaps 10 minutes) to finish up things before the vehicle is started again for the next delivery. The log data will indicate the delivery ends at 8:00 am, but the GPS data will show 8:10 am, resulting in a 10-minute difference. In this case, although it is debatable whether the delivery really ends at 8:00 am or 8:10 am, the above results and analyses do clearly show that, although GPS data are very useful, one should expect certain discrepancies between the performance results calculated using GPS data and the ground-truth data (e.g., those from the delivery logs). Thus, one needs to be cautious about these discrepancies when using GPS data to evaluate urban freight performances.

In this project, one main purpose of conducting freight performance measurement is to evaluate the performances of OHD. As shown in Table 41 and Table 42, OHD helps reduce the average service time by 7-8 minutes (GPS data) or about 5 minutes (delivery log data), although the standard deviation for off-hours is also a bit higher. This shows that OHD can help improve urban delivery efficiency, i.e., its mobility.

Table 41: Service time analysis using second-by-second GPS data

	All time period	Off-hour	Regular-hour
Average (minutes)	**45.8**	**43.8**	**51.4**
Standard Deviation (minutes)	16.9	17.5	13.7
Maximum (minutes)	92.9	92.9	68.4
Minimum (minutes)	22.5	22.5	32.5

Table 42: Service time analysis using delivery logs for second-by-second GPS data

	All time period	Off-hour	Regular-hour
Average (minutes)	**35**	**34**	**38.6**
Standard Deviation (minutes)	11	10.8	11.8
Maximum (minutes)	60	60	60
Minimum (minutes)	15	15	30

Trip Segment Analysis

The trip segment travel times were calculated for the trips between delivery stops as well as the trips between delivery stops and the warehouse. Note that the travel time between delivery stops can be computed from the GPS dataset, and is also available from the delivery logs. The travel time between warehouse and delivery stops, however, are not recorded in the delivery logs; they can only be inferred from the GPS data.

The aggregated statistics of travel time, speed, and distance traveled between delivery stops are provided in Table 44. Similar to the results of service times, the trip segment travel time between delivery stops estimated using the GPS data shown in Table 43 and the one recorded in the delivery logs (see Table 44), show similar trends. This again indicates that GPS data can be used to reproduce the freight performance measurements. Table 45 indicates higher travel time and also longer distances traveled between delivery stops during off-hours. This is not surprising because off-hour tours and regular-hour tours are not making exactly the same deliveries, and are thus running on different paths. By further comparing the average travel speeds for these trip segments, we can find that the speed during off-hours is higher than that during regular hours.

Similarly, the aggregated statistics of travel time, speed, and distance traveled between warehouse and delivery stops are shown in Table 45. The results reveal that the distances traveled between warehouse and delivery stops are higher during off-hours than regular hours, while the corresponding travel time during off-hours is even smaller. As a result, we can find the speed on these segments is also higher during off-hours. This suggests that OHD can help improve the mobility of urban freight deliveries.

Table 43: Type 2 segment analysis using second-by-second GPS data

		All time period	Off-hour	Regular-hour
Number of trip segments between delivery stops		30	17	13
Travel time (minutes)	Average	**19.9**	**21.4**	**17.9**
	Standard Deviation	11.3	11.4	11.4
	Maximum	52	52	50.1
	Minimum	6.2	7	6.2
Travel speed (miles/hour)	Average	**9.9**	**9.9**	**8.2**
	Standard Deviation	3.3	2.7	3.3
	Maximum	15.5	15.5	14.8
	Minimum	3.7	3.7	3.8
Distance (miles)	Average	**3.3**	**3.9**	**2.4**
	Standard Deviation	1.7	1.8	1.1
	Maximum	7.7	7.7	4.4
	Minimum	38.1	1.5	0.6

Table 44: Type 2 segment analysis using delivery log

	All time period	Off-hour	Regular-hour
Number of trip segments between delivery stops	31	17	14
Average (minutes)	**31**	**32.7**	**28.9**
Standard Deviation (minutes)	10.2	7.9	12.4
Maximum (minutes)	60	60	60
Minimum (minutes)	15	30	15

Table 45: Type 1 segment analysis using second-by-second GPS data

		All time period	Off-hour	Regular-hour
Segments between the warehouse and delivery stops		22	9	13
Segment travel time (minutes)	Average	**166.8**	**157.8**	**173.4**
	Standard Deviation	59.4	84.5	36
	Maximum	375.6	375.6	249
	Minimum	112.8	112.8	117
Average speed (miles/hour)	Average	**39.5**	**42.1**	**37.6**
	Standard Deviation	8.1	9.2	5.4
	Maximum	52.3	52.3	48.6
	Minimum	26.4	26.4	30.9
Distance (miles)	Average	**107.1**	**110.4**	**104.7**
	Standard Deviation	21.1	21.4	7.3
	Maximum	165.6	165.6	116
	Minimum	94.8	98	94.8

Environmental and Fuel Consumption Measures

To analyze fuel consumption and emissions, nine (9) road segments with relatively high trip frequency are selected, on which the second-by-second GPS trajectory (time-velocity) data are extracted. The nine road segments include three highway segments with a length of 0.25 mile (400 meters), three segments on New Jersey Turnpike toll road with a length of 0.19 mile (300 meters), and three arterial segments in Manhattan with a length of 0.06 mile (100 meters) as shown in Table 43, Table 44 and Table 45, with stars marking the end of a road section. Detailed information of these segments is provided in Table 46.

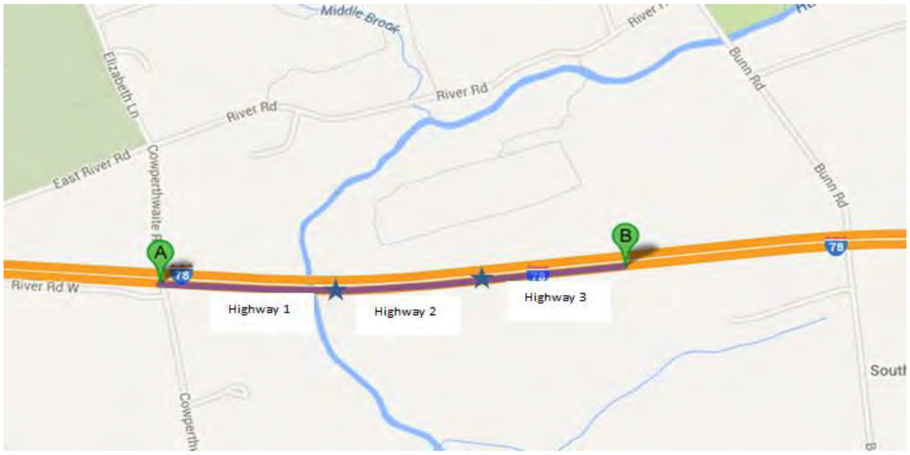


Figure 35: Three 400-meter-long trip segments on Interstate 78

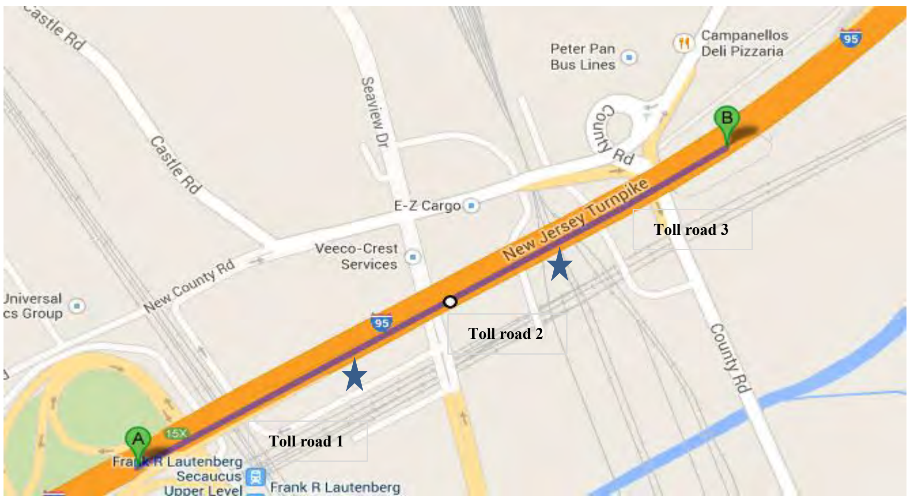


Figure 36: Three 300-meter-long trip segments on New Jersey Turnpike

Figure 37: Three 100-meter-long trip segments on 9th avenue in Manhattan

Table 46: Selected Road Segments

Segment ID	Segment Length (meters)	Number of Tours (off-hours)	Number of Tours (regular hours)
Highway 1	400	5	5
Highway 2	400	5	5
Highway 3	400	5	5
Toll Road 1	300	5	4
Toll Road 2	300	5	4
Toll Road 3	300	5	4
Manhattan 1	100	3	2
Manhattan 2	100	3	2
Manhattan 3	100	3	2

For the vehicle trajectories collected on these road segments, their corresponding fuel consumption and emissions are estimated using Comprehensive Modal Emission Model (CMEM) (Barth et al., 2000). The company was using tracker-trailer trucks (i.e., "18-wheekers") for all the deliveries. Therefore, the class of all the freight vehicles was set as the same (HDDV 5; see CMEM User's Guide V3.01). Given the second-by-second speed profiles, the fuel consumption rate and emissions rates (in terms of CO2, CO, HC, NOX) are estimated by CMEM. The results are shown in Table 47 and Table 48 for fuel consumption and emissions, respectively. The "Difference" row in the two tables shows the improvement (i.e., reductions) of the two measures for off-hours compared with regular hours (negative values indicate reductions). For illustration purposes, the fuel consumption rates and CO2 emission rates for the road segments are also plotted in different grey scales, as shown in Figure 38 and Figure 39, respectively.

Table 47: Average Fuel Consumption Rates

Average Fuel Consumption Rate (FR)	Highway (grams/mile)			Toll road (grams/mile)			Manhattan (grams/mile)		
	Segment 1	Segment 2	Segment 3	Segment 1	Segment 2	Segment 3	Segment 1	Segment 2	Segment 3
Off-hours	823.8	467.6	695.3	699.6	905.9	811.8	601.1	1259.3	675.7
Regular hours	801.8	752.3	1051.5	1251.5	1127.1	1143.4	2417.6	7109.6	2642.8
Difference	+2.7%	-37.80%	-33.90%	-44.10%	-19.60%	-29.00%	-75.10%	-82.30%	-74.40%

Table 48: Average CO_2 Emission Rates

Average CO_2 Emission Rate (ER_{CO2})	Highway (grams/mile)			Toll Road (grams/mile)			Manhattan (grams/mile)		
	Segment 1	Segment 2	Segment 3	Segment 1	Segment 2	Segment 3	Segment 1	Segment 2	Segment 3
Off-hours	2566.2	1496.2	2225.4	2232.4	2899.6	2286.8	1921.5	4028.8	2160.5
Regular hours	2636.8	2408	3365.9	4006.4	3607.9	3660	7747.8	7036.3	8458.7
Difference	-2.70%	-37.90%	-33.90%	-44.30%	-19.60%	-37.50%	-75.20%	-42.70%	-74.50%

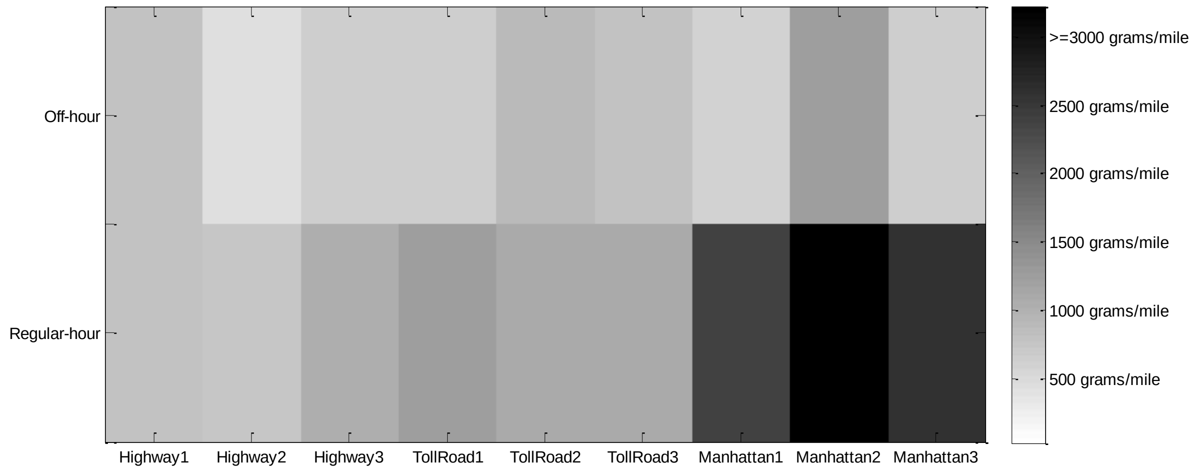


Figure 38: Average Fuel Consumption Rates in Grey Scale

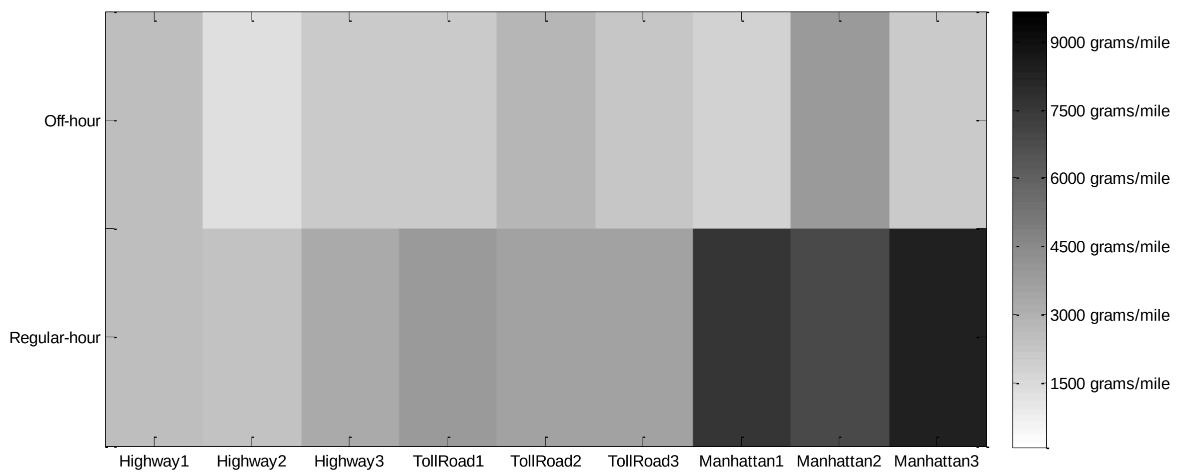


Figure 39: Average CO_2 Emission Rates in Grey Scale

In Table 47 and Table 48 the average fuel consumption rate and total emission rate during off-hours are shown to be lower than those during regular hours for the same segment, except the fuel consumption on highway segment 1. The differences are generally greater than 20% for highway and toll road segments, and greater than 50% for urban arterial road segments. We believe this is because: (i) traffic is generally much smoother during off-hours than regular hours, leading to reduced fuel consumption and emissions for off-hour deliveries; and (ii) for toll roads and urban arterials, such a ‘smoothing effect’ is more significant (e.g., vehicles stop less frequently at toll booths or signals), leading to more dramatic reductions of fuel consumption and emissions. In Figure 38 and Figure 39, these differences are shown more clearly, especially for toll road and arterial road segments. The results, therefore, confirm that OHD do help reduce fuel consumption and emissions during urban freight activities.

Summary of Findings

The investigations conducted in this project are based on freight GPS data (including three distinct formats: event-based, stop-based, and fine-grained or second-by-second GPS data) and company-specific data (including the "ground truth" delivery log files recorded by truck drivers). The results show that freight GPS data can be a valuable source for urban freight delivery performance evaluation. The mobility measures of urban freight activities such as the tour duration, number of delivery stops per tour, service time at a delivery stop, and travel times and speeds between delivery stops, can be measured relatively accurately and consistently from freight GPS data. The energy consumption and emission measures can also be measured accurately from fine-grained freight GPS data (such as second-by-second GPS data), but may not be easily measured if coarse-grained (such as event-based or stop-based) GPS data are considered. On the other hand, one should expect discrepancies between the performance measures calculated using GPS data and the "ground truth" performance measures (e.g., those calculated using log data). Discrepancies could be the result of time recording resolutions or manual errors, or different definitions of a "delivery stop" in GPS data and log data, among other reasons. The measures based on GPS data might be more accurate because of the technology's high accuracy in terms of time and objectivity. However, the discrepancies noted reflect the fact that GPS data are very accurate in showing *what* has happened, but not *why* it has happened. In other words, GPS data are relatively poor in terms of providing behavioral explanations. Therefore if possible, GPS data should be supplemented with other data sources (such as surveys or log data files) to provide more meaningful results. One should also note that currently, freight GPS data are more suitable for urban freight delivery (i.e., tour- or stop-based) performance measurements, not for network-wide performance measurements (such as route travel times, travel time reliability, etc.). Currently urban freight GPS data still represents a small sample of the entire urban traffic flow, but the suitability of this data will increase along with its availability.

Regarding the impact of the OHD policy on urban freight deliveries, the direct comparisons of delivery performances immediately before and after OHD implementation (i.e., based on the second-by-second GPS data as reported in Section 5.3) reveal that OHD can help improve delivery efficiency: it can reduce delivery service times and travel times between the warehouse and the stops. Although OHD might slightly increase the travel times between delivery stops, the decrease of the average service time and travel time between delivery stops and the warehouse is much larger than the increase in the average travel time between delivery stops. Furthermore, OHD can help dramatically reduce fuel consumption and emission rates (by over 20% in general, for the data used in this project). For deliveries on roads with significant traffic disruptions such as toll roads or urban arterials, the reductions can be over 50%. Since a company's delivery tours/stops likely remain unchanged immediately before and after OHD is implemented, the results in this research, therefore, verify that OHD can produce significant economic, social, and environmental benefits to urban areas.

The research also reveals that, in the long term, OHD could have a more profound impact on the operations of a logistics company (i.e., based on the event-based and stop-based GPS data, as reported in the first two sections of this chapter. This long-term effect of OHD indicates that if one is interested in figuring out the most direct impact of OHD (or other freight policies) to urban freight operations, before and after data should be collected immediately before and after the policy is implemented. In the long-term, companies may adapt their operations to best explore the opportunities provided by OHD (i.e., adding delivery time windows). In many cases, the company may make changes to the tours and deliveries during both regular hours and off-hours, implying that delivery activities during regular hours and off-hours can be very different. Since the logistics company knows its operations best, such changes would be made to improve the overall operational efficiency; an indication of the potential for improvement in both regular and off-hour deliveries. The research team therefore suggests that such long-term impacts of OHD be further investigated and systematically evaluated in future research.

CHAPTER 6 – ASSESSMENT OF IMPACTS

Introduction and Background

In June 2011, when the Off-Hour Delivery project implementation phase started, the project team began soliciting carriers, shippers and receivers to switch deliveries to the off-hours. Although the RITA-sponsored project ended in September 2013, NYCDOT is still actively promoting the program, and recruiting additional participants. The details related to the entire outreach project component can be found in Chapter 3; this section provides information specifically on those companies that chose to participate in the OHD program during the implementation phase.

When the implementation phase started, the team began by contacting past participants and companies that had contacted us following the project's pilot phase. During many of these conversations, especially with the larger companies, it became clear that the companies needed little convincing of the program's benefits, they already saw the long term value of shifting deliveries to the off-hours. In fact, during the period between the pilot phase completion in 2010, and the start of this implementation phase in 2011, many of their carriers and shippers had been conducting their own recruitment efforts to get receivers to accept off-hour deliveries. Several companies, including Sysco, Duane Reade, Dunkin Donuts and the GAP, that had expressed an interest in the program prior to June, 2011, had already shifted a significant portion of their deliveries to the off-hours when the team contacted them again, when the implementation phase began. This voluntary shift to the off-hours is a reflection of the acceptance and the benefits of OHD to the freight industry.

It is estimated that over 400 businesses in Manhattan shifted some of their deliveries to the off-hours. The businesses are predominantly located in Midtown and Lower Manhattan. This estimate includes businesses of various sizes that shifted after the pilot phase and through the implementation phase. It also includes businesses that did and did not receive financial incentives from the project team. Some of these businesses receive multiple deliveries per week in the off-hours, while others receive more limited overnight deliveries, such as once per week. For this program, a financial incentive of $2,000 was made available to Manhattan businesses that could demonstrate a shift to the off-hours. It was a requirement that the company had to have multiple deliveries per week shifted to the off-hours, and they had to participate for a minimum of six months. Many of the smaller companies were receptive to the financial incentive to help offset any additional costs, but for larger companies a financial incentive was not always needed. The larger companies that had multiple locations typically just started accepting off-hour deliveries once the logistics were defined, and did not want to be bothered filling out surveys and paperwork for the incentive. All of the companies that received the incentive for this phase continued accepting off-hour deliveries even after the required length of participation (six months) had passed. These businesses also indicated to the project team that they were working with their other vendors to shift additional deliveries to the off-hours.

Given this status of implementation, the research team further defines the metrics, and the process to collect them, to assess the benefits and costs of the implementation(s). Moreover, in order to ensure a successful OHD program, the team initiated the design and implementation of the evaluation plan in early stage of the project. Instead of hastily collecting necessary information by the end of the project, the team collected and analyzed data periodically. The analysis results were presented internally during the project meeting to make sure that the project is effectively carried out as planned and to identify the remaining gap between the objectives and the accomplished work.

Therefore, in addition to demonstrating the impacts of OHD, the evaluation plan in this project is also integrated with the overall project planning and implementation, and serves as an ongoing monitoring, risk management and internal review tool to enhance the effectiveness of the team's research efforts.

The following sections will present the design and implementation of the evaluation plan, including an impact assessment matrix that lists each of the pre-identified impacts, the corresponding measurement/ assessment mechanism, and resulted activities used to arrive at the evaluation procedures.

Design of Evaluation Metrics

In order to be comprehensive, the team designed an evaluation plan that quantifies the key impacts on a wide range of stakeholders. This includes the estimation of impacts on road users and communities, freight carriers, freight receivers, and the public sector. Through close collaboration between all partners, the team constructed an impact assessment matrix that covers each of the pre-identified impacts, the corresponding metrics, anticipated assessment processes, and data collection mechanism. Table 49 and Table 50 summarize this evaluation matrix.

Table 49: Impact Assessment Matrix (Part 1)

	Impacts	Metrics	Assessment Process	Data Collection Mechanism	Leader
Passenger cars	Regular hour traffic condition	Average user travel time	Modeling with local and regional traffic models		Rutgers
		Low speed operation time	Analysis based on b/a GPS data	Collect b/a GPS data from taxis, buses and participants	NYCDOT/ Rutgers
		Congestion	Show effects of trucks looking for parking; highlight number removed during peak hours	Time-lapse photography or video monitoring over an extended time period; OD data for trucks removed	NYCDOT
	Off-hour traffic condition	Average user travel time	Modeling with local and regional traffic models		Rutgers
		Low speed operation time	Analysis based on b/a GPS data	Collect b/a GPS data from taxis, buses and participants	NYCDOT/ Rutgers
Communities	Air Pollutants	Key pollutants emission levels	A post-processor using output of the BPM and air pollution models		Rutgers/ NYCDOT
	Noise	Noise measurement	B/a comparison of average ambient noise levels versus delivery noise	On-site noise level measurement	RPI/ NYCDEP
	Safety	No. of truck-related crash counts	Modeling using methodology from published research		Rutgers
Freight carriers	Productivity	Customer-to-customer space mean travel	Analysis based on b/a GPS data	Collect b/a GPS data from participants	RPI
		Service times	Analysis based on b/a GPS data	Collect b/a GPS data from participants	RPI
		Average miles traveled and number of deliveries/ tour	Analysis based on b/a GPS data	Collect b/a GPS data from participants	RPI
		Average truck load factor	B/a comparison based on survey data	Surveys 1&2: ask participants to keep records b/a implementation	RPI
		Driver stress	B/a comparison based on survey data	Survey 1: ask drivers to keep records b/a implementation	RPI
	Parking Fines	Average parking fines/tour	B/a comparison based on survey data	Surveys 1&2: ask participants to keep records	RPI/ NYCDOT
	Operational Costs	Itemized costs: fuel, labor, toll	Cost modeling based on b/a GPS data	Collect b/a GPS data from participants	RPI

Table 50: Impact Assessment Matrix (Part 2)

	Impacts	Metrics	Assessment Process	Data Collection Mechanism	Leader
Freight receivers	Reliability of delivery times	Percentage of deliveries within expected delivery window	Modeling with BMS.		RPI
			B/a comparison based on survey data.	Survey 1: ask drivers to keep records b/a implementation.	RPI
				Survey 3: ask receivers to keep records b/a implementation.	
	Delivery errors	Count of events	Analysis based on survey data.	Survey 3: ask receivers to keep records.	RPI
	Costs of doing OHD	Initial costs; Operational costs	Analysis based on survey data.	Survey 3: ask receivers to keep records.	RPI
	Property damage	Count of events; Total amount of loss	Analysis based on survey data.	Survey 3: ask receivers to keep records.	RPI
	Productivity	Average time used to receive delivery (including waiting, unloading, unpacking, etc.)	B/a comparison based on survey data.	Survey 3: ask receivers to keep records b/a implementation.	RPI
		Time gained for other duties, such as customer interaction	B/a comparison based on survey data.	Survey 3: ask receivers to keep records b/a implementation.	RPI
Public sector	Direct costs	Initial costs; Installments/Operationa l costs (to run public recognition or business assistance program)	Analysis based on records.	Acquire records from NYCDOT	NYCDOT
	Indirect costs	Administrative costs	Analysis based on records.	Acquire records from NYCDOT	NYCDOT
	Public image	Qualitative	B/a comparison based on survey data.	Focus group study: collect opinions of community (including participants and nonparticipants)	NYCDOT/ RPI
	External funding	Administrative costs associated with helping businesses apply for grants to support equipment costs, etc.		Records kept by appropriate agencies.	NYCDOT/ EPA/ NYSERDA
	Launch costs	Signs, marketing materials, etc.		Records kept by NYCDOT.	NYCDOT

After the evaluation plan was finalized, the team proceeded to collect and model data before and after the implementation for evaluation purposes. Key activities include GPS data collection and analysis, noise data collection and analysis, as well as a set of surveys and a range of modeling efforts. To the extent possible, the before data was collected to cover a period of time long enough to ensure it provides a statistically representative sample of the base case conditions. Similarly, the data collected after the implementation also aimed to cover a sufficiently long period of time to allow for meaningful conclusions to be achieved.

Each item in the evaluation plan was assigned to one group of team members, who reported progress of their efforts during project meetings. More specifically, activities taken by the team include:

- Code and isolate GPS data from taxis and buses to assess general traffic conditions. This data collection effort was also integrated with the modeling efforts include traffic modeling, environmental impact modeling, and behavioral modeling.

- Install GPS loggers on participating carriers. The data will be used as input to analyze the impact of OHD on carriers' delivery pattern and the consequent influence on environment.

- Conduct on-site noise level measurement, including assessment of surrounding environment, ambient noise level, and the noise profile throughout the delivery process.

- Collect truck-related accident data and conduct analysis to evaluate any potential safety implications caused by OHD.

- Design and conduct survey on participating drivers to assess the impact of OHD on their operation, costs, and safety. The questions include average truck load factor for every tour, percentage of deliveries made on time for every tour, potential conflict with passenger cars and pedestrians during every tour, parking fines, time spent finding parking, etc.

- Design and conduct survey on fleet operators/ carrier managers to assess the impact on the overall fleet operation. This survey supplements the survey of drivers, and collects additional information that the drivers may not be aware of. Questions include average truck load factor of the participating fleet, average dwell time, and situations like double parking and blocking of through-lanes, total number of accidents, total amount of parking fines, and average fuel usage and respective costs.

- Design and conduct survey for freight receivers to evaluate the impact of OHD on receivers. Questions include percentage of deliveries made in time, average labor hours used to receive delivery (e.g. waiting, unloading, unpacking), initial costs for participating OHD (e.g., installing necessary equipment, etc.), operational costs for participating in OHD every day (e.g., additional administrative/maintenance costs, etc.), occurrence of property damage and delivery errors, and benefits of participating in OHD, such as increased reliability and less interference with customers (qualitative).

- Conduct focus group study on community boards and business associations. Questions should involve general opinions about the effects of OHD on enhancing city's public image, awareness of transportation sustainability, and community building, etc.

More details of these data collection and analysis efforts are provided in the corresponding chapters. This chapter mainly describes the survey efforts that target carriers (including drivers and fleet managers), and receivers.

Traffic Impact Analysis

Potential benefits from an off-hour delivery (OHD) program include decreased travel times and increased travel speeds during congested time periods due to fewer commercial vehicles and trucks on the network. However, quantification of these expected benefits by developing a freight planning model is a challenging issue due to the difficulties in data collection and extensive time required for network calibration. In this section, two different approaches are provided for a precise estimation of the impacts of an OHD program to the traffic network of Manhattan and the New York metropolitan area. First, Global Positioning Systems (GPS) data collected from delivery trucks and taxis are used to forecast the potential travel time savings for shifting commercial vehicle movements to off-peak hours. Second, a readily available regional transportation planning model, New York Best Practice Model (NYBPM), which was developed by New York Metropolitan Transportation Council (NYMTC) is used to observe the effects on the entire network by manipulating the freight trip tables based on the estimated percentage of freight vehicles participating in the OHD program.

Analysis of OHD from GPS and Other Data Sources

Realistic travel time estimation for urban commercial vehicle movements is challenging due to limited observed data, the large number of Origin-Destination (OD) pairs, and high variability of travel times due to congestion. Moreover most traditional data collection methods can only provide information in an aggregated form, which is not sufficient for micro-level analysis. On the other hand, the usage of Global Positioning Systems (GPS) data for traffic monitoring and planning has been continuously growing with significant technological advances in the last two decades. In this report a practical integrated methodology is presented for using a robust source of taxi GPS data for commercial vehicle travel time prediction. Statistical methods are used to validate the provided approach and the estimations for OHD travel time savings are presented accordingly.

Background of GPS Data Analysis

Travel times in urban areas are subject to significant variations throughout the day, and specific locations may suffer from recurrent congestion. For the freight industry, poorly designed routing estimations that ignore travel time variations direct delivery trucks to congested arterials and streets, which in turn causes extra costs related to labor and customer delays. Furthermore, slow moving heavy vehicles in urban traffic aggravate traffic conditions for all users in the network, and increase negative externalities such as hazardous gas emissions and noise. Distance alone is not a good enough predictor for urban travel time estimation due to the differences in infrastructure and connectivity characteristics (e.g. turning movements) of the links. Therefore generalizing limited observed data to the entire network based on trip distances is almost impossible (Ehmke et al., 2012).

Understanding movement of commercial vehicles in urban areas is not an easy task because of the limitations of collecting a sufficient amount of disaggregate data (McCormack and Hallenbeck, 2006). Precise travel time estimation is crucial for a proposed policy change such as OHD; such estimates help to explain the policy’s expected benefits. However, traditional traffic surveillance methods such as loop-detectors or automatic vehicle identification systems are not able to deliver comprehensive data for network-wide analysis. Moreover, fixed-location equipment used for these methods comes at a high cost which makes them infeasible to install and maintain in places other than major corridors (Ehmke et al., 2012). Emerging technologies such as Global Positioning Systems (GPS) on the other hand, offer promising improvements in traffic monitoring technology and have become widely available within the last decade. Probe vehicles equipped with relatively cheap devices provide researchers with vast amounts of disaggregate traffic data that can be easily used for determining link travel speeds and detecting congested locations and traffic delays. Over the last two decades many freight companies have replaced their traditional sheet-based trip logs by GPS recordings which provide disaggregate information about trip chains, trip and customer service durations, distances, and routes(Greaves and Figliozzi, 2008).

Although the freight industry is aware of the importance of GPS-based vehicle tracking for commercial purposes, companies cannot or will not provide their information for planning or research purposes. Customer privacy and business-related strategic concerns prevent companies from sharing their GPS data and therefore available data is limited to small sets for only specific regions. However, where industry or mode-specific data is lacking, other sources of GPS data may be available to supplement available datasets. In the case of urban transportation, shared roadways and often-congested conditions lead to a somewhat homogenous distribution of traffic speeds and travel times across vehicles.

The methodology provided in this section attempts to use GPS data collected from taxi cabs to supplement the limited amount of available freight transportation data. An empirical methodology is presented for screening the noisy raw GPS data obtained from two different sources for the same network and develop time-based clusters to compare the travel times between origin-destination pairs for specific time intervals. Our approach leads to accurate commercial vehicle travel time estimations for regions where observed commercial vehicle data is limited or do not exist, by using taxi travel times that cover nearly the entire network. Obtained results can be used for predicting the travel time savings associated with the off-hour shifts. Realistic travel time estimations can also be used in the calibration process for simulation-based studies and as a result enhance the validity of the travel times obtained from simulation output.

Sources of Data

Truck GPS Data

Truck-GPS recordings were collected from two major food delivery companies that participated in the OHD pilot test during the Phase I of the "Integrative Freight Demand Management in the New York City Metropolitan Area" project. Both companies are serving the New York metropolitan area, and the GPS data consists of both regular daily operations and off-hour delivery operations that they performed during the pilot test. An extensive analysis for the savings associated with the travel time and customer service time using this GPS data was given in the Phase I final report of the project (Holguín-Veras et al., 2010b).

The first set of truck GPS data was from Baldor Specialty Foods, which was collected for a total of 6 months in 2009 and 2010 by monitoring 5 delivery trucks. Location information along with different fields such as operation status as the time of arrival to a customer ("stop"), departure ("start") and ignition on/off status were recorded with 2 minutes intervals throughout the delivery tour. Data collection was carried out in two ways: 1) driver activation was required by a simple button tap for indicating delivery tour start, stop or moving conditions, and 2) passive GPS recording for routing after driver pushes the tour start button. This method is advantageous since once the recording is completed, data analysis is much easier than with a continuous passive recording, since customer stops are clearly marked by drivers' manual effort. One of the earlier studies that used passive GPS data came up with a trip-identification algorithm that tried to identify customer stops by checking GPS coordinates (Greaves and Figliozzi, 2008). However this type of analysis may not be applicable to larger datasets because of the risk of identifying false customer stops when the truck is not moving due to congestion or traffic signals. Therefore in our methodology, manual input of drivers provides extra proof for trip identification which enhances the reliability of the data analysis.

The second set of truck GPS data was from Sysco Food delivery tours for one month of pre-pilot test period in 2009, and two months of pilot test period in 2009 and 2010. Location information was captured for every one or two minutes while the truck was moving and every half hour while it was stationary. Time stamped locations were also recorded for the arrival and departure when the truck made a stop for delivery. The final truck GPS data used in this analysis was a combination of the two datasets. A total of 4152 delivery trips between origins and destinations inside Manhattan were used. Trips included in the final dataset cover approximately 45% of the Manhattan region.

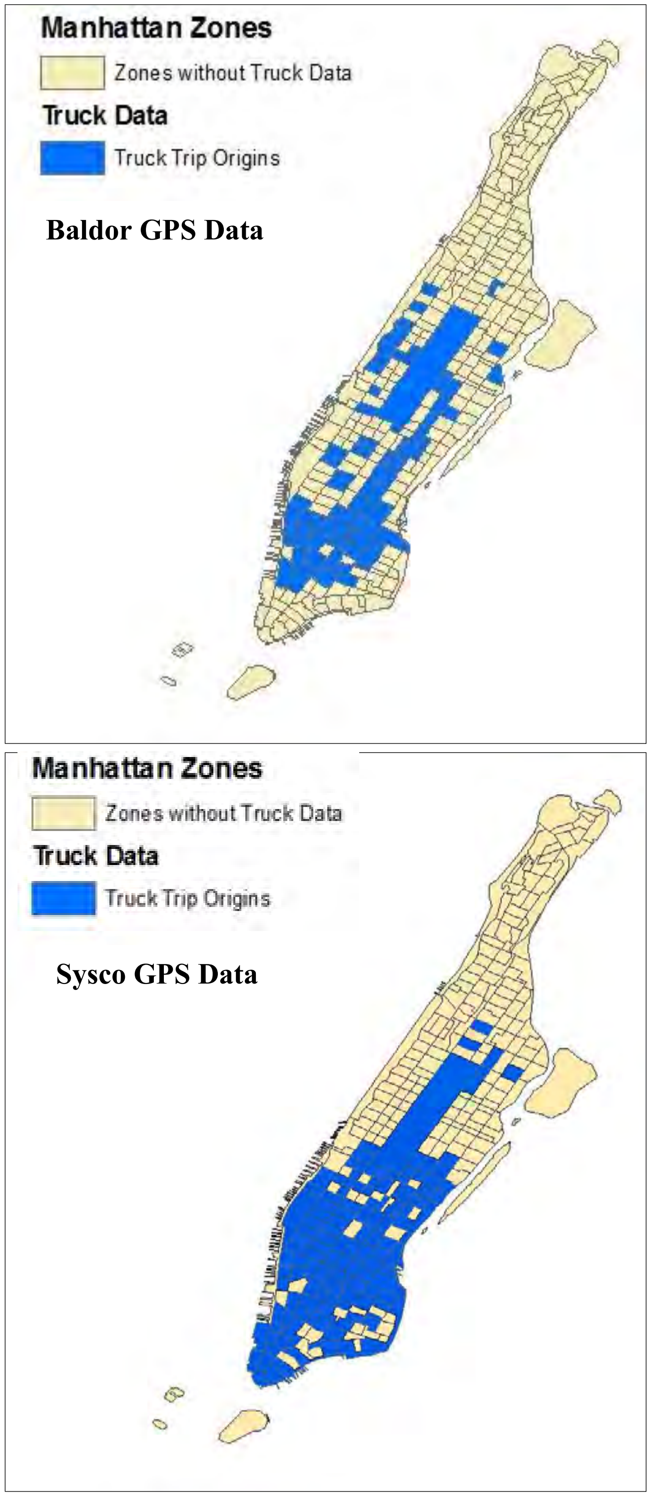


Figure 40: Truck GPS Data Area Coverage (a) Baldor Data (b) Sysco Data

Taxi GPS Data

Taxi-GPS data provided by NYC Taxi and Limousine Commission (TLC) includes more than 80 million records integrated to a single database. A trip is defined as the time period from when a customer enters and leaves the taxi; therefore empty trips are not included. Data were recorded per trip, and include fields such as trip start/stop times, trip duration, location of origins/destinations (ODs), and trip fare. Routing information was not available since it was not a continuous passive recording. In this study two years of data from 13,000 taxis covering all time periods and almost all regions in New York City were used. According to the calibrated New York Best Practice (NYBPM) travel demand model, taxi traffic accounts for 11.9% of total traffic flow in Manhattan.

Methodology

Analysis of commercial vehicle movements in urban networks generally requires consideration of a very large number of dense OD pairs compared to inter-city trips. However existing truck GPS data is not sufficient for network-wide analysis due to the lower number of commercial vehicles with respect to all other vehicles, and observations only represent a limited portion of actual trips. Figure 40 shows the observed data for truck delivery stop locations obtained from a major delivery company serving businesses in Manhattan, New York.

In this section, a practical methodology is presented for estimation of truck travel times using taxi-GPS data, and statistical comparison of available truck trip times with taxi trip times for the same OD pairs is provided. The null hypothesis that is tested in this paper is H_0: the average OD truck trip time based on observed GPS data for a given OD pair “ij” is not statistically different than the average trip travel times estimated using taxi-GPS data. With an alternative hypothesis of H_1: the average truck trip travel times obtained from truck-GPS data is statistically different from average trip travel times obtained from taxi-GPS data.

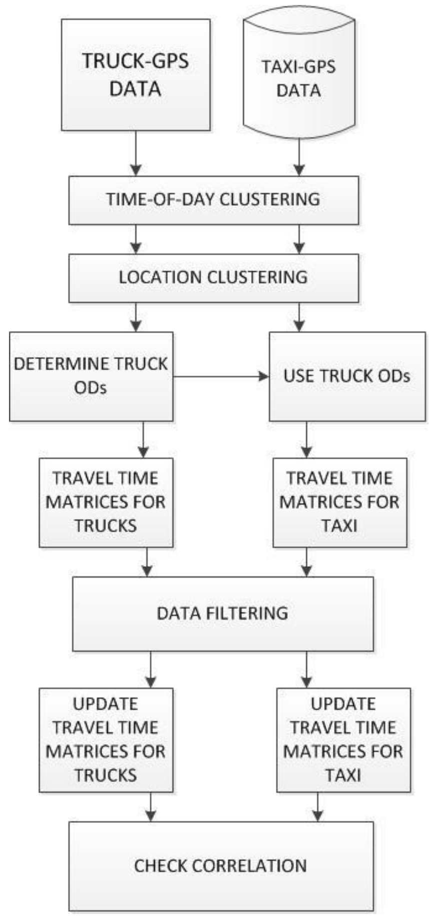


Figure 41: Data Analysis Flowchart.

Failure to reject H_0 indicates that taxi-GPS data is a viable option for estimating commercial vehicle travel times for regions where truck-GPS data is not available. Alternatively, travel time distributions can also be used depending on the size of the data. In this case a significant number of OD pairs with available truck-GPS data to conduct a distribution analysis is not available, therefore average values are employed. For taxi-GPS data, a full set of New York City taxi-GPS data is available. Statistical comparisons for hypothesis testing are carried out with average taxi travel times and travel time distributions are used for further analysis.

GPS data points need to be aggregated for useful analysis. Two types of clustering are performed; first by time-of-day and next by location. Aggregation level should be chosen carefully since too fine clustering of data points may lead to insufficient amount of data per cluster, whereas larger clusters may lead to difficulties in interpreting the results due to possible loss of detailed cluster-specific characteristics. Time-of-day clustering is done according to four time periods (AM: 6am-10am, Midday: 10am-3pm, PM: 3pm-7pm, Night, 7pm-6am). Readily available transportation analysis zones (TAZs) from the NYBPM provide spatial data aggregation for transportation planning studies. Location based clustering is performed by simple GIS geocoding techniques. A total of 318 zones are used for Manhattan, which covers a total of 33.8 sq. mi. One zone is approximately 0.1 sq. mi. large, and covers five city blocks on average. Figure 42 overlays the cluster zones and the road network in the study area.

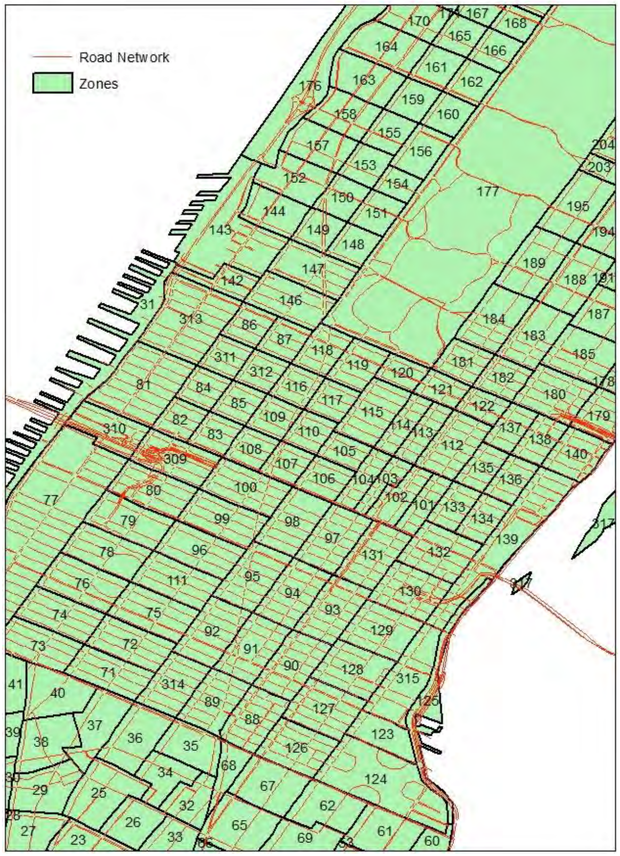


Figure 42: Manhattan Zones

A trip identification algorithm is generated for truck-GPS data to determine the exact trip start/stop locations and times, and filter trips outside of Manhattan. The algorithm checks the manual entries for vehicle statuses along with GPS coordinate information to ensure that the truck made a stop for a delivery. A total of 4,152 trips are identified from the truck-GPS dataset and these trips are classified by time of day. Taxi-GPS is clustered by the Origin-Destination pairs that are found from truck-GPS data and result in a total of 7,234 trips for the 1615 origin-destination pairs. Table 51 shows the number of matching OD pairs by time period, and total number of trips found from both datasets. 99% of the OD pairs found based on truck customer stops could be matched in the taxi data for the same time periods. A total of 1,615 OD pairs are found, which covers 45% of the entire network.

Table 51: Sample Size

Time Period		Matching OD Pairs	Number of Trips (Trucks)	Number of Trips (Taxi)
AM	(6am-10am)	239	724	1667
Midday	(10am-3pm)	674	247	1423
PM	(3pm-7pm)	471	9	38
Night	(7pm-6am)	231	802	4106
TOTAL		1615	1782	7234

Data rejection is an important step for reliable GPS data analysis, as pointed out in many of the earlier studies (Greaves and Figliozzi, 2008; Zhao and Goodchild, 2011; Ehmke et al., 2012) Major sources for false travel time measurements from GPS readings detected in this study are:

- Driver error / False entry
- GPS device malfunctioning
- Unrealistically short trips between zones (e.g. Truck changing parking spot, delivery delays, taxi trips shorter than 1 min.)
- Non-recurring traffic conditions (e.g. accidents, road work)

False measurements are generally observed as outliers in a travel time distribution between an origin-destination pair. One of the most widely used methods for outlier detection, Chauvanet's criterion, is applied to all calculated travel time distributions obtained after data processing. Chauvanet's criterion assumes a normal distribution of the data, and calculates the probability of occurrence of every single measurement in the distribution (Taylor, 1997). If there are N measurements $X_1, X_2, \ldots, X_N$ and X_{sus} is the suspicious measurement to be tested, first the deviance from the mean is calculated using

$$t_{sus} = \frac{|X_{sus} - X_{mean}|}{SD_X} \quad \textbf{(10)}$$

Where X_{mean} is the mean and SD_X is the standard deviation of all measurements. Then the probability of getting a measurement as deviant as X_{sus} is calculated by

$$n = N \times Pr(outside\ t_{sus}, SD) \quad \textbf{(11)}$$

In equation (11), n is called the threshold value, which is considered as 0.5 in most applications. Therefore, according to Chauvanet's criterion, if n<0.5, the measurement Xsus can be rejected. This method is found to be simple and effective for automatic detection for most of the outliers. However, additional manual detection is also useful for distributions that have a small number of measurements. For example, in our case it was observed that within-cluster measurements show significant variation for both taxi and truck GPS datasets. Some of the detected reasons include delivery trucks searching for a parking spot or making multiple stops for the same customer, resulting in very low travel times, or, taxis having extremely long trips within the same cluster due to driver input error, device malfunctioning, or a change in destination. Therefore in-cluster trips are excluded from the travel time analysis and comparisons are done for trips between different clusters.

Results

Travel times for each trip are calculated and the corresponding zones are considered as origin-destination pairs for both datasets. Hypothesis testing for statistical comparison of median travel time from both taxi and truck data is carried out by using the Wilcoxon signed-rank test for each OD pair. Table 52 shows the number of OD pairs and the percentages to the total sample for which the null hypothesis can be rejected at the 95% confidence interval. According to the analysis, the null hypothesis cannot be rejected at the 95% confidence level for 60% of the observed OD trips in the AM period. For the midday period, the null hypothesis cannot be rejected at the 95% confidence level for 39% of the trips. PM period trips are the lowest in sample size due to the lower frequency in truck delivery operations, and the null hypothesis cannot be rejected for 50% of the available data. Night period trips exhibit the lowest rejection rate, as the null hypothesis could not be rejected at the 95% confidence level for only 29% of the trips. These results show that daytime trip travel times associated with commercial deliveries, particularly those in the AM and PM Peak periods, can be better estimated by taxi-GPS data compared to the night period. This is most likely due to the nature of night time traffic conditions, where the network is closer to free flow conditions and vehicle characteristics or driver behavior is more likely to affect travel speeds. Since trucks generally move slower than automobiles, it is likely that they would experience slower speeds and higher travel durations than taxis during free flow conditions. This is also exhibited to a lesser degree in the Midday period.

Table 52: Wilcoxon Signed-Rank Test Results

Number of OD Pairs that H_0 is not rejected			
95% Confidence Interval			
AM	**Midday**	**PM**	**Night**
70	28	2	40
Percent of OD Pairs that H_0 is not rejected			
95% Confidence Interval			
AM	**Midday**	**PM**	**Night**
60%	39%	50%	29%

Second hypothesis testing is conducted by aggregating the travel time records using larger sample areas that are assumed to have similar traffic characteristics. Manhattan community districts are used to cluster the data points and travel times between each district obtained from taxi dataset and truck dataset are compared. There exist thirteen community districts in Manhattan, depicted in Figure 43. Two sample Kolmogorov-Smirnov (KS) test is conducted for the hypothesis testing, and the results are shown in Table 53. It can be seen that aggregation of data points in larger clusters using community districts result in a higher accuracy percentage between the two datasets for the midday, PM and night time periods (62%, 63%, and 32% respectively) compared to the results using Manhattan TAZs. For the AM period the accuracy percentage is 47% for the KS test. Figure 44 shows the data sample sizes of the OD pairs that hypothesis testing is conducted to demonstrate a possible correlation between data size and test results. The figures show that a certain trend for hypothesis testing rejection for the accuracy in travel times between the two datasets does not exist. For the AM period, OD pairs with comparably smaller sample sizes show higher accuracy whereas for the PM period the OD pairs with higher sample sizes show higher accuracy.

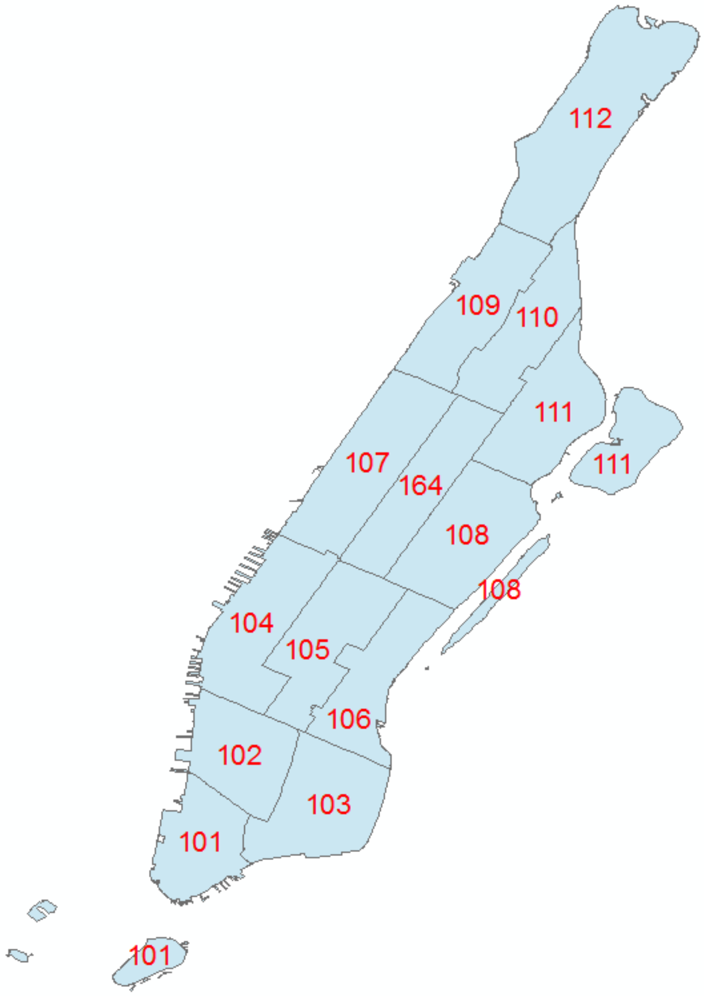


Figure 43: Manhattan Community Districts

Table 53: Two Sample Kolmogorov-Smirnov Test Results

Number of OD Pairs that H_0 is not rejected			
95% Confidence Interval			
AM	**Midday**	**PM**	**Night**
9	16	10	6
(N=19)	(N=26)	(N=16)	(N=19)
Percent of OD Pairs that H_0 is not rejected			
95% Confidence Interval			
AM	**Midday**	**PM**	**Night**
47%	62%	63%	32%

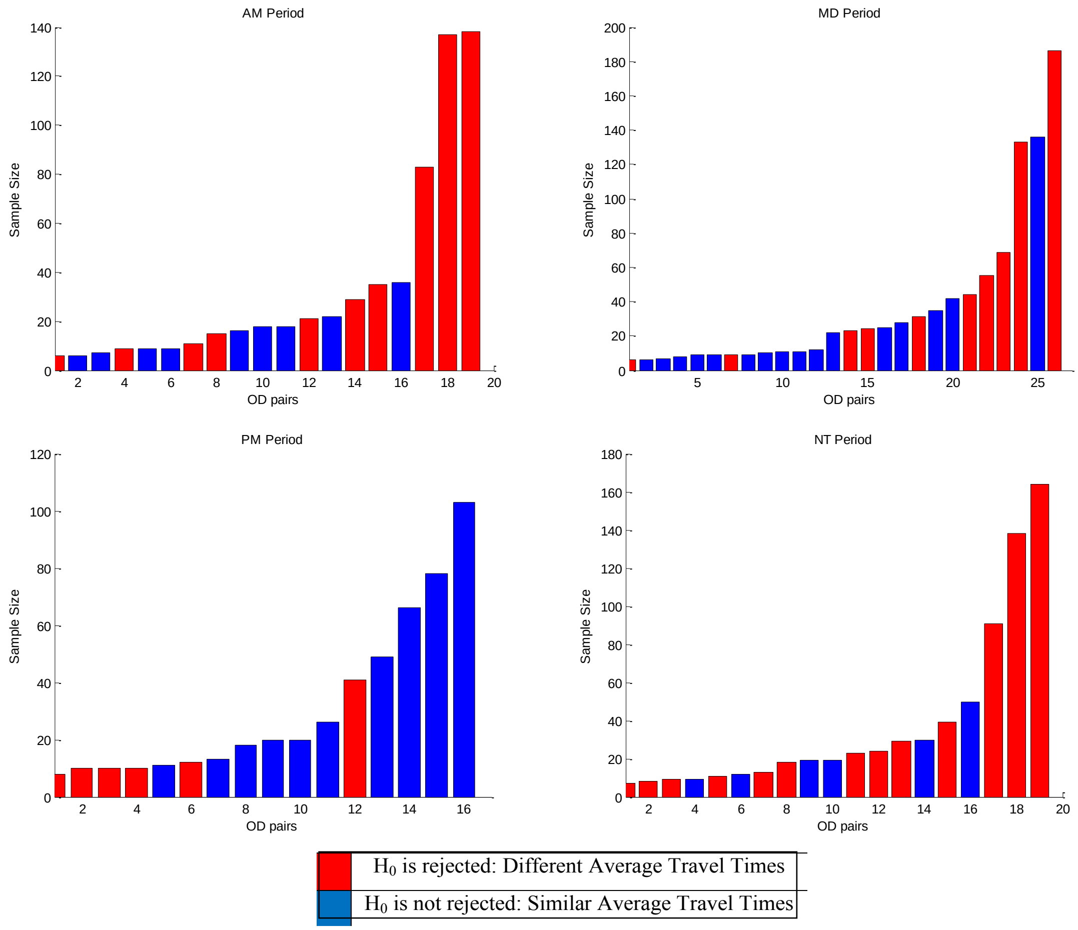


Figure 44: OD Pair Sample Sizes used in KS Test

Hypothesis testing are usually based on strong assumptions about the distribution of travel times and assumed critical values can be too strict to reject the null hypothesis. Therefore further comparison of travel times is conducted between the dispersion of travel time distributions for taxi-GPS data and central tendency of travel times for truck-GPS data. Measures of dispersion can be conducted in different ways such as standard deviation or inter-quartile difference (e.g. 90th-50th or 75th-50th). Measures of central tendency, on the other hand, include the mean or the median of travel times. It is assumed that for comparison purposes the upper tail of taxi travel time distributions is more meaningful for in-city traffic since travel speeds falling in the lower tail generally represent free flow conditions. Using this data may lead to an underestimation for realistic travel times. The probability of being exposed to delays is higher in city traffic due to several disturbances due to traffic signals or congestion, therefore the 90th-50th percentile range is chosen as the dispersion criteria. For truck-GPS data mean travel times are considered due to the smaller size of the dataset. Thus the criteria for comparison is developed as: if the mean truck travel time falls in an envelope between the 90th percentile and 50th percentile of the taxi-GPS travel time distributions, it is assumed to be a good estimation. When truck travel times do not fall into this range errors are calculated based on the difference between the closest strips of the envelope, that is either the 90th percentile value when the truck travel time is higher or the 50th percentile value when the truck travel time is lower.

Figure 44 shows the comparison results for the AM, Midday, and Night period results (PM Peak is eliminated due to low sample size). Error analysis shows that 60% of truck travel times for AM period are in the 90th-50th percentile envelope of taxi travel time distribution, and 52% and 55% for the Midday and PM periods respectively. Higher accuracy is observed in the daytime periods compared to the Night period for which only 49% of the truck trip travel times are within 90th-50th percentile of taxi travel time distribution. Table 54 summarizes the results and it is seen that a significant portion of OD travel times can be estimated within 1 minute of error (76% of AM trips, 70% of Midday trips, 74% of PM trips and 64% of Night trips). Moreover, almost all of the observed travel times are estimated within 5 minute error. Keeping in mind that these errors are strongly dependent on the observed truck trip duration, the results are very promising if a 1 minute or even 5 minute difference can be an acceptable variance for in-city trips.

Table 54: Comparison Results-Truck OD Travel Times vs Taxi OD Travel Times

Number of OD Pairs						
Time of Day	Total	Inside Envelope (50th-90th percentile)	<1 min. error	<2 min. error	<5 min. error	>5 min. error
AM (6am-10 am)	239	144	181	206	232	7
MD (10am-3pm)	674	353	473	562	666	8
PM (3pm -7pm)	471	257	349	415	468	3
NT (7pm-6am)	231	113	148	190	224	7
Time of Day		**Inside Envelope (50th-90th percentile)**	**<1 min. error**	**<2 min. error**	**<5 min. error**	**>5 min. error**
AM		60%	76%	86%	97%	3%
MD		52%	70%	83%	99%	1%
PM		55%	74%	88%	99%	1%
NT		49%	64%	82%	97%	3%

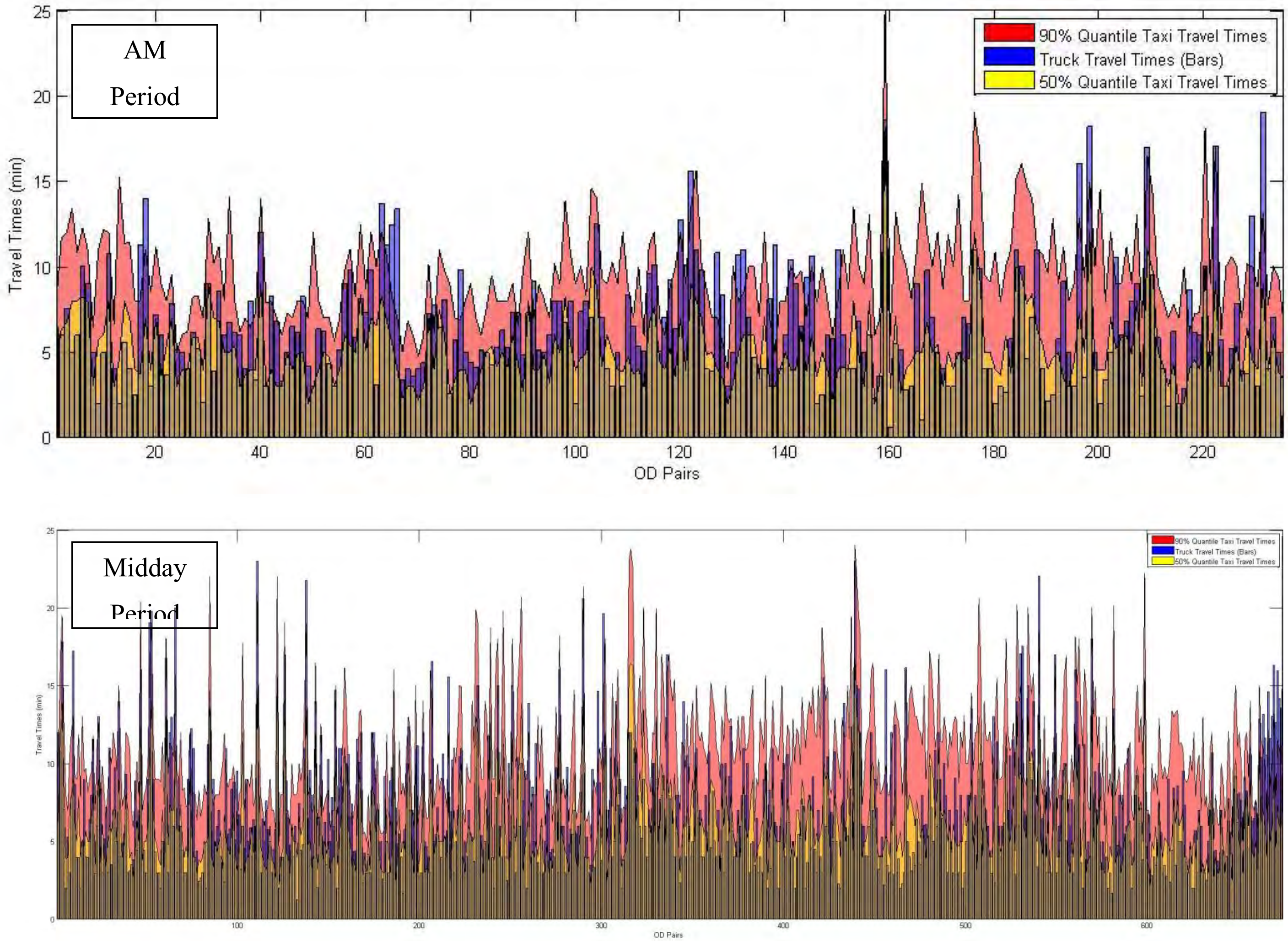


Figure 45: Travel Time Comparisons (AM and Midday Periods).

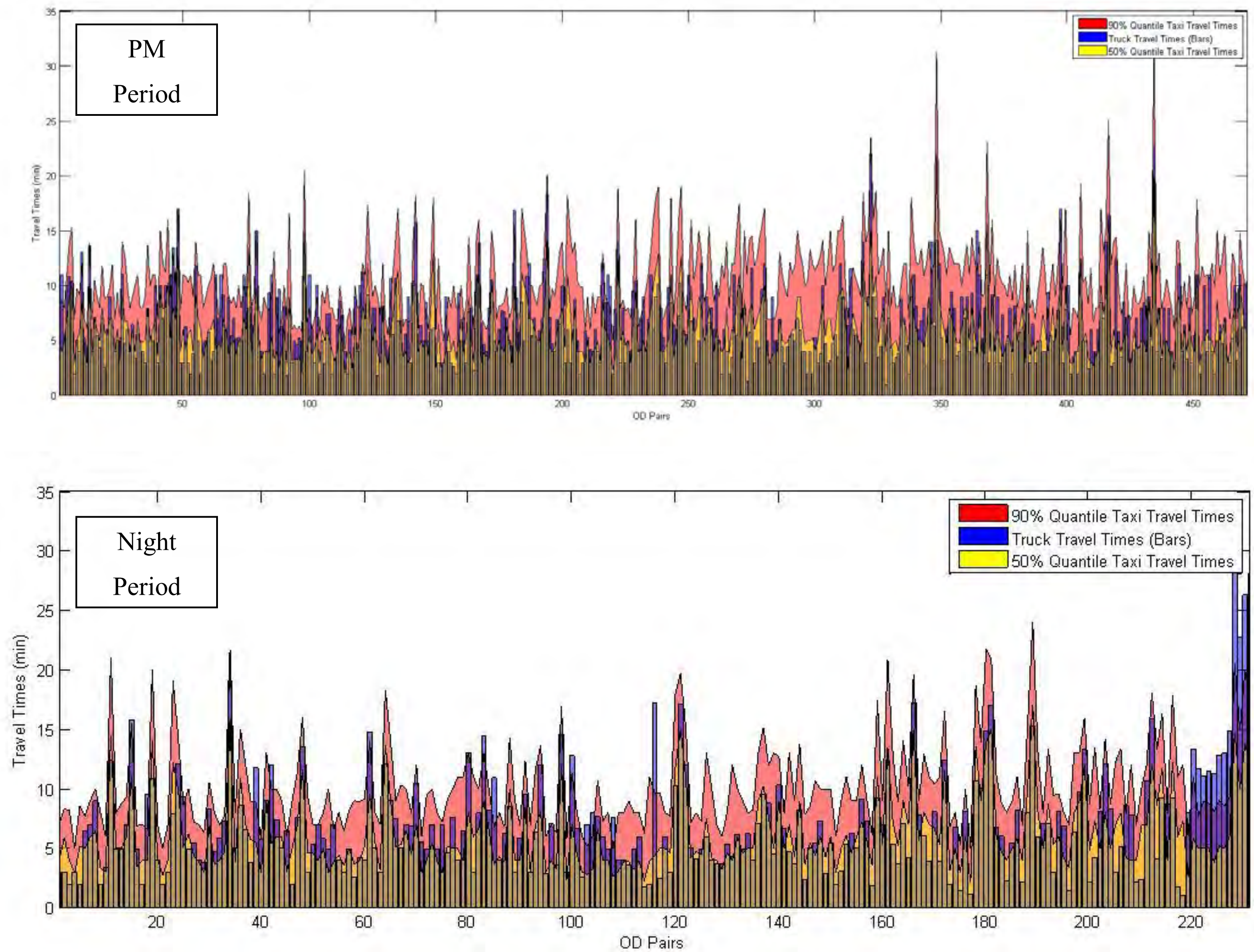


Figure 46: Travel Time Comparisons (PM and Night Periods).

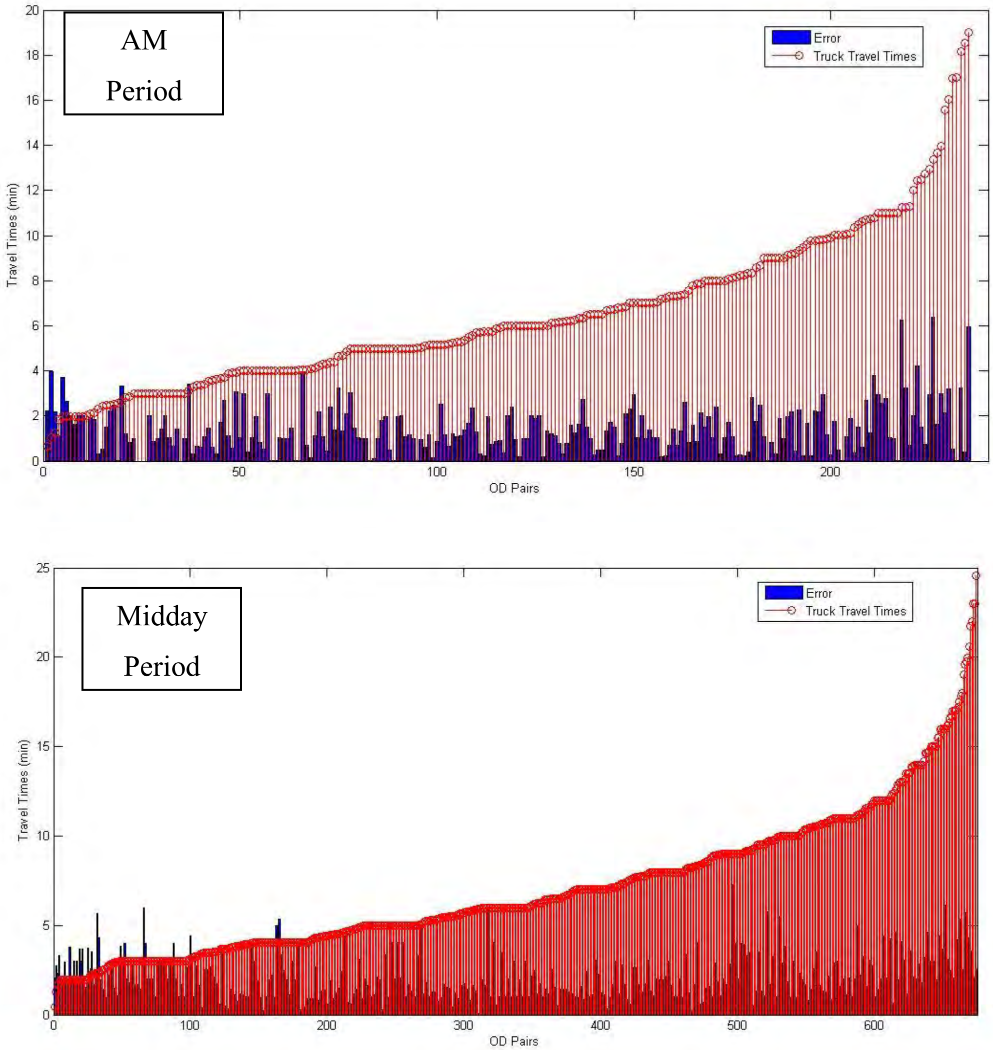
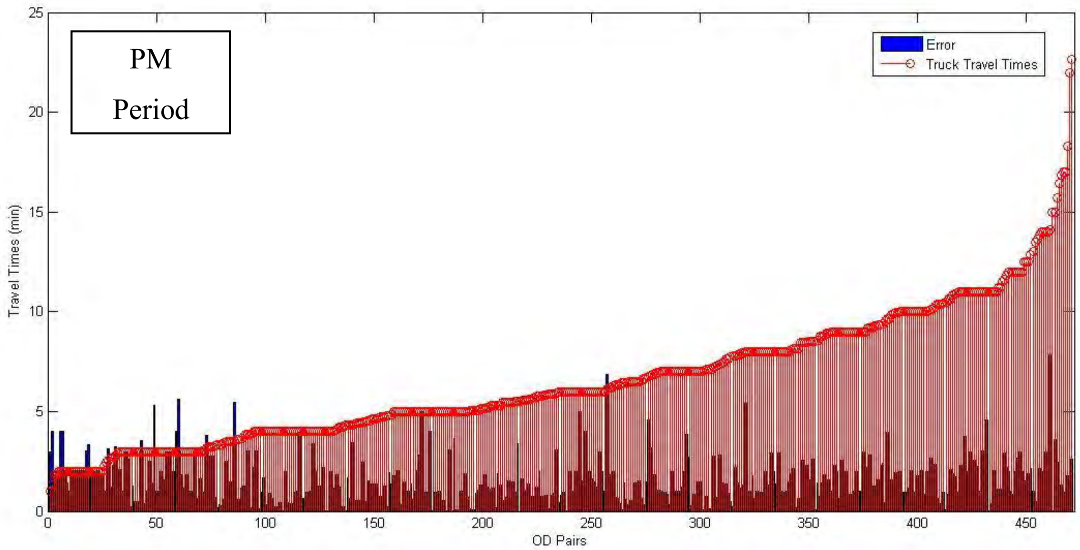


Figure 47: Distribution of Errors by Travel Time for AM and Midday Time Periods.



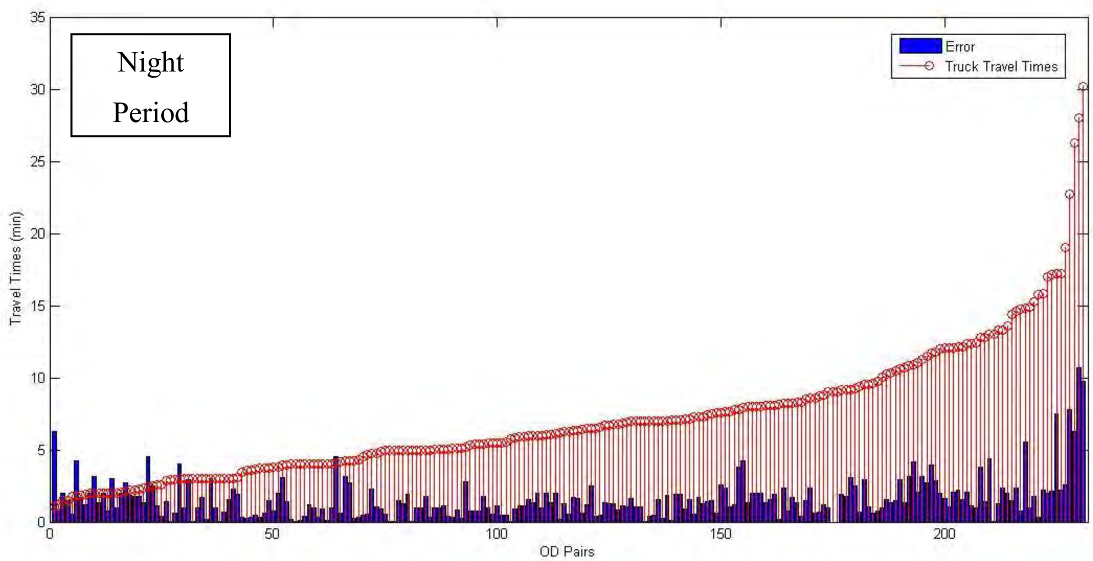


Figure 48: Distribution of Errors by Travel Time for Midday and Night Time Periods.

Figure 47 and Figure 48 shows the error for each OD pair, and their corresponding actual travel times from the truck-GPS data. The trips are sorted by ascending truck travel times and it is observed that for all time periods higher errors are concentrated mainly in the left hand of the graph corresponding to the lower travel times. Mid-range travel time values are generally estimated better considering the smaller error percentages to the actual truck measurements. Night period errors are distributed more evenly compared to daytime, and it can be observed that trips that are relatively longer can also be estimated with small error using taxi travel times. However, it should be noted that in our case it is not possible to fit a parametric distribution for the errors between the two datasets by trip duration and time of day.

Comparison results show that the developed methodology can be useful for estimating commercial vehicle travel times using the extensive amount of taxi-GPS data available. A more detailed analysis for error distributions, possibly using more data points from observed truck movements, enables generalization of the results for the remaining regions of the network. This way of analysis leads to many different applications for both delivery industry and transportation decision makers.

OHD Travel Time Savings

In this section, we estimate travel time savings from observed taxi-GPS travel times, following the results in the previous section, showing the accuracy between observed travel times in truck-GPS data. This analysis could be used to provide a solid understanding of travel time differences between customer delivery stops for different time periods of day.

In order to explore the benefits of off-hour deliveries, origin-destination pairs based on the customer locations determined from the truck-GPS data are used. The main objective is to observe the maximum benefit in travel times for a possible shift of daytime trips (e.g. AM, Midday) to the off-peak (e.g. Night period) for the same origin-destination pair. Travel time distributions from taxi-GPS data for determined OD pairs are calculated for the actual daytime trips and theoretical night trips.

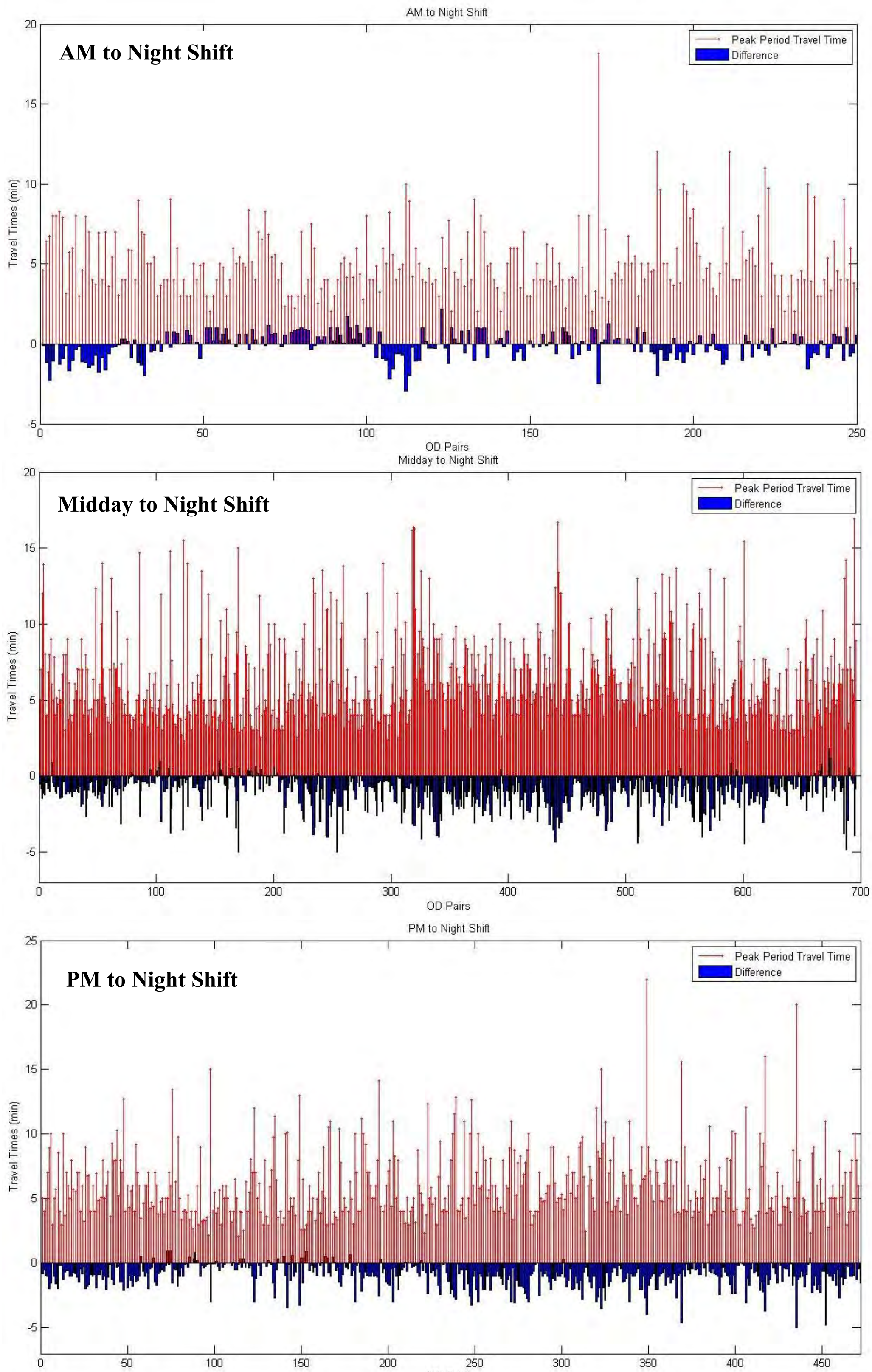


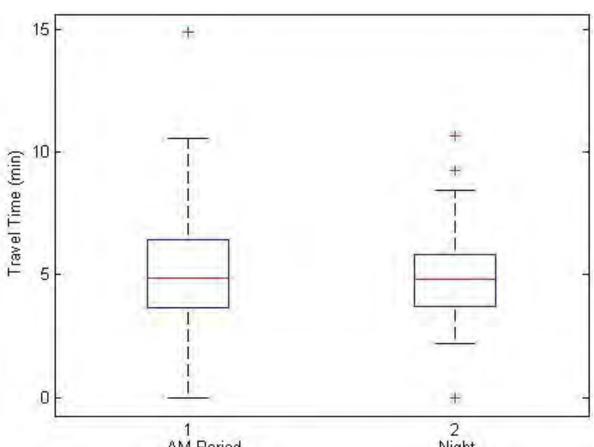
Figure 49: Travel Time Differences by Off-Hour Delivery Shifts

Figure 49 shows the median travel times for different time periods for all origin-destination pairs where customers are located. Travel times are obtained by taking the median of taxi-GPS travel time data distribution, red stem bars show the daytime travel times and blue solid bars are the differences observed when the same trip is done at the night period. A negative value in the solid bar means that night period travel times are shorter than daytime travel times. It is seen that significant improvements can be obtained in daytime to night shifts from all daytime periods (e.g. AM, Midday, PM), and the maximum travel time savings can be up to 5 minutes per trip in median travel times. As shown in Table 55 for the shifts from Midday and PM to Night period, it is seen that 93% of the analyzed trips can be performed with shorter travel times. For AM period, 57% of the trips are observed to be faster in the night period.

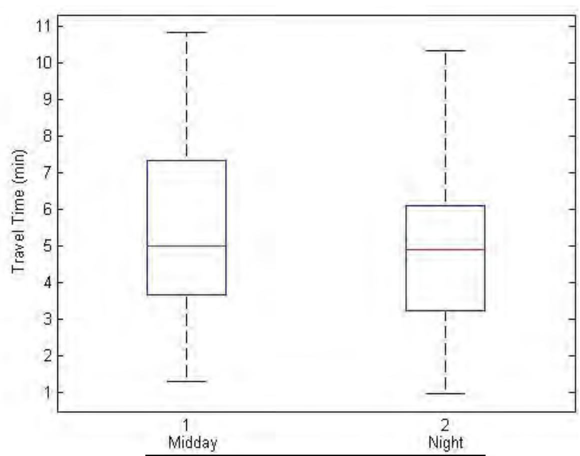
Table 55: OHD Travel Time Savings for Delivery OD Pairs in Manhattan

Time of Day	Total Number of OD Pairs	Number of OD Pairs with Shorter Travel Times During Night Period	% of Shorter Trips During the Night Period
AM (6am-10 am)	250	143	57%
MD (10am-3pm)	696	648	93%
PM (3pm -7pm)	472	439	93%

In addition to the observed savings in mean travel times, the reliability of the travel times can also be observed using the same methodology. Figure 50 shows aggregated and individual travel time distributions for the shift scenarios. Two graphs on top show the average travel times for all delivery activities during the daytime and night periods. It is observed that nighttime period distribution is more reliable as the variances showed in the box plots are smaller. Similarly, trips can also be analyzed individually, as shown in the two below graphs as examples from AM and midday shifts. In the AM to night period shift case it is clearly seen that for the analyzed origin-destination pair mean travel time is lower and the variance is much smaller in night-time. Similar results can be observed for the second example, and it can be concluded that night period travel times are more reliable for the analyzed origin-destination pairs.



All Network Aggregated Values



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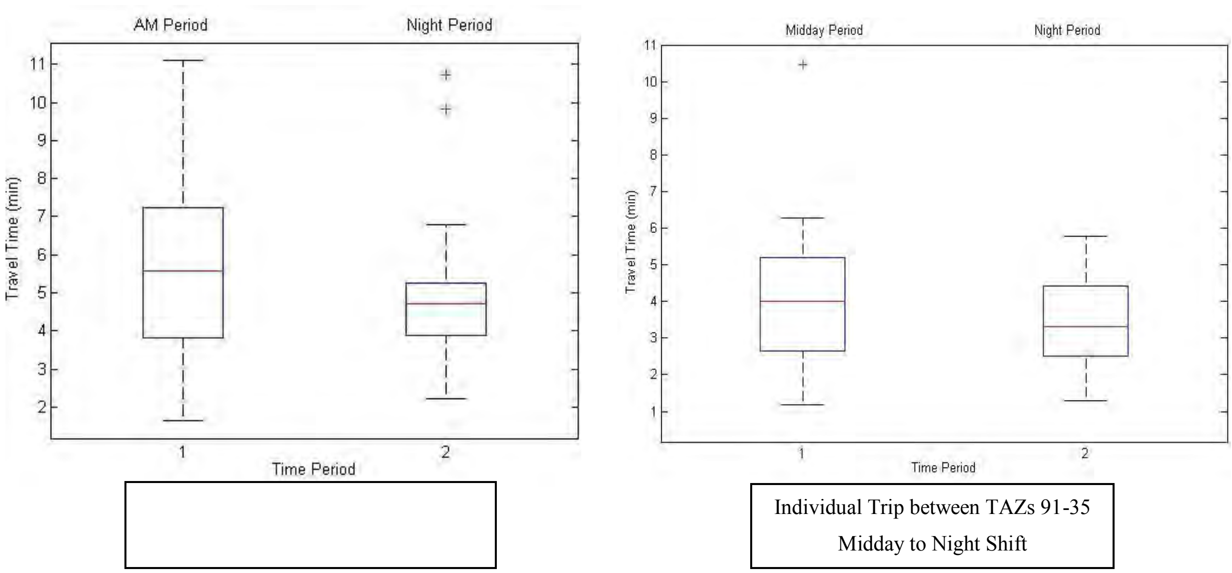


Figure 50: Travel Time Distributions for Shift Scenarios

As addressed by several studies, data associated with commercial vehicle movements are sparse and not always easily reachable (Greaves and Figliozzi, 2008; Ehmke et al., 2012). The idea of employing taxis as probe vehicles for transportation studies is becoming increasingly popular, and has been implemented for various purposes such as real-time routing, link speed estimation, and travel time estimation. This section provides a practical methodology for time-dependent commercial vehicle travel time estimation for planning purposes, by comparing a relatively small amount of available truck-GPS data with a robust database of taxi-GPS data. The presented approach has potential to be used as an accurate travel time prediction method for several different business-related applications, or it can be utilized by decision-makers for transportation planning purposes.

Analysis of OHD from Traffic Models

In order to investigate the impact of the proposed OHD program, the changes in the entire highway network are considered using NYBPM, a comprehensive macroscopic travel demand model which is developed for the TransCAD software tool. NYBPM covers almost all major transportation facilities within the Lower New York/ Western Connecticut/ Northern New Jersey region. NYBPM uses a typical four-step transportation modeling procedure, and offers particularly useful features (i.e. multi-class assignment) for the assessment of the changes in truck travel patterns(Holguín-Veras et al., 2001). A methodology is developed to assess the impacts of the shifts associated with the OHD scenarios and the findings from the simulation runs are summarized.

Macroscopic Modeling of OHD with BPM

This sub-section focuses on macroscopic network modeling to estimate the traffic impacts of the OHD program. The regional planning model Best Practice Model (BPM) is used for traffic simulation of various OHD scenarios, and benefits in terms of savings from traffic congestion decreases are presented.

Description of New BPM and Changes

The updated version of New York BPM behavioral regional model (NYBPM 2G) which was released in February 2012 is used for the traffic simulation and economic impact estimation in this report.

NYBPM 2G Model is based on the new release of TransCAD 6.0, which offers faster and more accurate results with enhanced traffic assignment methods. The new TransCAD 6.0 64-bit version uses the all available RAM memory, whereas the earlier 32-bit versions could only access a maximum of 2GB of memory which gave considerably slower performances. The NYBPM model comes with a new interface which is accessible as a new menu bar in the original TransCAD software. This new user-friendly feature makes it easier to follow the traffic assignment steps and run the models by making desired changes only within TransCAD rather than using a client software (Caliper Corporation, 2010).

The new version of BPM model uses improved travel demand forecasting function with a user-friendly Graphical User Interface (GUI) where the users can easily follow the running progress with the help of a flow-chart. Simulation running time and the memory required to execute the NYBPM has been optimized to obtain shorter process time. From the transportation demand modeling point of view, traditional trip distribution and mode choice model has been replaced by a novel model called the Mode, Destination and Stop Choice (MDSC) model. Combining the two steps enables one to model the relationship between trip destination or trip purpose and the choice of mode. Additionally MDSC includes intermediate stops in a journey with stop frequency and stop location as model parameters (NYMTC, 2013).

Scenarios from BMS

BMS scenarios tested in this sub-section define potential OHD shifts to study the effects of the OHD program on the roadway network. For the scenarios simulated in BPM regional model, individual shift factors for trucks and commercial vehicles are defined for every TAZ when the receivers accept tax incentives. Average shift factors for different tax incentive levels are given in Table 56 and Figure 51.

Table 56: Average Shift Factors for Tax Incentive Scenarios

Scenario No.	Tax Incentive Level	Average Shift Factor
OTI0K	$-	2.15%
OTI1K	$1,000	2.41%
OTI2K	$2,000	2.69%
OTI3K	$3,000	3.04%
OTI4K	$4,000	3.40%
OTI5K	$5,000	3.85%
OTI6K	$6,000	4.25%
OTI7K	$7,000	4.91%
OTI8K	$8,000	5.44%
OTI9K	$9,000	6.15%
OTI10K	$10,000	7.02%

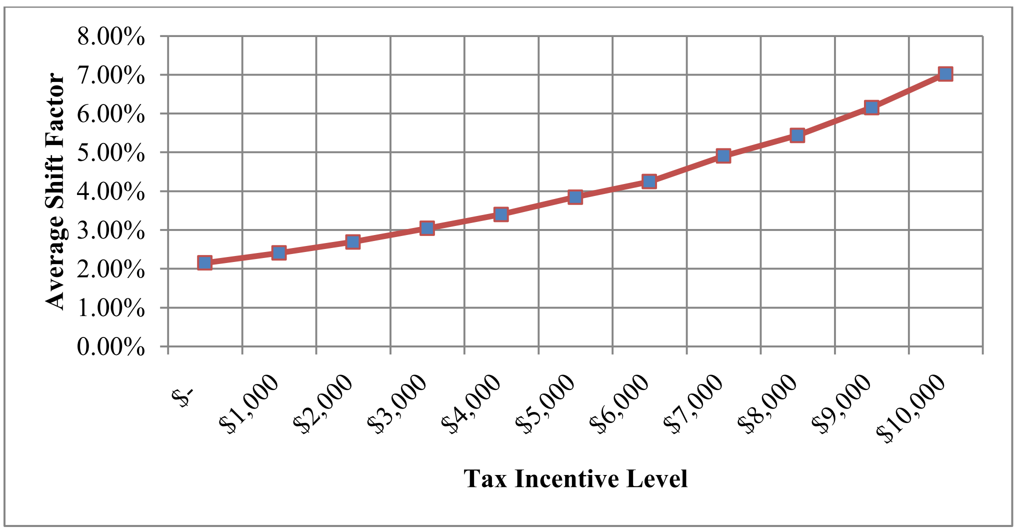


Figure 51: Average Shift Factors for Tax Incentive Scenarios

Demand-Shift Scenario Results

The traffic assignment output of the macroscopic network model BPM includes vehicle flows by class, travel time and average speed information for 53,399 links. The outputs of each OHD shift scenario is compared to the BPM base case scenario which is calibrated for the actual traffic conditions. Two important parameters for assessing the effects of OHD on traffic can be calculated using the simulation output: (1) Vehicle Miles Traveled (VMT), which gives the total distance traveled by all vehicles in the highway network on a typical day; and (2) Vehicle Hours Traveled (VHT) which is the daily sum of all travel times experienced by each vehicle in the region. Although VMT is not a direct measure for traffic congestion since the shortest route is not necessarily the fastest route, it is still an important parameter for observing the overall network performance. VHT is the direct measure of total time spent in traffic, and by extension, traffic congestion. Another important parameter for measuring traffic congestion that can be obtained from the simulation output is the volume over capacity ratio which indicates the physical occupancies on the links. Since the simulation scenarios are based on travel time shifts of trucks and commercial vehicles which have destinations in Manhattan, changes in overall network links and changes in Manhattan links are given separately.

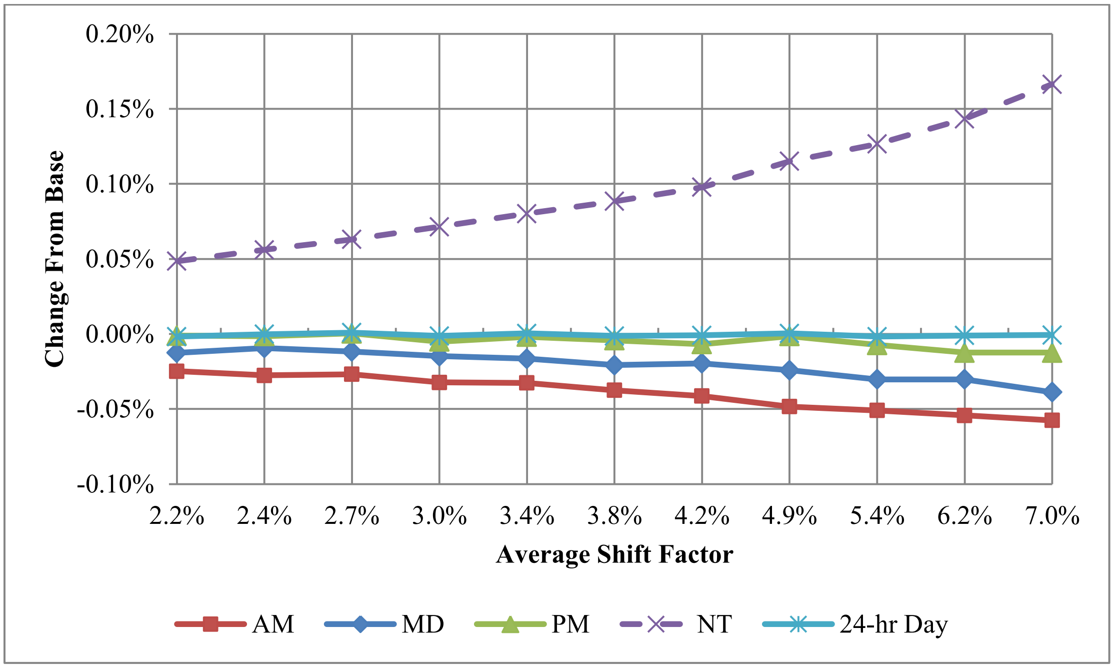


Figure 52: Change in VMT for the Entire BPM Network Links- All Manhattan Destinations Shifted

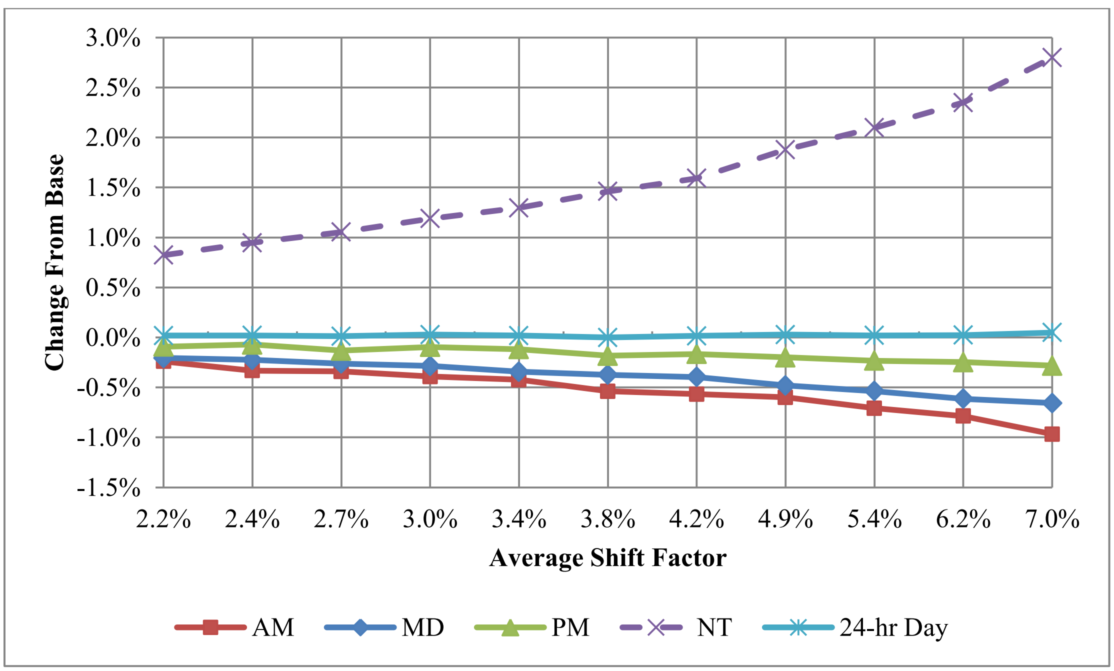


Figure 53: Change in VMT in Manhattan Links- All Manhattan Destinations Shifted

The percent changes in VMT in the entire New York City metropolitan area network of all links in BPM, and the percent changes in VMT in only Manhattan links, are given in Figure 52 and Figure 53, respectively. Daytime periods "AM-MD-PM" are presented separately while each line represents the change in VMT when the truck traffic is subtracted from this period and added to the night (NT) period.

The sum of all periods is given with the "24-hr Day" line. Similar representations are used in Figure 54 and Figure 55 which are the changes to VHT for the users in the entire network and users in only Manhattan network cases, respectively.

The figures show that as the average shift levels increase VMT and VHT both decrease for daytime periods. The composite full-day results on the other hand indicate that VMT has a stable trend for different shift scenarios. VHT for the entire network is lower than the base case for all tested scenarios meaning that combined time spent in network is lower for all of the OHD scenarios. For Manhattan links there is a slight change in full-day VHT with increasing average shift levels.

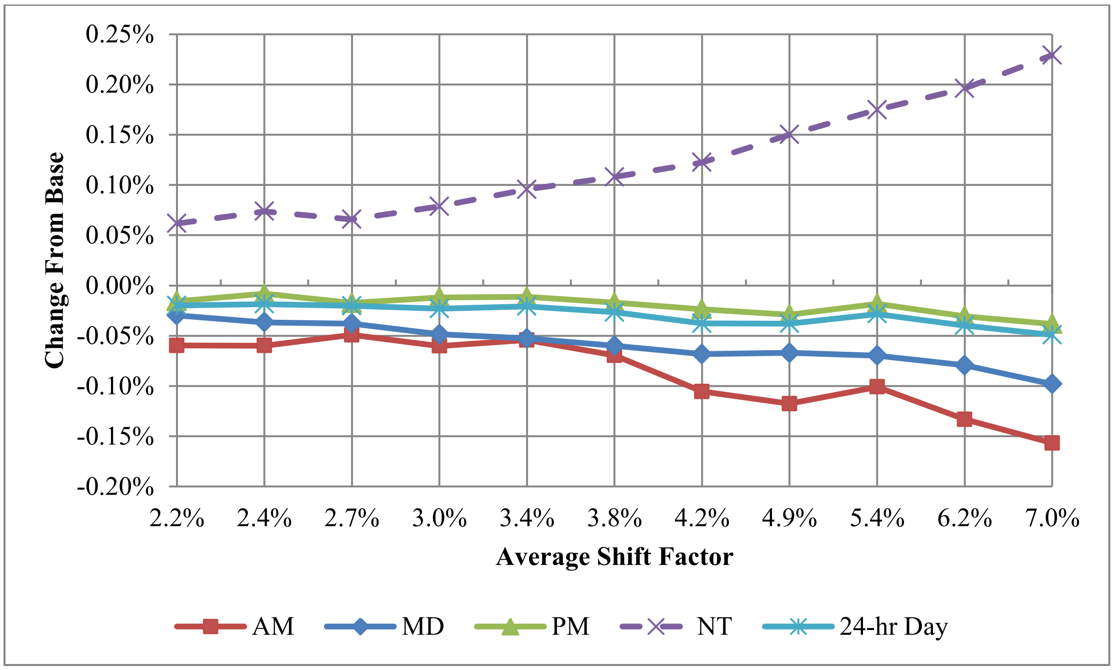


Figure 54: Change in VHT for the Entire BPM Network- All Manhattan Destinations Shifted

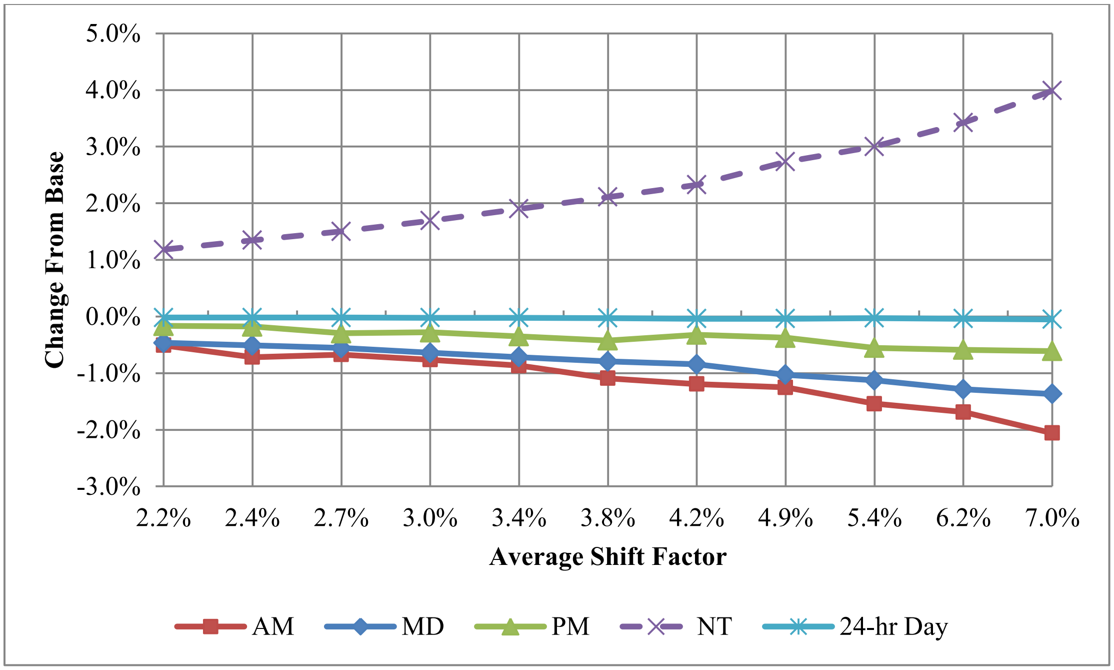


Figure 55: Change in VHT Manhattan Only- All Manhattan Destinations Shifted

The full day net changes in VMT and VHT compared to the base scenario for all network users in the OHD scenarios are given in Figure 59. For all scenarios, lower net VHT values are obtained indicating an overall saving in travel time. Figure 60 shows the daily net benefits from the OHD scenarios observed for trucks in the entire BPM simulation network. The graph shows that for all scenarios both VMT and VHT values are lower, indicating savings from both distance traveled and time spent in traffic. Similarly, as seen in Figure 61, net VHT values for commercial vehicles on Manhattan links depict the net daily savings in travel time from the simulation outputs. Another measure of congestion, the change in volume to capacity ratio for all BPM network roads is given in Figure 62. Based on the scenarios of demand shift, daytime congestion in terms of volume capacity ratio is estimated to reduce approximately 0.2% for significant demand shifts.

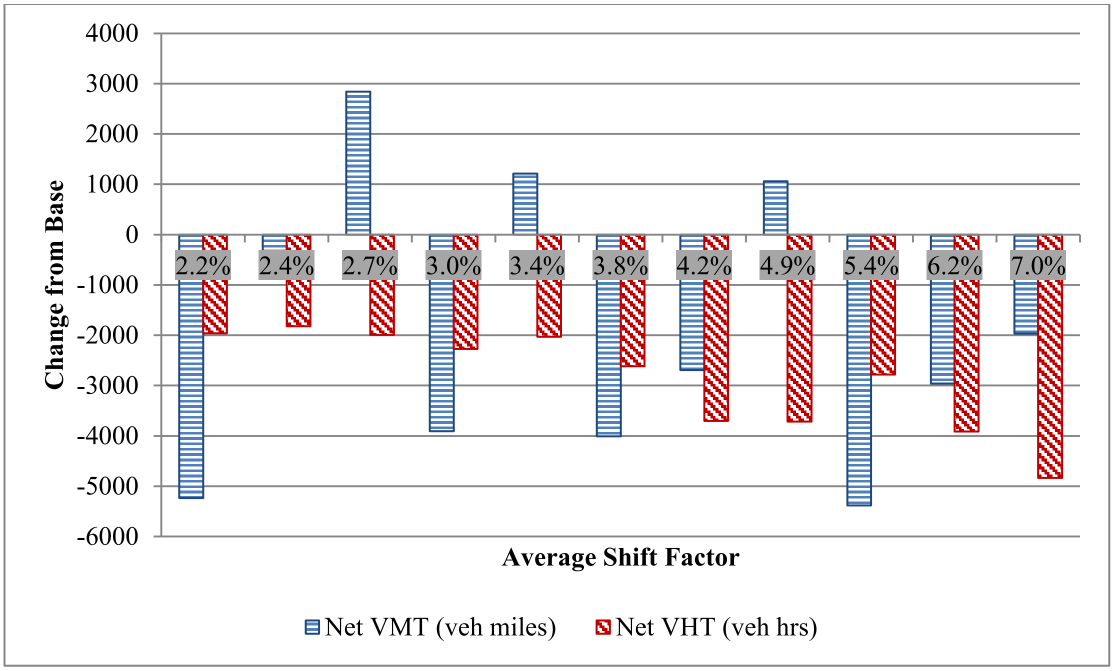


Figure 56: Network Users: Scenario Net Benefits- All Network

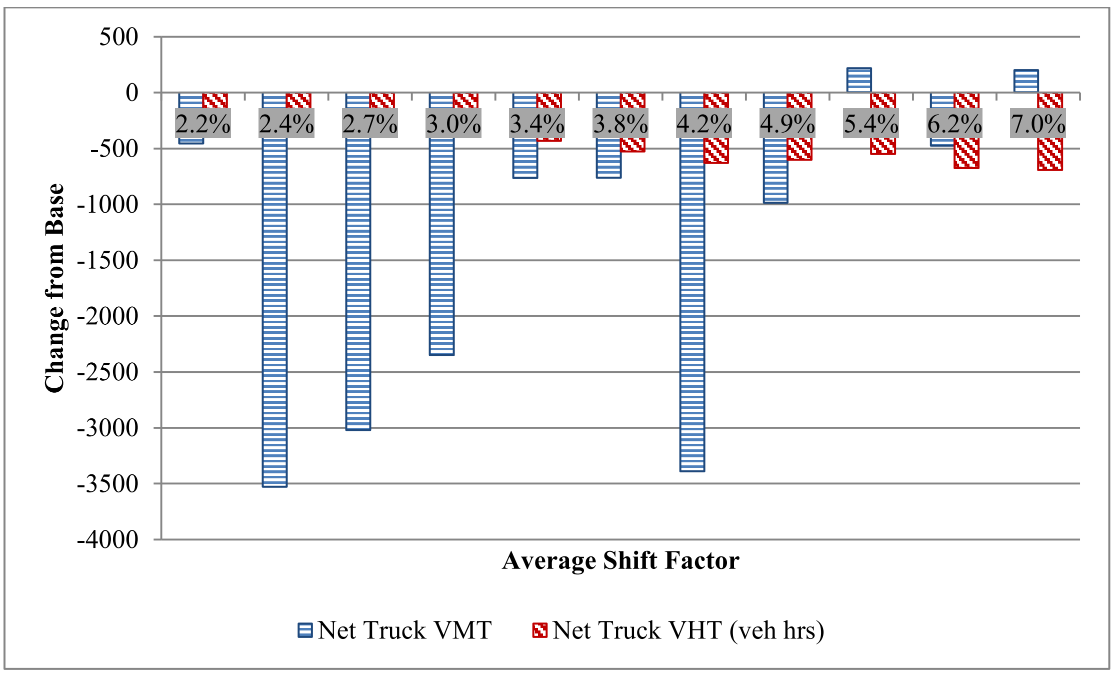


Figure 57: Trucks: Scenario Net Benefits- All Network

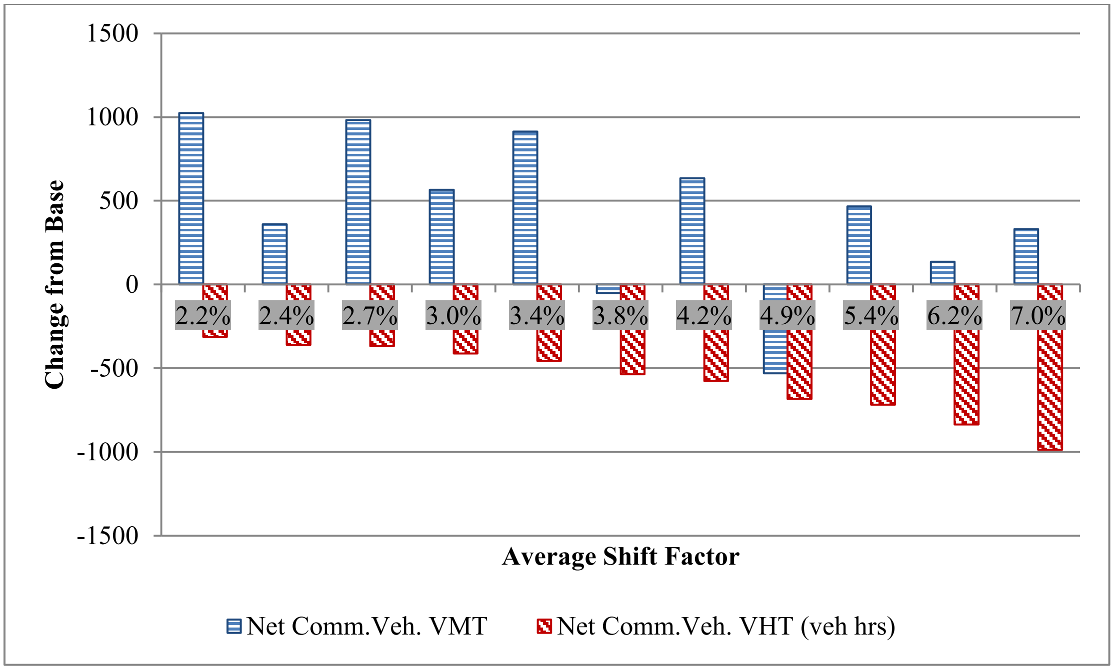


Figure 58: Commercial Vehicles: Scenario Net Benefits- All Network

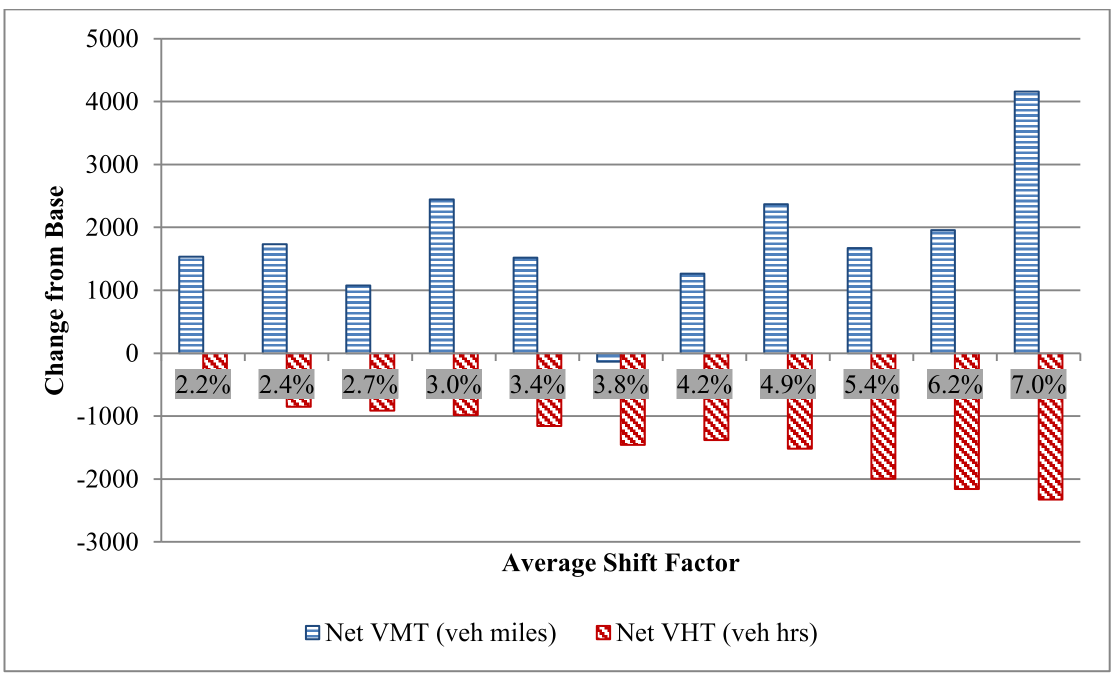


Figure 59: Network Users: Scenario Net Benefits- Manhattan Links

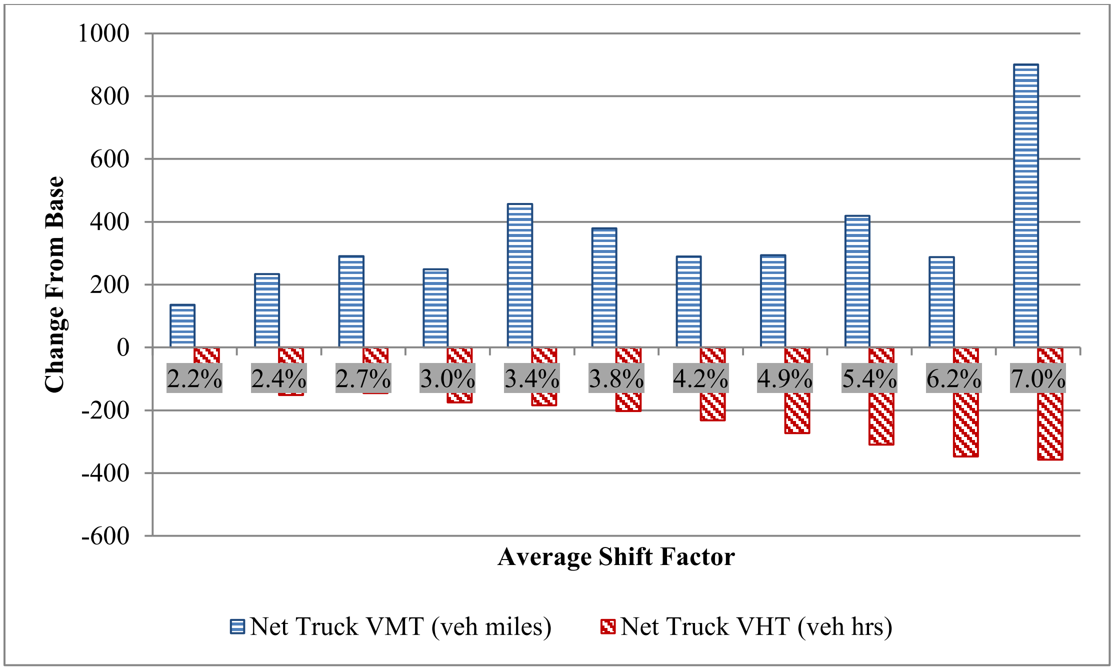


Figure 60: Trucks: Scenario Net Benefits- Manhattan Links

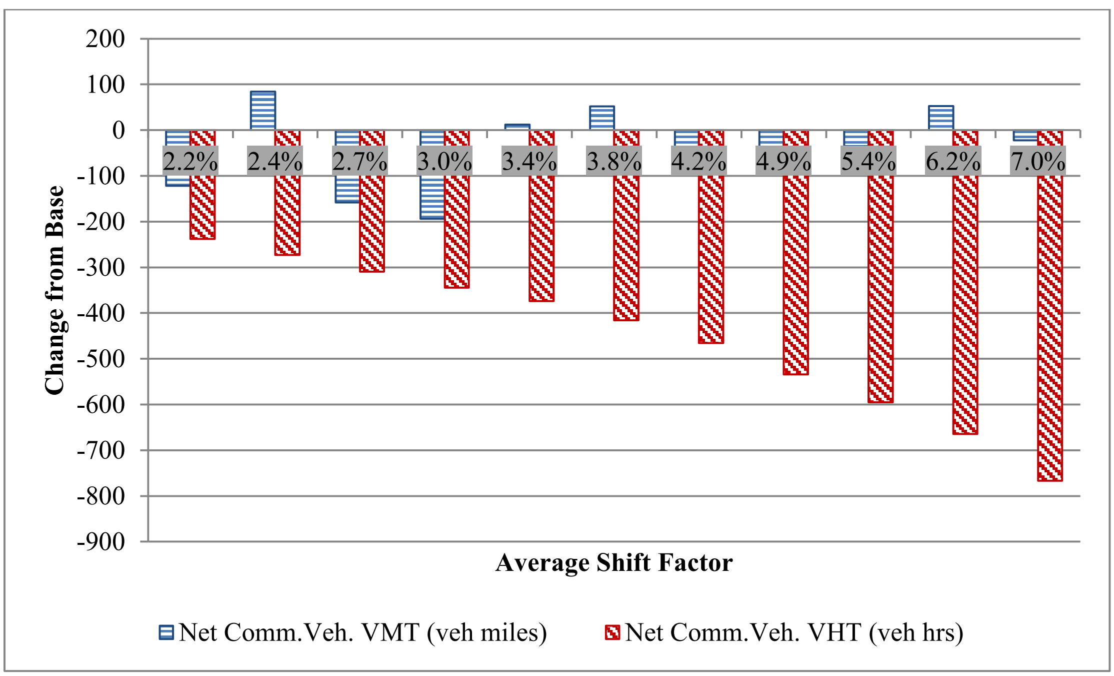


Figure 61: Commercial Vehicles: Scenario Net Benefits- Manhattan Links

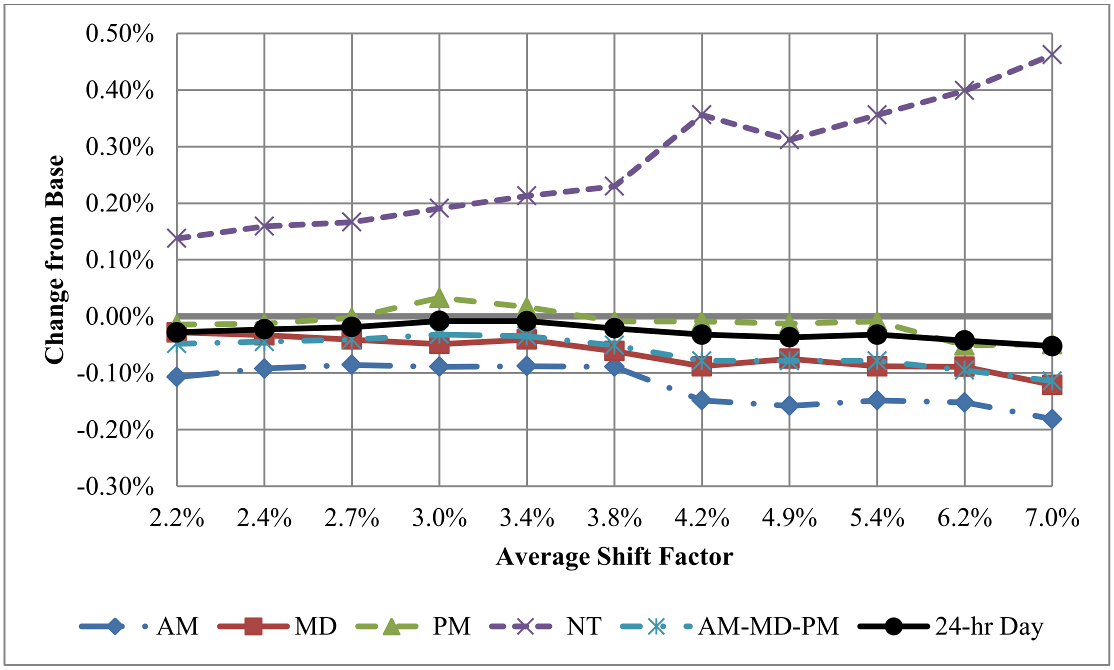


Figure 62: Change in All Network Links' Volume/Capacity Ratios

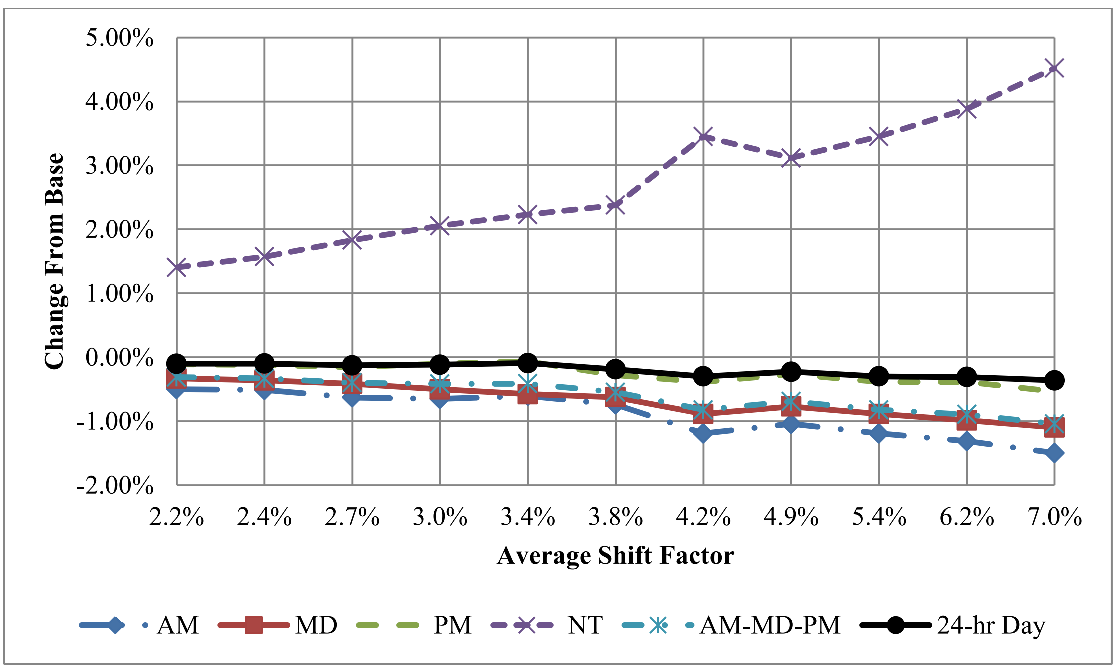


Figure 63: Change in Manhattan Links' Volume/Capacity Ratios

Discussion

This sub-section gives the traffic simulation analysis using the provided BMS scenarios based on truck and commercial vehicle shifts. The results shown in this part show the expected relationship between financial incentive scenarios and the percentage of freight traffic shifted. However it should be noted that the network assignment procedure used in the travel demand model BPM affects the simulation results. Since BPM employs user-equilibrium assignment instead of system optimal assignment, the effect of OHD to the entire system is not always desirable. For example, vehicle miles traveled do not always decrease with decreased levels of daytime truck traffic. Specifically, this can be explained as vehicles taking longer paths that are less congested, which might still save them time, as they seek to minimize their individual total trip costs. Vehicle hours traveled, however, do incrementally decrease with increasing tax incentives and therefore decreased freight traffic in most cases. It should also be noted that not all roads are represented in the BPM network since the model is developed for macro analysis.

Mesoscopic and Microscopic Modeling of OHD

There are generally two types of transportation models utilized in alternative analysis–travel demand models and traffic operations models. New York Metropolitan Transportation Council's (NYMTC) Best Practice Model (BPM), is the region's state-of-the-art multimodal travel demand model, and is utilized in regional and sub-regional analysis studies. While this level of detail is sufficient for regional analysis evaluating corridor scenarios such as the ones envisioned for 34th Street, it requires additional network and zonal detail, and a model capable of analyzing the operational effects of these scenarios.

Traffic operation models, in contrast with travel demand models, are specifically developed to assess the traffic operating conditions of congested environments.

Traffic operation models have undergone an evolution from macroscopic, to mesoscopic and to microscopic models. Methodological advances, as well as advances in the computing environment, have allowed microscopic traffic operation models to provide a detailed evaluation platform for large transportation networks.

The Manhattan Traffic Model (MTM) network development followed a two-phase approach. During the first phase, the MTM network was built from the GIS layers of the BPM and LION files and linked to a number of databases that could be used either for the Origin Destination Matrix Estimation (ODME) process (e.g., field inventory, traffic counts) or the mesoscopic/microscopic Aimsun network development (e.g., signals, transit) and validation. During the second phase, the MTM GIS network was migrated to the Aimsun environment and manually further refined.

While the BPM includes all of the avenues in Manhattan, a number of cross-streets were collapsed to a single "composite" street with the "composite" street reflecting the cumulative operating characteristics of the individual collapsed streets. For example, if 28th Street is a "composite" street in the BPM it will topologically be correct, but the number of lanes most probably will be equal to the number of lanes carried by 28th, 26th, and 24th (or some other street combination). Therefore, utilizing the LION file, the BPM network within the Primary study area will be enhanced to include all the streets and their operating characteristics, based either on field survey results or secondary sources. For the secondary study area, it has been decided that the topology and operating characteristics of the BPM will be kept. Appendix 3A provides details on the MTM modeling structure and network reconfiguration. Using this framework, the base network was created, updated, expanded, validated, and calibrated to reflect the network operational characteristics in the base year scenario. The stable base model was then modified with related truck matrices and double parking events for each incentive scenario. Multiple scenarios were created to evaluate the network response to incentive levels. For each scenario, multiple replication runs were conducted if the result was deemed to be flawed with random gridlocks.

Table 57: Total Truck Volumes for Daytime Analysis Hours

Scenario	Total Number of Trucks (trips)						
	6-7AM	7-8AM	8-9AM	9-10AM	6-10AM	Incremental demand	Incremental demand per hour
OTI0K	6,002	6,461	6,081	7,601	26,145		
OTI1K	5,989	6,447	6,068	7,585	26,089	-56	-14
OTI2K	5,979	6,437	6,058	7,573	26,047	-42	-10.5
OTI3K	5,959	6,415	6,038	7,547	25,959	-88	-22
OTI4K	5,942	6,396	6,020	7,525	25,883	-76	-19
OTI5K	5,916	6,369	5,994	7,493	25,772	-111	-27.75
OTI6K	5,902	6,354	5,980	7,475	25,711	-61	-15.25
OTI7K	5,869	6,318	5,947	7,433	25,567	-144	-36
OTI8K	5,843	6,291	5,921	7,401	25,456	-111	-27.75
OTI9K	5,808	6,253	5,886	7,357	25,304	-152	-38
OTI10K	5,766	6,208	5,842	7,303	25,119	-185	-46.25

OTI stands for the truck incentive levels. OTIXK means the monitory incentives provided to the receivers in ‘x’ thousand dollars. For example, OTI2K means total incentive package would be at the $2000 per receiver level.

The actual demand relocated to the night hours would include trucks from all the daytime hours (6 AM – 8PM). Generally, the level of added night truck demand in nighttime hours ranged from 130% to 170% of the reduced truck demand in AM peak hours. Due to uneven changes of demand levels between various OD zones, the actual total truck volumes did not follow a straight line. The total actual truck volumes were summarized in Table 58.

Table 58: Total Truck Volumes for the Night Analysis Hours

Night Time Period (10 hours: 8PM-6AM)			
Scenario	Total Number of Trucks (trips)		
	Analysis period (2 hours: 2-4AM)	Incremental demand *	Incremental demand per hour
OTI0K	2,435		
OTI1K	2,485	50	24.9
OTI2K	2,514	28	14.2
OTI3K	2,574	60	30.1
OTI4K	2,630	56	28.0
OTI5K	2,705	75	37.3
OTI6K	2,748	43	21.6
OTI7K	2,846	98	48.9
OTI8K	2,924	79	39.4
OTI9K	3,027	103	51.5
OTI10K	3,156	129	64.5

**The diverted truck demand in the AM peak hours was supposed to scattered to 10 night hours (8 PM – 6 AM) when most of the streets only carry light traffic. For conservative analysis, the incremental hourly truck demand during night hours is higher than the average hourly reduction during AM hours.*

The total vehicular demand is more than 83,000 trips per hour in the daytime study period in the Midtown study area. The difference of detoured truck demand was averaged 14 - 46 per hour or 0.02%-

0.06% of the overall vehicular demand in the four analytical hours. The performance difference would be very subtle at the 1000 individual intersections. For meaningful comparison of scenarios, the measurements-of-effectiveness (MOEs) was only limited to Vehicle Mile Traveled (VMT) and Vehicle Hours Traveled (VHT).

Network Level Traffic Impacts: Vehicle Mile Traveled (VMT) Daytime Analysis

The Vehicle Mile Traveled (VMT) was the total of distance traveled for each vehicle. The micro-simulation output table provided the average number of vehicles for each link. The link distance can be obtained from the ArcGIS tools. The ArcGIS records were linked back to the Aimsun output table to update the link distance for each record. The total travel distances for all vehicles on a specific link can be calculated in Equation $\boldsymbol{Vehicle\ feet\ traveled}\ (\boldsymbol{veh} * \boldsymbol{feet}) = \boldsymbol{Flow}(\boldsymbol{veh})\ \boldsymbol{X\ Link\ Distance}\ (\boldsymbol{ft})$ (12).

$$\boldsymbol{Vehicle\ feet\ traveled}\ (\boldsymbol{veh} * \boldsymbol{feet}) = \boldsymbol{Flow}(\boldsymbol{veh})\ \boldsymbol{X\ Link\ Distance}\ (\boldsymbol{ft}) \qquad \textbf{(12)}$$

Table 59 illustrated the calculation results for various OTI scenarios, simulation replications, time periods, vehicle types, and link types.

Table 59: Vehicle Travel Distance Estimation from Simulation Output

OTIno	did	oid	sid	ent	vehType	linkType	flow	linkLen	VFT
5	14987016	13701695	0	1		5	313	190	59603
5	14987016	13701695	1	1	21	5	309	190	58841
5	14987016	13701695	2	1	52	5	1	190	190
5	14987016	13701695	6	1	42	5	3	190	571
5	14987016	13701695	0	2		5	391	190	74456
5	14987016	13701695	1	2	21	5	379	190	72171
5	14987016	13701695	2	2	52	5	4	190	762
5	14987016	13701695	4	2	21	5	1	190	190
5	14987016	13701695	6	2	42	5	7	190	1333
5	14987016	13701695	0	3		5	385	190	73313
5	14987016	13701695	1	3	21	5	376	190	71600
5	14987016	13701695	2	3	52	5	1	190	190
5	14987016	13701695	4	3	21	5	3	190	571
5	14987016	13701695	6	3	42	5	5	190	952
5	14987016	13701695	0	4		5	428	190	81502

After calculating vehicle feet traveled for each individual link, the overall vehicle miles traveled can be summarized for the subgroups classified by OTI scenarios, simulation replications, time periods, vehicle types, and link types. The following formula was used to convert vehicle feet traveled to vehicle mile traveled:

$$Vehicle\ mile\ traveled\ (veh * miles) = Vehicle\ feet\ traveled\ (veh * feet)/5280 \qquad \textbf{(13)}$$

The overall VMT difference between scenarios did not show a consistent VMT decreasing trend following the increased number of trucks diverting to off-peak hours. Figure 64 illustrates the trend of the VMT values.

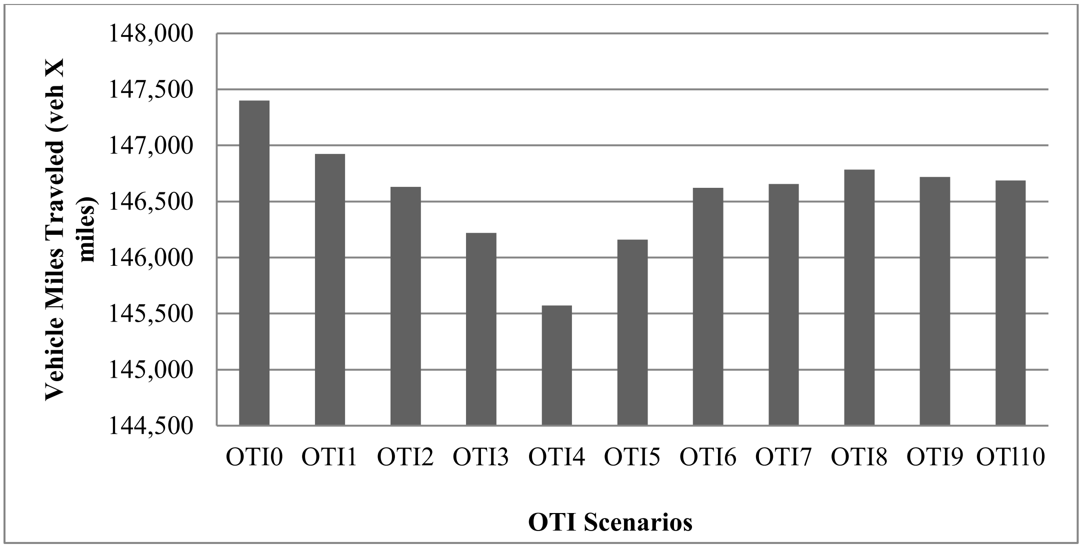


Figure 64: Daytime (8-9am) VMT for All Vehicles in the Overall Network

From Figure 64, the overall VMT from Scenario OTI0 to Scenario OTI4 was consistently reduced from 147,400 vehicle miles to 145,600 vehicle miles with the incremental financial incentives.

The daytime network-wide VMT result is listed in Table 60.

Table 60: Network-Wide Daytime VMT Analysis

Scenario IDs	Vehicle Miles Traveled (VMT)	Incremental VMT	Incremental Truck Demand	VMT Reduction per Diverted Truck
OTI0k	147,400			
OTI1k	146,923	-477.2	-14	34.1
OTI2k	146,631	-291.4	-10.5	27.8
OTI3k	146,219	-412.3	-22	18.7
OTI4k	145,574	-645.6	-19	34
OTI5k	146,159	585.7	-27.8	-21.1
OTI6k	146,622	462.8	-15.3	-30.3
OTI7k	146,657	34.9	-36	-1
OTI8k	146,784	126.8	-27.8	-4.6
OTI9k	146,720	-64.3	-38	1.7
OTI10k	146,689	-30.9	-46.3	0.7
Total	1,612,377	-711.5	-256.5	2.8*

**This value represented network-wide VMT reduction per diverted truck between OTI0K to OTI10K.*

To evaluate the benefit to traffic operations, the truck demand difference of each scenario was cited for detail comparison. The truck demand was listed at column as "Incremental Truck Demand". The VMT reduction rate per diverted truck was calculated using the following formula:

$$\boldsymbol{VMT\ Reduction\ Rate\ per\ Truck} = \frac{\boldsymbol{Vehicle\ Miles\ Traveled\ (veh{*}miles)}}{\boldsymbol{Number\ of\ Trucks}} \qquad \textbf{(14)}$$

The VMT reduction rate was listed as the last column in Table 60. From the last column in the table, the reduction of VMT rate ranged between 18 and 35 vehicle miles per truck trip removal for the additional $1000 incentives.

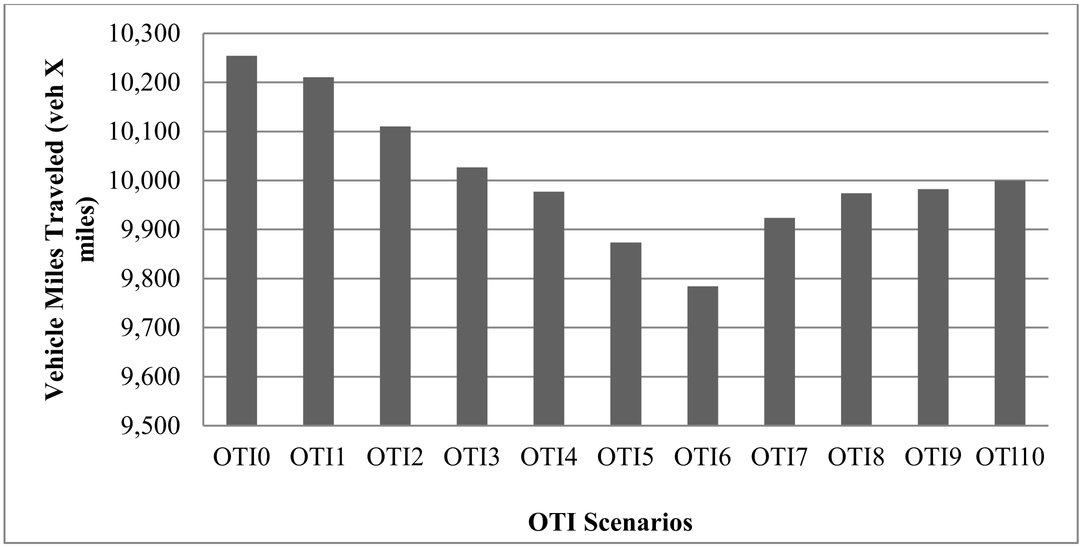


Figure 65: Daytime (8-9am) VMT for Trucks Only in the Overall Network

From Scenario OTI4, the overall VMT started to increase gradually to OTI8. The trend displays a typical paradox phenomenon for congestion mitigations. Further investigation of the simulation animation indicated that the traffic network usually operated well for these scenarios. More vehicles were able to move in the network to complete their trip for scenario OTI5 to OTI10, than scenario OTI0 to OTI4. The number of participating trucks was accumulated to a significant level so that the network operations were improved in the critical bottlenecks. The same vehicles can travel more miles in a less congested network.

The overall average VMT reduction rate was 2.8 vehicle mile per diverted truck, including the newly induced VMT by relieving network congestion. This number does not reflect the actual VMT savings by the participating trucks without induced VMT from general traffic.

The overall VMT decreased slightly from OTI8 to OTI10. The reduction of the truck VMT itself would greatly improve traffic operations for these scenarios. More vehicles would be able to choose shorter routes so that the overall VMT can be reduced with fewer miles than the low incentive scenarios.

To identify the amount of VMT reduction by the participating trucks themselves, the truck VMT output was summarized separately in Table 61.

Table 61: Network-Wide Daytime Truck VMT

Scenario IDs	Vehicle Miles Traveled (VMT)	Incremental VMT	Incremental Truck Demand	VMT Reduction per Diverted Truck
OTI0	10,254			
OTI1	10,211	-44	-14	3.12
OTI2	10,110	-101	-10.5	9.58
OTI3	10,027	-83	-22	3.79
OTI4	9,977	-50	-19	2.63
OTI5	9,873	-104	-27.8	3.73
OTI6	9,784	-89	-15.3	5.81
OTI7	9,924	139	-36	-3.87
OTI8	9,974	50	-27.8	-1.81
OTI9	9,982	8	-38	-0.22
OTI10	9,999	17	-46.3	-0.36
Total	110,116	-255	-257	1

From Table 61, the truck VMT reduction rate was generally three to five miles per truck, except a significant reduction for OTI2. OTI2 was a rare case with truck VMT reduction in the OD pairs with relatively long travel distances and long traversing routes in the study network. Travel distances of trucks would include the distance approaching the destination in the study network. It is averaged to a three to five mile range for the internal truck trips.

Compared with the VMT reduction rate column on Table 60, it could be concluded that the reduction of truck demand would generally bring the network-wide VMT reduction benefit at 6-10 times of truck VMT reduction itself.

The truck VMT values were illustrated in Figure 65. The truck VMT reduction rates were attributed directly to the participating trucks. The VMT trend showed a consistent decrement line from OIT0 to OTI6, and a consistent incremental curve from OTI6 to OTI10. Compared with Figure 64, the truck VMT trend is as similar as the general vehicle trend in a lagged pattern. The general traffic was more sensitive to the impact of reduced truck traffic and double parking events than the remaining truck flow.

Network Level Traffic Impacts: Vehicle Mile Traveled (VMT) Nighttime Analysis

New York Metropolitan Transportation Council (NYMTC) conducted extensive, socio-economic data collection, traffic counts, travel time, and OD data to develop the Best Practice Model (BPM). The BPM has a nighttime scenario extending from 8 PM to 6 AM. The demand matrices of nighttime model simulations were created on the basis of the NYCDOT nighttime counts, and the BPM seed matrices from the subarea extraction process.

In normal traffic conditions, no serious congestion was observed in the nighttime hours except for temporary construction closures, event closures, or emergency street closures. The nighttime model reached equivalence in about half an hour in the microscopic simulation area. Therefore, only two average modeling hours were determined to be enough in the nighttime. Intensive validation and calibration were conducted using traffic counts between 3 AM and 4 AM against the simulation output in the second simulation hour.

To simplify the modeling process, only one replication was conducted for each scenario in the nighttime model. The overall VMT output was summarized separately in Table 62 as follows:

Table 62: Network-wide Nighttime VMT

Scenario IDs	Vehicle Miles Traveled (VMT)	Incremental VMT	Incremental Truck Demand	VMT Reduction per Diverted Truck
OTI0	20,239			
OTI1	20,221	-18	24.9	-0.71
OTI2	20,321	100	14.2	7.03
OTI3	20,330	9	30.1	0.31
OTI4	20,347	16	28	0.58
OTI5	20,285	-61	37.3	-1.64
OTI6	20,475	189	21.6	8.76
OTI7	20,414	-61	48.9	-1.24
OTI8	20,459	45	39.4	1.13
OTI9	20,473	15	51.5	0.29
OTI10	20,565	92	64.5	1.42
Total	224,129	326	360	0.91

Due the random variation of simulation seeds, three scenarios displayed irregular trends: Scenario OTI1 with a VMT reduction of 18 vehicle miles, Scenario OTI5 and OTI7 with VMT reduction of 61 vehicle miles. However, the overall results formed to a consistent incremental line from OTI0 to OTI10 as shown in Figure 66. The average incremental VMT was deemed to be adequate to represent the VMT trend for the consistent line. Further simulation runs were not conducted.

At night, the network operates well and no induced demand significance was observed. The overall incremental VMT rate per diverted truck was therefore reflecting the impact level of 0.90 vehicle miles per participating truck trip. Compared with daytime scenarios from OTI0k to OTI4k, the average VMT reduction in the daytime would be much higher than the VMT increment in the nighttime hours for the same truck trip. The daytime scenarios from OTI5k to OTI10k indicated additional benefits of congestion alleviation, which was not measurable simply by the VMT trend.

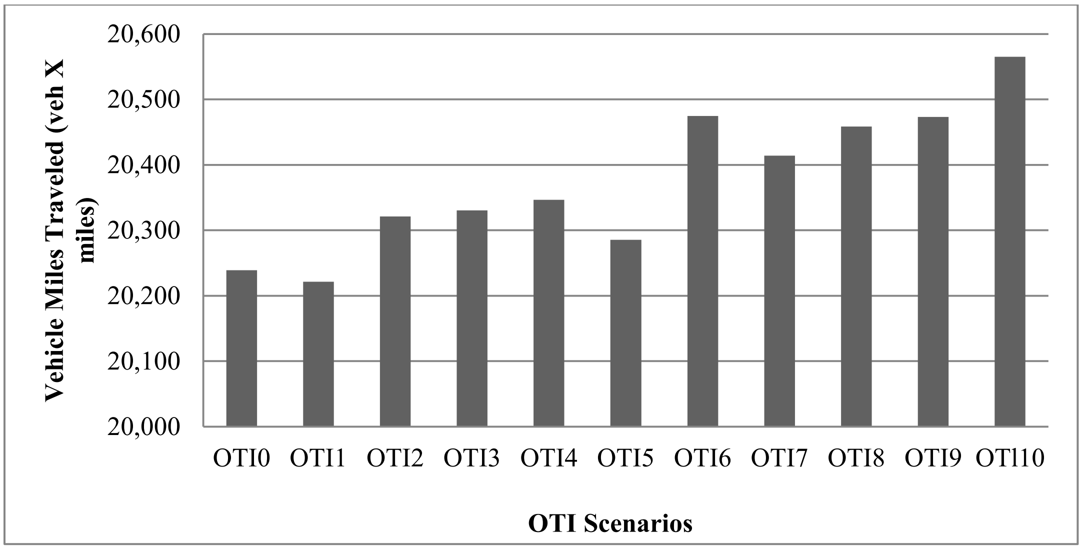


Figure 66: Nighttime (3-4 am) VMT for All Vehicles in the Overall Network

At night, the trucks traveled in a non-congested network. The overall truck VMT was separated from the general traffic, and summarized in Table 63.

Table 63: Network-Wide Nighttime Truck VMT

Scenario IDs	Vehicle Miles Traveled (VMT)	Incremental VMT	Incremental Truck Demand	VMT Reduction per Diverted Truck
OTI0	945			
OTI1	966	20	24.9	0.8
OTI2	956	-10	14.2	-0.7
OTI3	1,019	62	30.1	2.06
OTI4	1,028	9	28	0.32
OTI5	1,074	46	37.3	1.23
OTI6	1,095	21	21.6	0.97
OTI7	1,098	3	48.9	0.06
OTI8	1,103	5	39.4	0.13
OTI9	1,107	4	51.5	0.08
OTI10	1,199	92	64.5	1.43
Total	11,590	254	360	0.7

Except for Scenario OTI1, all other scenarios showed a consistent incremental trend as expected. The average incremental rate was determined to be adequate, and no further multi-runs were replicated.

General vehicles did not suffer much from the increased truck VMT. The truck VMT trend is illustrated in Figure 67.

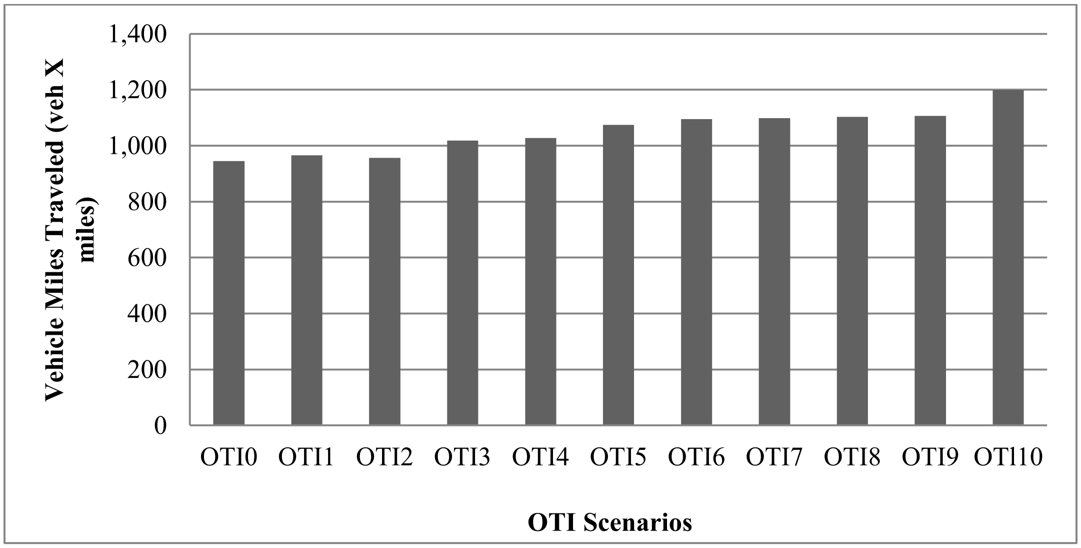


Figure 67: Nighttime (3-4 am) VMT for Truck Only in the Overall Network

The nighttime traffic conditions have rarely been modeled in the New York City area. From Figure 67, the first random simulation run displayed a consistent trend and no more simulation runs were needed. The nighttime street system mostly operated as typical light traffic network.

Network Level Traffic Impacts: Vehicle Hours Traveled (VHT) Daytime Analysis

In the previous VMT analysis, the induced traffic demand was identified as a major factor affecting the network performance when significant amounts of trucks were removed from the congested daytime network. To further investigate the phenomenon, another MOE - vehicle hours traveled (VHT) was calculated from simulation output using Equation ***Vehicle Hours Traveled (VHT) = Flow (vehicles) * (Link Travel Time (seconds)/3600)*** (15).

$$\textit{Vehicle Hours Traveled (VHT)} = \textit{Flow (vehicles)} * \textit{(Link Travel Time (seconds)/3600)} \quad \textbf{(15)}$$

The sample procedure was illustrated in Table 64.

Table 64: Vehicle Hours Traveled (VHT) Estimation from Simulation Output

OTIno	did	oid	sid	ent	vehType	linkType	flow	ttime	VHT
5	14987016	13701695	0	1		5	313	4	0.385
5	14987016	13701695	1	1	21	5	309	4	0.379
5	14987016	13701695	2	1	52	5	1	6	0.002
5	14987016	13701695	6	1	42	5	3	5	0.004
5	14987016	13701695	0	2		5	391	4	0.479
5	14987016	13701695	1	2	21	5	379	4	0.463
5	14987016	13701695	2	2	52	5	4	5	0.005
5	14987016	13701695	4	2	21	5	1	5	0.001
5	14987016	13701695	6	2	42	5	7	5	0.009
5	14987016	13701695	0	3		5	385	4	0.464
5	14987016	13701695	1	3	21	5	376	4	0.452
5	14987016	13701695	2	3	52	5	1	5	0.001
5	14987016	13701695	4	3	21	5	3	5	0.004
5	14987016	13701695	6	3	42	5	5	5	0.007
5	14987016	13701695	0	4		5	428	4	0.53

Similar with VMT calculations, the overall vehicle hours traveled were summarized for the subgroups classified by OTI scenarios, simulation replications, time periods, vehicle types, and link types. The VHT reduction rate per diverted truck was also computed the same way as the VMT reduction rate.

The daytime network-wide VHT result was listed in Table 65. The average VHT Reduction rate was about 6.2 VHT per diverted truck from OTI0 to OTI4.

Table 65: Network-wide Daytime VHT Analysis

Scenario IDs	Vehicle Hours Traveled (VHT)	Incremental VHT	Incremental Truck Demand	VHT Reduction per Diverted Truck
OTI0	14,306			
OTI1	14,217	-89.2	-14	6.4
OTI2	14,134	-83	-10.5	7.9
OTI3	13,953	-180.9	-22	8.2
OTI4	13,909	-43.9	-19	2.3
OTI5	13,947	37.8	-27.8	-1.4
OTI6	14,105	158.4	-15.3	-10.4
OTI7	14,148	43	-36	-1.2
OTI8	14,033	-115.2	-27.8	4.1
OTI9	13,547	-485.9	-38	12.8
OTI10	13,414	-133	-46.3	2.9
Total	153,710	-891.9	-256.5	3.5

From Table 65, the overall daytime VHT for all vehicles showed a similar fluctuation pattern as the overall daytime VMT. The result was illustrated in Figure 68.

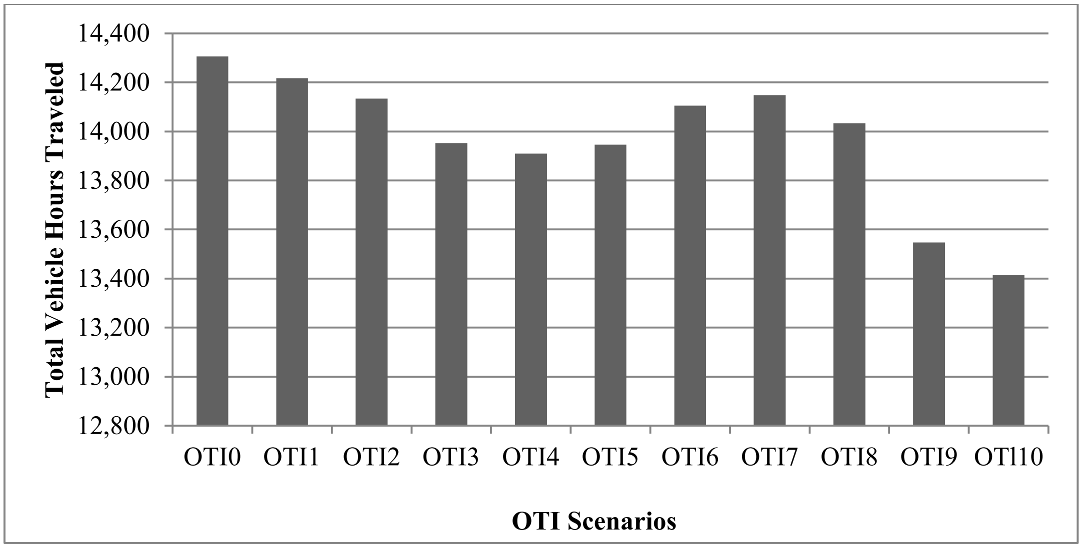


Figure 68: Daytime (8-9 am) VHT for All Vehicles in the Overall Network

From Figure 68, the overall VHT was increased from OTI4 to OTI8, similar to the VMT trend; wherever the explanation for the VMT increment was not applicable to the VHT increment. If the number of vehicles is fixed for each scenario, the total VHT should be decreased when the network operations were improved. From the simulation animation, these scenarios displayed much better network performance than Scenario OTI0 to OTI3. The general explanation was that more vehicles entered into the micro-simulation sub-network from Scenario OTI4 to OTI8. These vehicles waited in a virtual queue outside of the micro-simulation network from OTI0 to OTI3, and their performance was not able to be recorded in the micro-simulation output. These vehicular volume demands were virtually induced for the micro-simulation sub-network. From OTI8 to OTI10, most of network bottleneck was cleared and the induced demand was drastically reduced. It was concluded that the diverted truck demand would help relieve the congestion in the critical bottlenecks, which were not fully included in the micro-simulation sub-network.

To identify the travel time of the trucks in the micro-simulation network, the truck VHT output results were summarized in Table 66.

Table 66: Network-Wide Daytime Truck VHT Analysis

Scenario IDs	Vehicle Hours Traveled (VHT)	Incremental Truck VHT	Incremental Truck Demand	VHT Reduction per Diverted Truck
OTI0	1,186			
OTI1	1,175	-11	-14	0.78
OTI2	1,162	-12	-10.5	1.19
OTI3	1,137	-26	-22	1.17
OTI4	1,134	-3	-19	0.15
OTI5	1,129	-5	-27.8	0.18
OTI6	1,118	-10	-15.3	0.67
OTI7	1,116	-2	-36	0.06
OTI8	1,109	-7	-27.8	0.24
OTI9	1,103	-7	-38	0.18
OTI10	1,081	-22	-46.3	0.48
Total	12,450	-105	-256.5	0.41

Obviously, the truck VHT pattern was different from the overall network VHT pattern. The truck VHT was consistently reduced from OTI0 to OTI10, as shown in Figure 69.

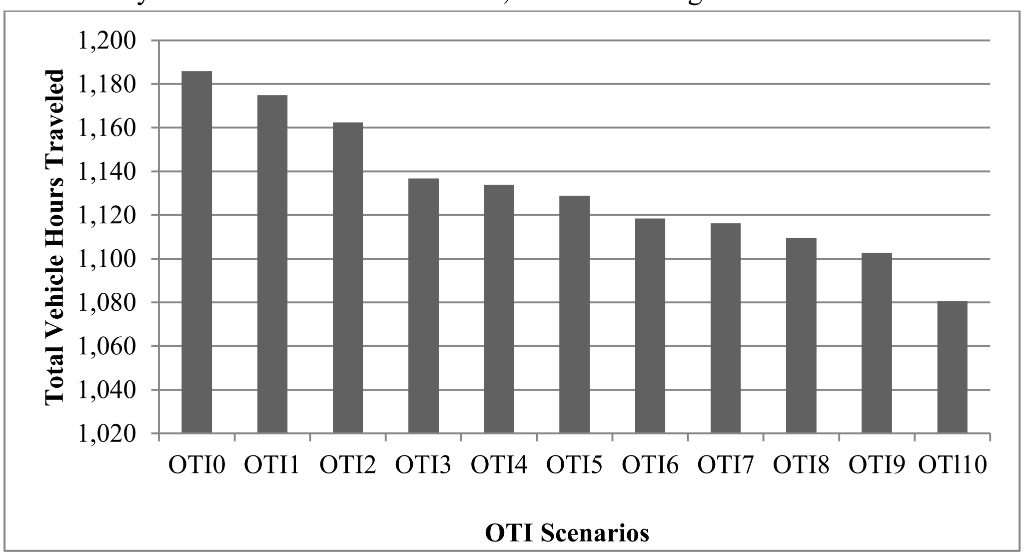


Figure 69: Daytime (8-9 am) VHT for Truck Only in the Overall Network

The truck VHT trend verified the explanation for the overall VHT trend. The truck travel times were consistently reduced together with the incremental incentives compensated to the freight receivers or carriers. By removal of trucks in the daytime, the total truck travel time will be reduced, although induced demand brought more general autos into the network. In comparison to truck VMT Figure 65, truck VHT was reduced while the truck VMT was increased from OTI6 to OTI10. The trucks can travel more distance with less travel time. The travel speeds of the trucks were consistently increased from OTI6 to OTI10. The truck travel speeds also representing the network travel speeds as probe vehicles because the truck demand exceeds 7000 truck per hour. Therefore, the overall network performance was consistently improved from OTI5 to OTI10 in the daytime.

Network Level Traffic Impacts: Vehicle Hours Traveled (VHT) Nighttime Analysis

Similar with the nighttime VMT analysis, the nighttime VHT output were obtained from one random simulation replication. The results were summarized into Table 67.

Table 67: Network-Wide Nighttime VHT

Scenario IDs	Vehicle Hours Traveled (VHT)	Incremental VHT	Incremental Truck Demand	VHT Increment per Diverted Truck
OTI0	1,164			
OTI1	1,163	-1	24.9	-0.04
OTI2	1,172	10	14.2	0.7
OTI3	1,172	-1	30.1	-0.03
OTI4	1,174	3	28	0.11
OTI5	1,173	-1	37.3	-0.03
OTI6	1,183	10	21.6	0.46
OTI7	1,184	1	48.9	0.02
OTI8	1,181	-3	39.4	-0.08
OTI9	1,185	4	51.5	0.08
OTI10	1,189	4	64.5	0.06
Total	12,940	25	360	0.07

From Table 67, the nighttime scenarios generally showed an incremental VHT trend except for Scenario OTI1, OTI3, OTI5 and OTI8. No multiple runs were further replicated because the network operated well with no congestions. The incremental trend provided adequate reference to represent the light traffic conditions at night.

In comparison to Table 65, the network VHT increment per diverted truck was 0.07 hours at nighttime hours compared to 3.5 hours during daytime hours, respectively. Without considering the induced demand benefit, the direct benefit of the travel time savings was 3.5– 0.07 = 3.43 vehicle hours per diverted truck. The night time VMT trend line was plotted on the nighttime VMT chart at the following Figure 70.

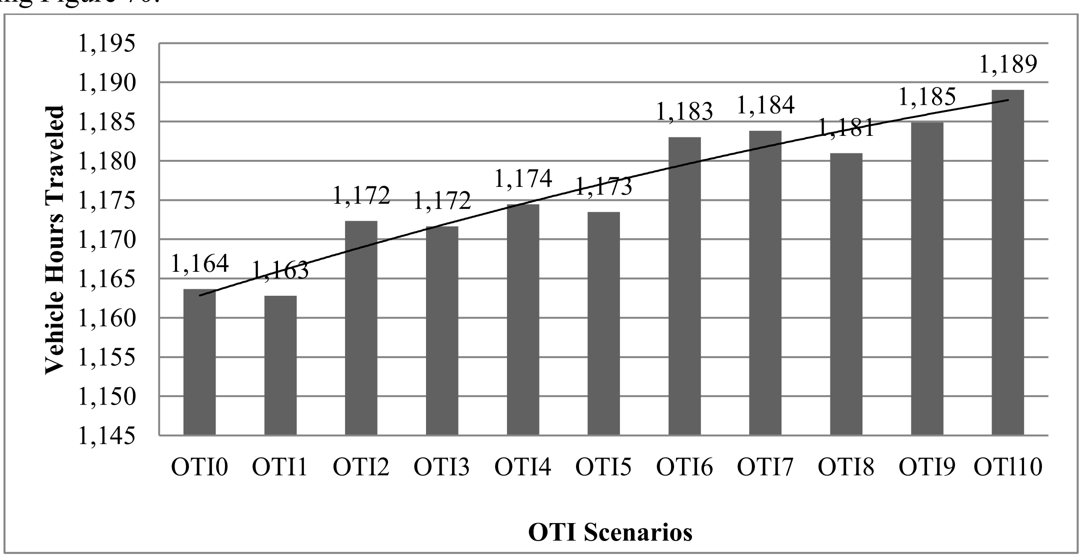


Figure 70: Network-Wide Nighttime (3-4 am) VHT Trend for All Vehicles

The truck VHT output was summarized on Table 68 and showed a more consistent incremental trend at night. From Table 68, nine out of ten scenarios showed increase consistency of travel hours per diverted truck.

Table 68: Network-Wide Nighttime Truck VMT

Scenario IDs	Truck Hours Traveled (VHT)	Incremental Truck VHT	Incremental Truck Demand	VHT Increment per Diverted Truck
OTI0	60			
OTI1	62	2	24.9	0.08
OTI2	62	1	14.2	0.07
OTI3	66	3	30.1	0.1
OTI4	67	2	28	0.07
OTI5	71	3	37.3	0.08
OTI6	72	1	21.6	0.05
OTI7	73	1	48.9	0.02
OTI8	72	-1	39.4	-0.03
OTI9	73	1	51.5	0.02
OTI10	80	7	64.5	0.11
Total	756	20	360	0.06

From Table 68, the total truck VHT was 756 vehicle hours. From Table 66, the total nighttime truck VMT was 11,590 vehicle miles. Average travel speeds for trucks at nighttime can be roughly estimated as 11,590 vehicle miles/756 vehicle hours = 15.3 mph. For the signalized urban network, the actual moving speed would exceed 20 miles per hour at night. The nighttime truck VHT results were illustrated in Figure 71 as follows.

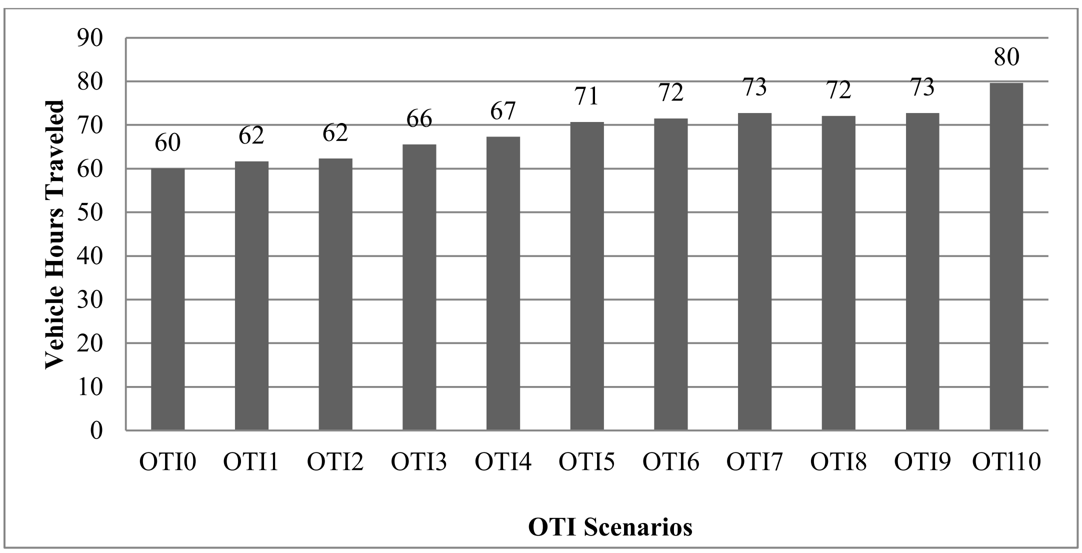


Figure 71: Nighttime (3-4 am) VHT for Truck Only in the Overall Network

From Figure 71, the nighttime VHT would be slightly increased mostly by the newly added truck trips themselves. Compared with over 1,000 truck hours in Figure 69 in the daytime hour, the nighttime truck hour was less than 10% of the daytime trucks. From Figure 68 and Figure 70, the nighttime vehicle hours were also less than 10% of the daytime vehicle hours for all classifications of vehicles. The nighttime traffic network was far from saturated and was able to accommodate more diverted truck trips from the daytime periods.

Discussion

The Midtown Manhattan network features a typical, oversaturated urban network with mixed use traffic (bike lanes, bus routes, bus stops, heavy pedestrian blockage, flexible curbside activities, illegal parking, intersection channelization, taxi traffic, grid-lock, managed use lanes, reversible lanes, flexible tunnel usage, queuing on major crossings, and other various complicated factors). Microscopic traffic simulation with macroscopic path assignment was selected as the feasible methodology to represent the traffic conditions in the study area. The micro-simulation model was developed and expanded to evaluate the performance of various incentives to encourage off-hour truck deliveries in the area from 14th Street to 66th Street in Midtown Manhattan.

The micro-simulation output generally showed three response stages of the traffic networks. In the first stage, a certain percentage of the trucks were diverted to off-hours. The participating trucks could benefit from less travel times and shorter route distances than the daytime periods. The overall daytime started to have better performance. The overall VMT and VHT generally displayed a trend of consistent decrement following the increment of the incentive values. The overall VMT reduction rate ranged from 18 to 35 vehicle miles per diverted truck at daytime, without considering induction demand. The average VMT incremental rate at nighttime was about 0.9 miles per truck. The network-wide VMT reduction for the diverted truck fell into the range of 20 to 40 times of generated network VMT at nighttime.

In the daytime, the network-wide VHT Reduction rate was at least 6.2 VHT per diverted truck before more autos were able to enter into the network in the improved traffic conditions. If additional VHT from the induced demand was excluded from the network, average emissions savings would exceed 6.2 VHT per diverted truck from the scenario of OTI0 to OTI10 in the daytime. For the nighttime hours, the VHT increment was only 0.07 hours per added truck from the scenarios of OTI0 to OTI10. The network-wide VHT reduction for the diverted truck in the daytime was 88 times that of network-wide VHT increments caused by the same truck at nighttime.

When the incentive package was increased to a certain level, the overall network started to perform at the second stage. Serious congestion at critical bottlenecks was alleviated. More drivers were able to complete their trips quicker with higher travel speeds. Consequently, more vehicles were able to enter the study area from the congested crossings or critical bottlenecks at the edge of the network. The overall VMT and VHT generally displayed a consistent incremental trend following the increment of the incentive values. The overall network was capable of operating at higher travel speeds. More vehicles can be carried by the street network with shorter travel times. The benefit for this stage could not be quantified by the VMT and VHT reduction in the study area only. More benefits were achieved by greatly improved network performance to benefit vehicles outside of the study area in the previous scenarios.

On alleviating congestion at most of the bottlenecks, the volume of the vehicles entering into the sub-network began to stabilize. Without demand induction, the network started to perform better in the third stage. Both VMT and VHT were drastically reduced in response to the incremental incentive values.

During the all three stages, the air emissions were consistently decreased with the incremental incentive to encourage off-hour deliveries. Although the simulation results showed fluctuation for some specific scenarios and specific emissions factors, the emissions reductions for the overall network indicated the benefits of emissions savings by higher traveling speeds. Due to the induced demand by more vehicles entering the study network, the total emissions were only slightly decreased from OTI0 to OTI8. Only in the third stage, the total emissions were observed to decrease drastically without additional emissions from additional demand.

In the nighttime hours, each additional truck would generate 0.0016 ton emissions of selected pollutants. The diverted trucks would cause emission reductions of 0.028 ton in the overall daytime network. Without considering induced demand by allowing more vehicles to enter into the network, the network-wide emissions savings of the daytime hours per diverted truck was 17.5 times of the newly generated emissions for the same truck for the nighttime hours. The additional demand induction represented the major benefit of air emission savings by alleviating network congestions. If the demand induction was included, the overall emissions savings would be much more, similar to the VMT and VHT savings.

In conclusion, each participating truck diverted away from daytime would generate the benefit of emissions and network-wide VMT and VHT savings. Generally, the emissions reduced in the daytime would be more than 10 times of the emissions increments by the same truck at nighttime. The overall network also operated better with less congestions, more general autos, and higher speeds.

Accident Cost Analysis

Economic impact analysis for an OHD program requires quantification of several cost components associated with roadway users. This sub-section focuses on predicting the accident costs in New York City Metropolitan Area. First crash frequency models are developed using 3-year Manhattan crash records, and next, using these crash frequency models, accident cost functions are provided. The accident cost functions are included in the total cost for the economic impact analysis for roadway users in Manhattan, which are given in the following sections.

Crash Frequency Models for Manhattan

Crash frequency models (CFMs) are equations that estimate the number of crashes as a function of contributing factors such as traffic volume and roadway characteristics (e.g. number of lanes, median type, intersection control. In this section, the overall CFMs for Manhattan road network are developed. The major goal of this effort is to use these Manhattan-specific CFM's to estimate the changes in the accident costs for various OHD scenarios.

Data

Based on the available data sources, a total of 397 road segments in Manhattan were sampled for model development. Three variables for each road segment, including annual average daily traffic (AADT), length and type associated with each road segment were used for modeling. Road segments were categorized into two types according to their functional properties: (1) freeway and (2) arterial. Three-year crash data from 05/01/2008 to 04/30/2011 was used for this study. Crashes were classified into three categories according to their severity namely, property-damage-only (PDO), injury and fatality. To obtain accurate crash cost estimations, the injury crashes were further divided into three categories namely, possible injury, non-incapacitating injury and incapacitating injury. We prefer to use three-year crash frequency as the dependent variable because the fatality crashes for one year are too few to estimate a valid model. The descriptive statistics of the variables included in the CFMs are shown in Table 69.

Table 69: The Descriptive Statistics of Variables

Variable	Description	Min	Max	Mean	S.D.
Total crash	The total frequencies of crashes for 3 years	0	845	81.25	122.69
PDO	The frequencies of PDO crashes for 3 years	0	384	38.12	56.78
PosInjury	The frequencies of possible injury crashes for3 years	0	445	37.76	60.7
NonIncapInjury	The frequencies of non-incapacitating injury crashes for 3 years	0	119	8.24	13.83
IncapInjury	The frequencies of incapacitating injury crashes in 3 years	0	57	4.14	7.24
Fatality	The frequencies of fatality crashes for 3 years	0	7	0.27	0.75
AADT	The annual average daily traffic (veh)	327	282095	14497	40184
Length	Length of the road segments (mile)	0.02	5.7	0.74	0.64
Road type	0 for arterials; 1 for freeways	0	1	0.13	0.34

Model Specification

Generalized linear models (GLMs), such as Poisson models and negative binomial (NB) models have been widely used to develop CFMs. Poisson models can accommodate the nonnegative, random and discrete features of crash frequencies (Miaou and Lum, 1993), but the over-dispersion of crash data violates the Poisson distribution's assumption that the variance of the crash data is equal to its mean (Maher and Summersgill, 1996). NB models have been proven to perform better than Poisson models in dealing with over-dispersed crash data by introducing an error term. NB models were selected to develop CFMs in this report.

The general form of CFMs is can be expressed as:

$$y \sim \text{Negbin}(\theta, r) \quad \textbf{(16)}$$

$$\log(\theta) = \beta_0 + \beta_1 \log(AADT) + \beta_2 \log(L) + \beta_3 T \quad \textbf{(17)}$$

Where:

y =Crash frequency for a certain road segment in 3 years

θ=Expectation of y

AADT= Annual average daily traffic (veh)

L=Road length (mile)

T=Road type, dummy variable, 0 for arterial, 1 for freeway

r = Over-dispersion coefficient

Modeling Results

Both NB and Poisson models were used to develop CFMs for PDO, injury (including possible, non-incapacitating and incapacitating injury) and fatality crashes, respectively. Table 70 shows comparisons of NB and Poisson models using various statistical measures including, Log Likelihood (LL), Akaike Information Criterion (AIC), Akaike Information Criterion Correction (AICC) and Bayesian Information Criterion (BIC).

Table 70: Comparisons between Poisson and NB Models

Measures	PDO		PosInjury		NonIncapInjury		IncapInjury		Fatality	
	NB	Poisson	NB	Poisson	NB	Poisson	NB	Poisson	NB	Poisson
LL	38549	35310	51516	48004	6113	5540	1945	1679	-170	-181
AIC	3165	9643	3227	10250	2119	3265	1649	2180	429	449
AICC	3165	9643	3228	10250	2120	3265	1650	2180	429	450
BIC	3185	9659	3247	10266	2139	3281	1669	2196	449	465

(Note: Models with greater LL and smaller AIC, AICC and BIC are better)

The greater values of LL and smaller values of AIC, AICC and BIC for the NB models show that they are substantially better compared with the Poisson models. Therefore the NB models were adopted to develop CFMs for Manhattan. Table 71 shows the parameters of CFMs using NB models along with their p-values. Assuming a significance level of 0.05, the results of the CFMs indicate that the road type, the logarithm of roadway length, and the logarithm of AADT have statistically significant effects on the crash occurrence.

Table 71: Parameters of CFMs for PDO, Injury and Fatality Crashes

Parameter	PDO		PosInjury		NonIncapInjury		IncapInjury		Fatality	
	Coeff.	P-Val.	Coeff.	P-Val.	Coeff.	P-Val.	Coeff.	P-Val.	Coeff.	P-Val.
Intercept	-1.45	0.0174	-2.84	<.0001	-3.2	<.0001	-5.58	<.0001	-10.84	<.0001
Road Type										
Freeway	-1.35	<.0001	-2.25	<.0001	-2.39	<.0001	-2.66	<.0001	-2.03	<.0001
Arterial	0	.	0	.	0	.	0	.	0	.
LogLength	0.99	<.0001	1.02	<.0001	1.1	<.0001	1.07	<.0001	1.29	<.0001
LogAADT	0.54	<.0001	0.71	<.0001	0.59	<.0001	0.77	<.0001	1.02	<.0001
Dispersion	1.11		1.22		0.97		1.03		1.08	

The CFMs in Table 71 can be used to estimate the crash frequencies by severity during a period of 3 years. Predicted PDO crash per year for each road segment can be obtained by:

$$P_{PDO} = AADT^{0.54} L^{0.99} exp\left(-1.35\ T\right) / 12.75 \quad \textbf{(18)}$$

Predicted possible, non-incapacitating and incapacitating injury crash per year for each highway can be obtained by using the following functions:

$$P_{PosInj} = AADT^{0.71} L^{1.02} exp\left(-2.25\ T\right) / 51.21 \quad \textbf{(19)}$$

$$P_{NonIncapInj} = AADT^{0.59} L^{1.10} exp\left(-2.39\ T\right) / 73.41 \quad \textbf{(20)}$$

$$P_{IncaPInj} = AADT^{0.77} L^{1.07} exp\left(-2.66\ T\right) / 796.01 \quad \textbf{(21)}$$

Predicted fatality crash per year for each highway can be obtained by:

$$P_{Fatality} = AADT^{1.02} L^{1.29} exp(-2.03\ T) / 153110.1 \qquad \textbf{(22)}$$

Equations (18) - (22) can be used to predict the annual crash frequencies of segments. Table 72 shows that the predicted annual crash frequencies by severity for all the segments. It can be seen that the estimated numbers are quite close to the observed values. The predicted PDO, injury and fatality crash frequencies for each road segments were separately compared with the observed ones as shown in Figure 72 to Figure 76.

Table 72: Comparison of Predicted and Observed Annual Crash Frequencies for All Segments

Frequency	PDO	PosInjury	NonIncapInjury	IncapInjury	Fatality	Total
Observed	4081	4996	1091	548	37	10752
Predicted	3864	4810	1015	550	39	10279

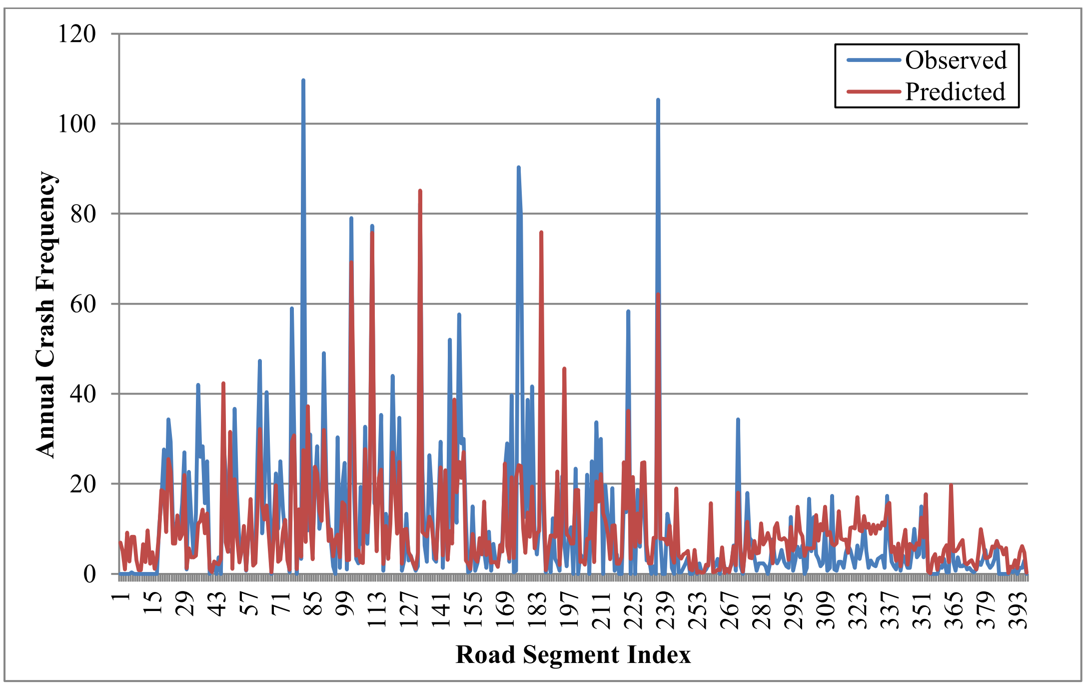


Figure 72: Comparison of Predicted and Observed PDO Crashes for Each Road Segment

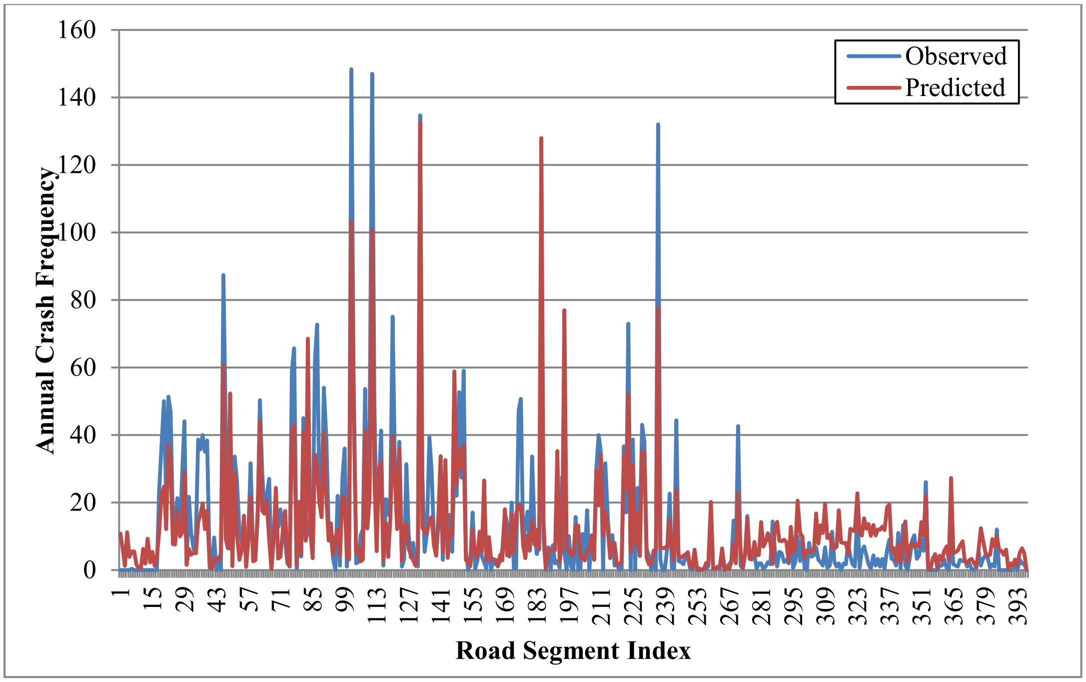


Figure 73: Comparison of Predicted and Observed Possible Injury Crashes for Each Road Segment

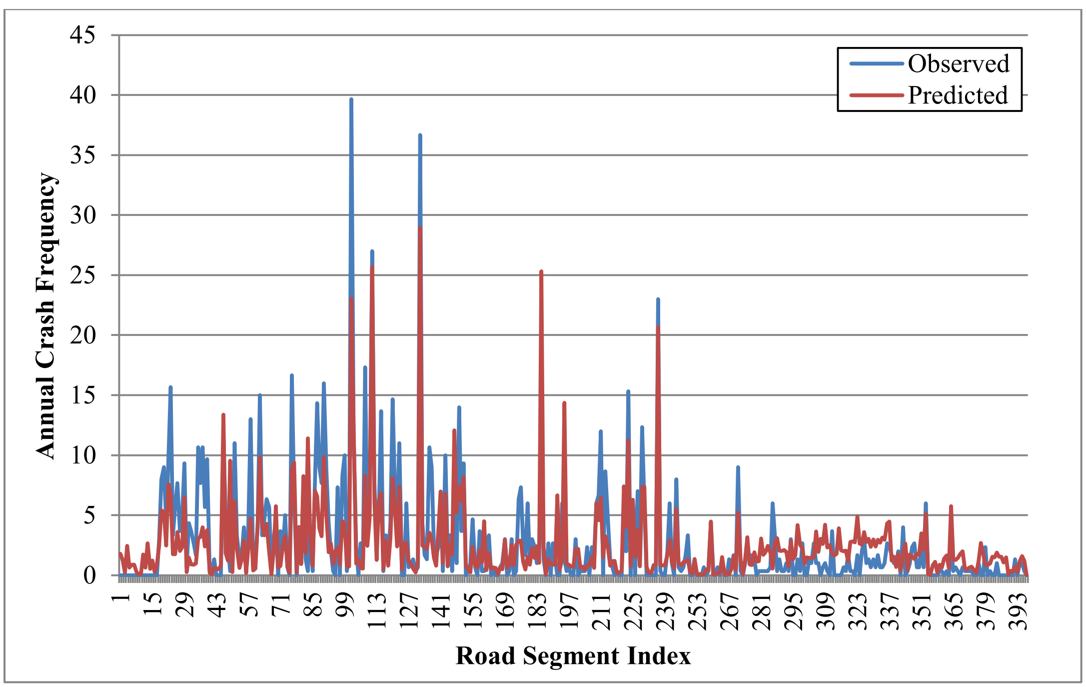


Figure 74: Comparison of Predicted and Observed Non-Incapacitating Injury Crashes for Each Road Segment

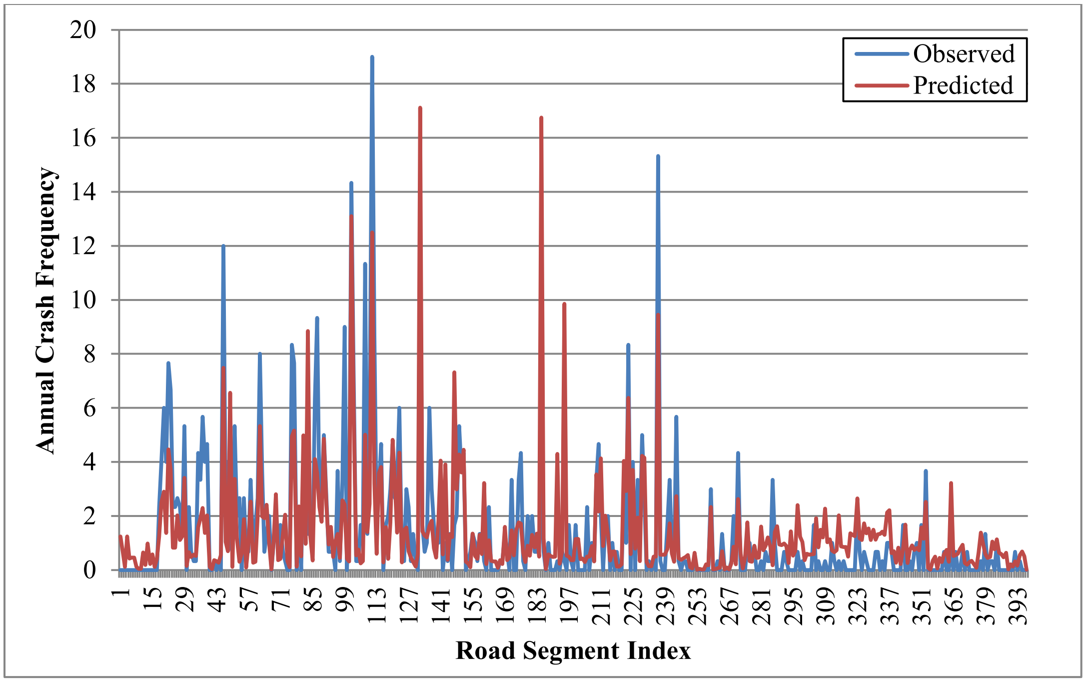


Figure 75: Comparison of Predicted and Observed Incapacitating Injury Crashes for Each Road Segment

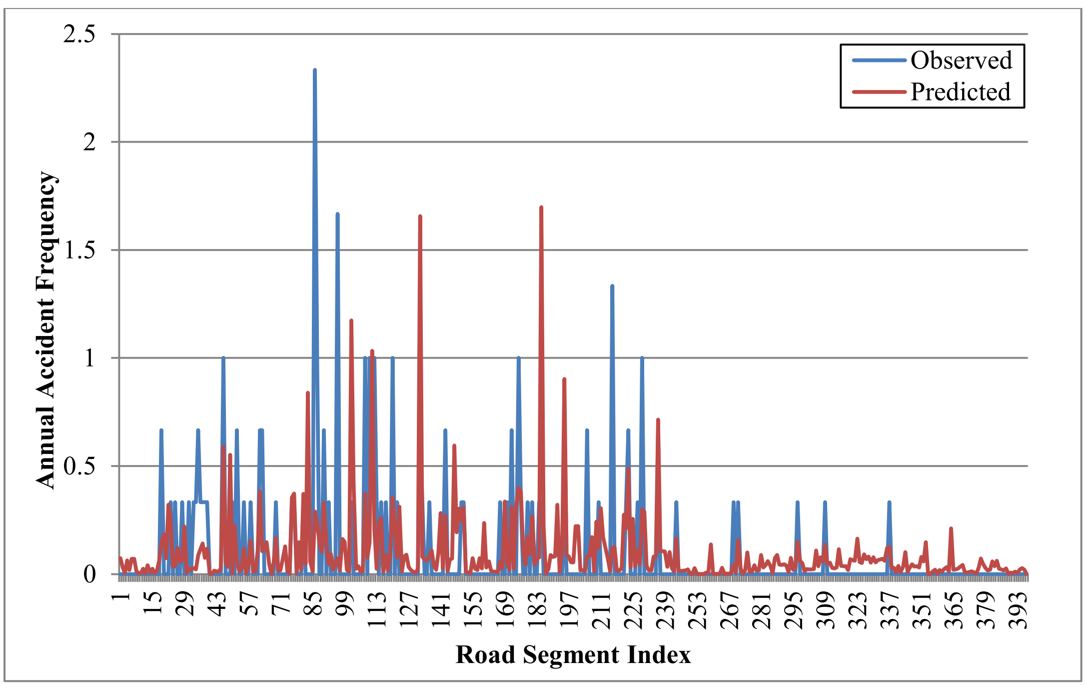


Figure 76: Comparison of Predicted and Observed Fatality Crashes for Each Road Segment

Accident Cost Estimation for Manhattan

Crash costs can be classified into two major groups: (1) lost production/consumption by individuals, and (2) life-injury damages. In order to estimate the crash costs, the crash occurrence rate and the unit cost of crash should be known. Since costs vary by crash type, crashes can be classified into five categories: property damage only (PDO), possible injury, non-incapacitating injury, incapacitating injury and fatality. The generalized total crash cost function can be expressed as follows:

$$C_{acc} = C_{PDO}P_{PDO} + C_{PosInj}P_{PosInj} + C_{NonIncapInj}P_{NonIncapInj} + C_{IncapInj}P_{IncapInj} + C_{Fatality}P_{Fatality} \quad \textbf{(23)}$$

Where:

C_{acc} = Total crash cost ($/year)

C_{PDO} = Unit cost of property damage only crash ($)

C_{PosInj} = Unit cost of possible injury crash ($)

$C_{NonIncapInj}$ = Unit cost of non-incapacitating injury crash ($)

$C_{IncapInj}$ = Unit cost of incapacitating injury crash ($)

$C_{Fatality}$ = Unit cost of fatality crash ($)

P_{PDO} = Number of property damage crashes per year

P_{PosInj}= Number of possible injury crashes per year

$P_{NonIncapInj}$= Number of non-incapacitating injury crashes per year

$P_{IncapInj}$= Number of incapacitating injury crashes per year

$P_{Fatality}$= Number of fatality crashes per year

We can also obtain the average crash cost and marginal crash cost by:

$$C_{ave} = \frac{C_{acc}}{AADT} \quad \textbf{(24)}$$

$$C_{mag} = \frac{\partial C_{acc}}{\partial AADT} \quad \textbf{(25)}$$

The unit cost of crashes as shown in Table 73, are taken from the website of National Safety Council (NSC, 2013).

Table 73: Unit Crash Costs by Type

Crash Type	Value per Crash ($)*
Fatality	4,360,000
Incapacitating injury	220,300
Non-incapacitating injury	56,200
Possible injury	26,700
Property damage only	2,400

*2010 dollars

As shown in the generalized total crash cost function, (23) above, to calculate the total crash cost, first the frequency of a particular crash type is multiplied by the unit cost of that crash type, and then summed over all crash types. Using the annual crash frequencies obtained from Equations (**19**)- (**22**) and the unit crash costs in Table 73 respectively, the total, marginal and average crash cost functions are calculated as shown in Table 74.

Table 74: Yearly Crash Cost Functions in U.S. Dollars

Cost Type	Cost Function
Total Cost	$188.22 AADT^{0.54} L^{0.99} exp(-1.35\ T) + 521.34\ AADT^{0.71} L^{1.02} exp(-2.25\ T) + 765.52\ AADT^{0.59} L^{1.10} exp(-2.39\ T) + 276.76\ AADT^{0.77} L^{1.07} exp(-2.66\ T) + 28.48\ AADT^{1.02} L^{1.29} exp(-2.03\ T)$
Marginal Cost	$102.03 AADT^{-0.46} L^{0.99} exp(-1.35\ T) + 370.41\ AADT^{-0.29} L^{1.02} exp(-2.25\ T) + 454.64\ AADT^{-0.41} L^{1.10} exp(-2.39\ T) + 212.74\ AADT^{-0.23} L^{1.07} exp(-2.66\ T) + 29.08\ AADT^{0.02} L^{1.29} exp(-2.03\ T)$
Average Cost	$188.22 AADT^{-0.46} L^{0.99} exp(-1.35\ T) + 521.34\ AADT^{-0.29} L^{1.02} exp(-2.25\ T) + 765.52\ AADT^{-0.41} L^{1.10} exp(-2.39\ T) + 276.76\ AADT^{-0.23} L^{1.07} exp(-2.66\ T) + 28.48\ AADT^{0.02} L^{1.29} exp(-2.03\ T)$

Truck Crash Frequency Models

In this section, truck crash frequency models for daytime and night time are developed in order to investigate the safety impacts of truck traffic during different periods of the day.

Data Preparation

The total number of truck crashes in Manhattan from 05/01/2008 to 04/30/2011 is 3075. Truck crashes account for 6.8 percent of all crashes. For the analysis in this sub-section, crashes that occurred during 6 am-7 pm are defined as daytime crashes, and those that occurred during 7 pm-6 am are defined as nighttime crashes. According to the record of crash time available, 1412 truck-involved crashes can be classified as daytime crashes, and 341 truck-involved crashes can be classified as nighttime crashes. Since occurrence time of some crashes is missing, we excluded these from the dataset. The daytime and nighttime truck crash frequencies by severity are presented in Table 75.

Table 75: Truck Crash Frequencies during Daytime and Nighttime

Crash Type	Daytime	Nighttime
PDO	783	166
Possible injury	495	132
Non-Incapacitating injury	78	27
Incapacitating injury	49	12
Fatality	7	4
Total	**1412**	**341**

For the analysis presented in this sub-section, crashes at different levels of severity are not modeled separately to avoid unreliable estimations caused by insufficient amount of crash counts. Considering the similarity of crash features, five crash types were combined into two categories for model development, namely minor truck crashes including PDO and possible injury crashes, and serious truck crashes including non-incapacitating injury, incapacitating injury and fatality crashes. Thus, truck crashes are divided into four types by time period and severity as shown in Figure 77.

Figure 77: Truck Crash Types by Time Period and Severity in Manhattan

Traffic and geometric design features of 256 road segments in Manhattan were collected from available data sources. AADT for each segment in Manhattan was obtained from Short Count Program (SCP) of New York State Department of Transportation (NYSDOT). In the SCP, approximately 12,000 statewide counts of 2-7 days duration are taken every year. AADT for each road segment is calculated after undergoing quality control procedures for this count data obtained by NYSDOT.

Outputs of four time periods from BPM were used to estimate the ratios of daytime and nighttime truck volume to daily vehicle volume for each segment. By multiplying the truck ratios with the count AADT, we can obtain the daytime and nighttime truck volumes for each segment, as shown in Figure 78.

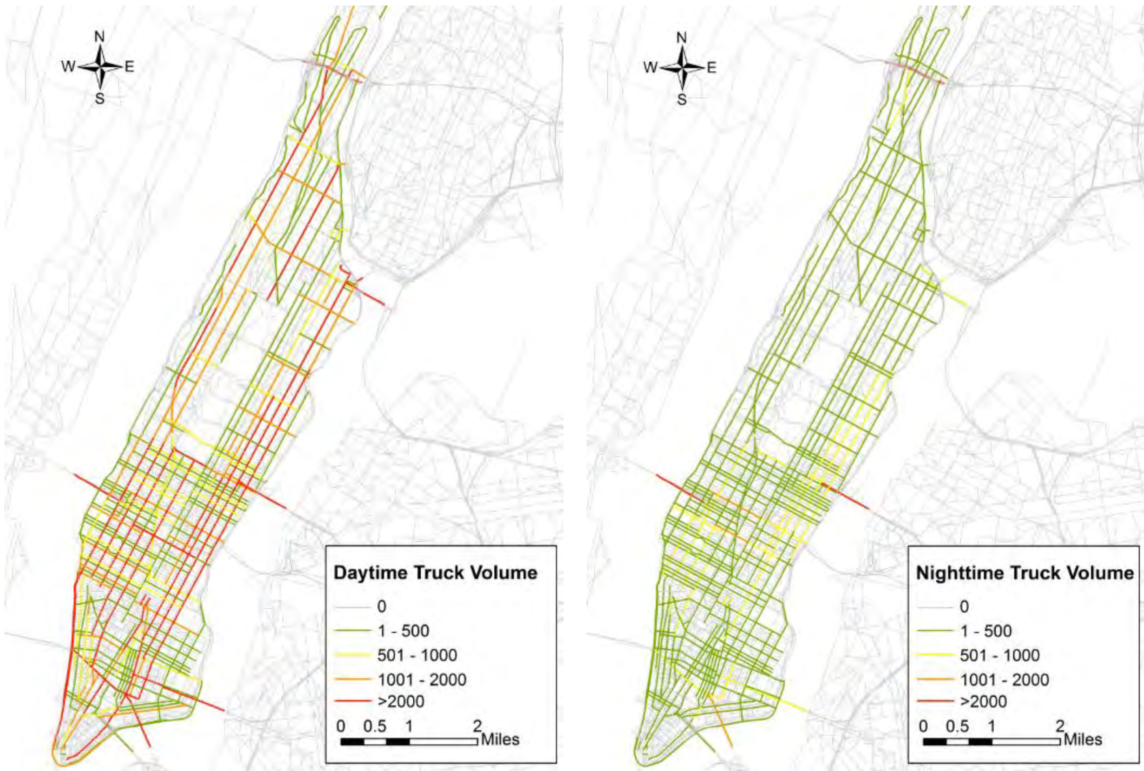


Figure 78: The Estimated Truck Volumes during Daytime and Nighttime

The truck crash frequencies and rates during daytime and nighttime for selected segments are shown in Table 76. The crash rates during the nighttime are slightly higher than those during the daytime.

Table 76: Truck Crash Frequencies and Rates during Daytime and Nighttime

Truck Crash	Daytime			Nighttime		
	Minor	Serious	Total	Minor	Serious	Total
Crash Frequency	863	97	960	214	28	242
Crash Rate[1] (10^{-6} veh)	2.72	0.31	3.03	3.39	0.44	3.83

1. Crash Rate= Annual Truck Crash Frequency/Annual Truck Flow

The Geographic Information System (GIS) data of road segments was provided by NYSDOT. The length and average intersection spacing of segments were determined from their geographic coordinates. In addition, the GIS data allowed us to classify roads into either one or two-way. The mean speed, number of lanes and road class for each segment were obtained from the BPM. The road class was treated as a binary variable, with one level for principle arterials and a second level for minor arterial, collectors and local roads since the average truck crash frequencies of principle arterials were higher than those of other road types. The segment variables for modeling with brief descriptions and their descriptive statistics are listed in Table 77.

Table 77: Descriptive Statistics of Data

Variable	Description	Mean	SD	Min	Max
Daytime minor truck crash	Count of PDO and possible injury truck crashes during daytime over observation period	3.37	4.94	0	35
Daytime serious truck crash	Count of non-incapacitating injury, incapacitating injury and fatal truck crashes during daytime over observation period	0.38	0.74	0	4
Nighttime minor truck crash	Count of PDO and possible injury truck crashes during nighttime over observation period	0.84	1.38	0	9
Nighttime serious truck crash	Count of non-incapacitating injury, incapacitating injury and fatal truck crashes during nighttime over observation period	0.11	0.41	0	4
Logarithm of AADT	Logarithm of annual average daily traffic volume in two directions	9.48	0.86	6.62	11.8
Logarithm of daytime truck volume	Logarithm of average truck volume in two directions during daytime	6.32	1.49	-0.03	9.01
Logarithm of nighttime truck volume	Logarithm of average truck volume in two directions during nighttime	4.57	1.62	-0.78	7.25
Mean speed	Mean speed for each road segment (mile/h)	43.4	7.1	8.05	72.42
Road class	0 for minor arterial collector and local road, 1 for principal arterial	0.66	0.47	0	1
Length	Length of road segment (mile)	0.77	0.7	0.07	5.7
Intersection spacing	Average intersection spacing for each road segment (mile)	0.19	0.23	0.02	2.44
Number of lanes	Number of lanes in two directions	3.68	1.5	1	9
One-way road or not	0 for two-way road, 1 for one-way road	0.46	0.5	0	1

Model Specification

A novel modeling approach that involves the use of the multivariate Poisson-lognormal model integrated with measurement errors in truck volume (MVPLME) is proposed in this part to accurately capture the safety effects of truck volume on minor and serious truck crashes during daytime and nighttime.

Multivariate Poisson-Lognormal Models

Let y_{ik} (i=1, 2, …, n; k=1, 2, …, K) denote the count of type k crashes at i^{th} location over a given time period. In this study, truck crashes at each road segment are classified into four types, namely the daytime minor crash, the daytime serious crash, the nighttime minor crash and the nighttime serious crash. It is assumed that y_{ik} follows the Poisson distribution with the mean μ_{ik} :

$$y_{ik} \sim Poisson(\mu_{ik}) \quad \textbf{(26)}$$

Safety effects of truck volumes on different crash types are modeled. Truck volumes as well as other control variables are used to specify the parameter μ_{ik} :

$$\ln(\mu_{ik}) = \beta_{k0} + \beta_{k1}X_{i1} + ... + \beta_{kJ}X_{iJ} + \beta_{kT}\ln(TrVol_{ik}) + \varepsilon_{ik} \quad \textbf{(27)}$$

where

$X_{i1}, X_{i2}, ..., X_{iJ}$ = Explanatory variables used for control

$TrVol_{ik}$ = Truck volumes corresponding to type k crashes

$\beta_{k0}, \beta_{k1}, ..., \beta_{kJ}$ and β_{kT} = Regression coefficients to be estimated for control variables and truck volumes

To account for the correlation among the crash frequencies of specific types at one segment, let the error term ε_{ik} follow the K-dimensional multivariate normal distribution:

$$\varepsilon_i \sim MVN_K(0, \Sigma) \quad \textbf{(28)}$$

Modeling Measurement Errors in Truck Volume

A measurement error term was introduced into the model to consider the measurement error in the truck volume. Specifically, it is assumed that the correct value of truck volume on the log-scale is equal to the measurement obtained plus an additive error:

$$\ln(TrVol_{ik}^{*}) = \ln(TrVol_{ik}) + \tau_{ik} \quad \textbf{(29)}$$

where

$TrVol_{ik}^{*}$ = True truck volume corresponding to type k crashes for i^{th} segment

$TrVol_{ik}$ = Measured tuck volume, and τ_{ik} is the measurement error term

Assuming the τ_{ik} follows a normal distribution $N(0, \sigma_{T_k}^2)$, we have:

$$\ln(TrVol_{ik}^{*}) \sim N(\ln(TrVol_{ik}), \sigma_{T_k}^2) \quad \textbf{(30)}$$

It should be noted that $\sigma_{T_k}^2$ in the daytime minor and serious truck crash models is supposed to be the same, and this also applies to $\sigma_{T_k}^2$ in the nighttime minor and serious crash models. After replacing the measured truck volume $TrVol_{ik}$ in (27) with the true truck volume $TrVol_{ik}^{*}$, the mean function can be rewritten as follows:

$$\ln(\mu_{ik}) = \beta_{k0} + \beta_{k1}X_{i1} + ... + \beta_{kJ}X_{iJ} + \beta_{kT}\ln(TrVol_{ik}^{*}) + \varepsilon_{ik} \quad \textbf{(31)}$$

Equations (**26**), (**28**), (**30**) and (**31**) represent the fundamentals of the proposed MVPLME model.

Modeling Results

The proposed MVPLME model was developed using a Bayesian approach. The WinBUGS statistical software package was used for the estimation of Bayesian models using Markov Chain Monte Carlo MCMC(Spiegelhalter et al., 2002). The logarithm of truck volume as well as three covariates namely, logarithm of length, intersection spacing and road class was included into the proposed models. Bayesian posterior estimations of the proposed MVPLME model are shown in Table 78. The 95% Bayesian Credible Interval (95% BCI) was used to examine the significance of estimations. Estimations can be regarded as significant at the 95% level if the BCIs do not cover zero and vice versa(Gelman, 2004). According to Table 78, except intersection spacing in the daytime serious crash model and intersection spacing, road class and logarithm of truck volume in the nighttime serious crash model, all the other variables were found to be significant.

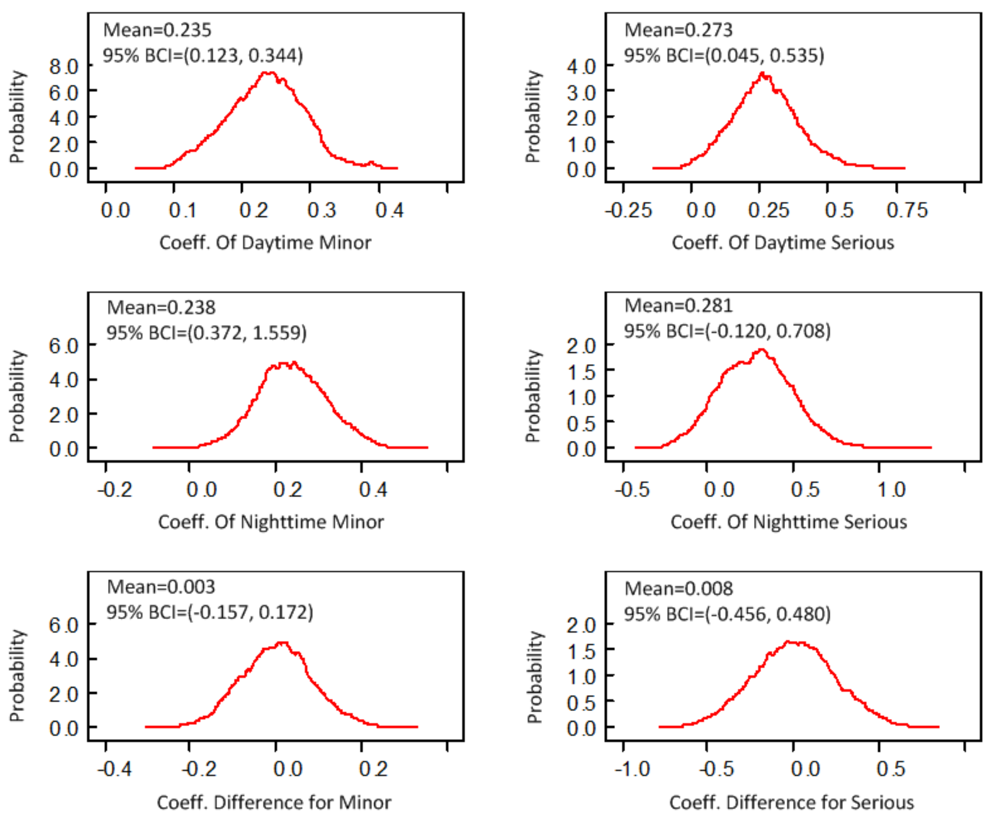
Table 78: Modeling Results for the MVPLME Model

Variable	Mean	SD	95% BCI	Mean	SD	95% BCI
	Daytime Minor			Daytime Serious		
Intercept	-0.724	0.352	(-1.423, -0.029)	-3.791	0.817	(-5.461, -2.281)
Logarithm of length	1.107	0.092	(0.932, 1.293)	0.858	0.168	(0.534, 1.197)
Intersection spacing	-1.022	0.278	(-1.582, -0.482)	-0.807	0.478	(-1.828, 0.046)
Road class	0.775	0.171	(0.452, 1.117)	1.35	0.413	(0.604, 2.241)
Logarithm of daytime truck volume	0.235	0.056	(0.123, 0.344)	0.273	0.122	(0.045, 0.535)
Variation of daytime truck volume	0.25	0.635	(0.001, 2.41)	0.25	0.635	(0.001, 2.41)
	Nighttime Minor			Nighttime Serious		
Intercept	-1.918	0.399	(-2.726, -1.172)	-4.77	1.108	(-7.169, -2.765)
Logarithm of length	0.98	0.131	(0.731, 1.244)	1.576	0.351	(0.939, 2.306)
Intersection spacing	-1.158	0.434	(-2.072, -0.364)	-1.083	0.813	(-2.88, 0.332)
Road class	0.922	0.285	(0.368, 1.491)	0.875	0.748	(-0.529, 2.429)
Logarithm of nighttime truck volume	0.238	0.081	(0.084, 0.401)	0.281	0.214	(-0.120, 0.708)
Variation of nighttime truck volume	0.039	0.123	(0.001, 0.375)	0.039	0.123	(0.001, 0.375)

Safety Impacts of Off-Hour Deliveries

After adjusting for the effects of control variables, the safety effects of truck volume can be evaluated. According to the coefficients of truck volume shown in Table 78, each 1% increase in truck volume predicts a 0.235% increase in daytime minor truck crash frequency and a 0.273% increase in daytime serious truck crash frequency, whereas the percentage increases in nighttime minor and serious truck crashes are expected to be slightly higher, 0.238% and 0.281%, respectively. In order to test whether or not these increases are statistically significant, we monitored the posterior distributions of the coefficient differences between daytime and nighttime truck volumes on the log-scale. As shown in Table 78, probability density plots of all the parameters are bell-shaped, meaning that all of these parameters are exhibiting a good convergence behavior. The means of coefficient differences for minor and serious crashes 0.003 and 0.008 are slightly greater than 0, but their 95% BICs (-0.157, 0.172) and (-0.456, 0.480) cover 0. This indicates that the safety effects of daytime and nighttime truck volumes are not significantly different.

Additionally, the truck crash frequencies were estimated using the MVPLME model under scenarios with different proportions of truck traffic shifted to nighttime off-hours. A MCMC simulation through WinBUGS was conducted for the estimation and the results were reported in Table 78. In the base scenario without a shift of truck traffic (Prop.=0%), all the estimated truck crash frequencies are equal to the observed ones, which shows the powerful ability of the MVPLME model in estimation. In the scenario with 10% shift of truck traffic (Prop.=10%), in contrast with the base scenario, the daytime minor and serious truck crashes decrease by 2.43% and 2.73%, respectively, due to the lower truck volume, whereas the nighttime minor and serious truck crashes increase by 11.22% and 13.98%, respectively. For all time periods, there is a slight increase of 0.28% in minor truck crashes, 1.01% in serious truck crashes, and 0.36% in total truck crashes. Similar results can be obtained when a higher proportion of truck traffic is shifted. For example, in the scenario Prop=20%, the minor truck crashes fall by 0.20%, the serious truck crashes rise by 1.22%, and the total truck crashes drop slightly by 0.06%. When 30% of trucks are shifted (Prop=30%), we can see a 1.19% decrease in minor truck crashes and 0.88% increase in serious truck crashes. In this scenario, the total truck crashes are predicted to be reduced by 0.98%, which is a tiny change compared to the percentage of truck traffic shifted. These results show that off-hour delivery programs wouldn't increase the risk of truck-involved crashes significantly.



Note: Coeff. Difference for Minor=Coeff. of Nighttime Minor-Coeff. of Daytime Minor
Coeff. Difference for Serious=Coeff. of Nighttime Serious-Coeff. of Daytime Serious

Figure 79: The Posterior Distributions of the Coefficients for Truck Volume on the Log-Scale

Table 79: Truck Crash Frequency Estimation under Scenarios with Different Proportions of Daytime Truck Traffic Shifted

Crash Type	Observed	Prop.=0%		Prop.=10%		Prop.=20%		Prop.=30%	
		Est.	Diff. (%)	Est.	Diff. (%)	Est.	Diff. (%)	Est.	Diff. (%)
Minor	1077	1077	0%	1080	0.28%	1075	-0.20%	1064	-1.19%
Daytime	863	863	0%	842	-2.43%	819	-5.08%	794	-7.99%
Nighttime	214	214	0%	238	11.22%	256	19.46%	270	26.21%
Serious	125	125	0%	126	1.01%	126	1.22%	126	0.88%
Daytime	97	97	0%	94	-2.73%	91	-5.68%	88	-8.90%
Nighttime	28	28	0%	32	13.98%	35	25.13%	38	34.77%
Total	1202	1202	0%	1206	0.36%	1201	-0.06%	1190	-0.98%

In this sub-section, the overall crash frequency models for Manhattan road network were developed based on the 3-year crash dataset, traffic characteristics and roadway geometric features. Using these crash frequency models, crash cost functions were developed for economic impact analysis of various OHD scenarios. In addition, truck frequency models were developed to evaluate the safety impacts of shifting truck traffic from the daytime regular hours to nighttime off-hours. The results showed that OHD were not expected to increase the risk of truck-involved crashes.

Air Pollution Cost Analysis

Air pollution savings are expected to be one of the most significant components of the economic benefits from the proposed OHD program. An air pollution cost estimation methodology based on MOVES (MOtor Vehicle Emissions Simulator) is presented in this sub-section. MOVES is a computer program designed by the US Environmental Protection Agency (EPA) to predict air pollution emissions from mobile sources. MOVES replaces EPA's previous emissions model for on-road mobile sources, MOBILE6.2. MOVES can be used to estimate exhaust and evaporative emissions as well as brake and tire wear emissions from all types of on-road vehicles. The MOVES model incorporates input data that include vehicle composition, traffic activities, fuel information and meteorology parameters and conducts modal-based emissions calculations using a set of model functions. Based on the resulting modal-based vehicle emission rates, emission inventories or emission factors are then generated for the desired geographic scale for the selected time frame. In this context, the objectives of this sub-section include:

- Reviewing the relevant literature of air pollution and traffic emission estimation procedures,
- Comparing MOVES with older emission model MOBILE6.2,
- Developing an efficient traffic emission estimation and analysis procedure using MOVES.
- Developing approximation methods to MOVES emission estimates to be used for large scale traffic simulation networks such as NYBPM.
- The County level analysis of EPA MOVES to estimate pollutants based on travel activity from MTM simulation output.

Comparison to Older Emission Models

Compared to MOBILE6.2, MOVES incorporates substantial new emissions test data and accounts for changes in vehicle technology and regulations as well as improved understanding of in-use emission levels and the factors that influence them. MOVES has a completely new software framework that includes many new features and provides much more flexibility for input and output options than MOBILE6.2. New input options in MOVES and changes in the way MOVES handles existing information may appear to create significant new information burdens for states preparing submissions for SIP and conformity related purposes. Moreover, some MOVES features will ultimately make it easier for users to develop local data for MOVES. For example, MOVES uses a vehicle classification system based on the way vehicles are classified in the Federal Highway Administration's Highway Performance Monitoring System (HPMS) rather than on the way they are classified in EPA emissions regulations. This change should make it easier to use highway activity information as inputs to MOVES (Environmental Protection Agency (EPA), 2012).

The primary emission models used in the U.S developed for regulatory purposes have been the U.S EPA's MOBILE and MOVES and California Air Resources Board's EMFAC model. Both these models are conceptually similar as they use network wide average speed as input to produce activity-specific emission factors which when multiplied by vehicle activities such as vehicle miles traveled (VMT) gives the total emission inventories. EPA has recently released the final version of the next generation mobile source emission model called the Motor Vehicle Emission Simulator (MOVES). MOVES is intended to include and improve upon the capability of the other emission tools, and eventually to replace all of EPA's current emission models (MOBILE for on-road emission estimates and NON-ROAD used for off-road estimates). MOVES replaces MOBILE as the approved model for state implementation plans and regional or project-level transportation conformity analyses (Vallamsundar and Lin, 2011).

Table 80 highlights the prominent differences between MOBILE and MOVES models in terms of methodology, scope and features.

Table 80: Comparison of Mobile 6 and MOVES(Vallamsundar and Lin, 2011)

	Mobile 6	MOVES
Model Methodology	• Emissions by speed characterized by set of driving cycles	• Emissions stored by unique combination of source and operating mode bins
	• Lacked flexibility to analyze different driving patterns	• Any driving pattern can be analyzed as a sum of appropriate modes
Software Interface	• Model embedded calculation	• Graphical User Interface allows easier use
		• Relational database structure with all inputs, outputs, default activities, base modal emission rates and all intermediate calculation data stored and managed in MySQL database
		• Allows multiple computer processing
Emission Sources	• On-road	• On-road and off-road
Spatial Scale	• Single large regional scale	• Three scales of analysis: macroscopic, mesoscopic, microscopic
Pollutants	• Criteria Pollutants, Hydrocarbons, Particulate Matter, Air Toxics, GHGs - Carbon dioxide (CO2), Methane (CH4)	• All pollutants estimated by MOBILE 6.2 plus new pollutants: Sulfur dioxide (S02), Ammonia (NH3), Nitrogen oxides (NO2, NO), Energy Consumption
Emission Process	• Running Exhaust	• Running Exhaust
	• Start Exhaust	• Start Exhaust
	• Hot Soak	• Extended idling
	• Diurnal	• Off-gassing (well-to-pump)
	• Resting Loss	• Evaporative Fuel Permeation
	• Running Loss	• Evaporative Fuel Vapor Venting
	• Crankcase	• Evaporative Fuel Leaking
	• Refueling	• Brake wear
	• Brake wear	• Tire wear
	• Tire wear	• To be added in future versions:
		• Energy and emissions from vehicle manufacture and disposal

Results of a comparative study between MOVES and MOBILE6 study indicate the following (Venugopal, 2010):

- NO_x emission levels are higher in MOVES. There is an increase in NO_x levels by 63% for 2012.
- CO emission levels are lower in MOVES. There is a decrease in CO levels by 10% for 2012.
- Emission rates are very sensitive to the speeds.
- MOVES requires longer run times, which makes it resource intensive.

Similar results are obtained in a study conducted by Texas Transportation Institute (TTI, 2010). NO_x rates are substantially higher in MOVES, whereas CO levels are greater in MOBILE6. Another comparison between MOVES and EMFAC models is presented for Los Angeles County, California as a case study. As a result of this study, the authors state that, in contrast to traditional mobile source emission models such as EMFAC or MOBILE, MOVES uses a combination of VSP and speed bins, rather than speed correction factors, to quantify running exhaust emissions; uses vehicle operating time rather than vehicle miles traveled as the unit of measure for various vehicle activities and emissions; and uses a relational database to manipulate data and enable multi-scale emissions analyses from regional down to link-level applications (Bai et al., 2009). In light of these new features, they find out that MOVES is a superior analysis tool certainly, and it should be more responsive to variations in traffic dynamics and roadway congestion levels.

Another model on dynamic modeling with capabilities for second-by-second emission estimation of various pollutants is the Comprehensive Modal Emissions model (CMEM). The CMEM model was developed at the University of California, Riverside as a microscopic scale emissions predictions model, that was specially designed to improve the prediction of the variation of the vehicle's operating conditions (i.e. the various driving 'modes', such as idle, steady-state cruise, various levels of acceleration/deceleration, etc). This approach needs detailed information on the fleet distribution of vehicles, including age and fuel information (Barth et al., 2000). The latest version is CMEM2.0, released in 2000. Using the methodology of CMEM, the model called PERE (Physical Emission Rate Estimator) is designed to support MOVES. PERE is a series of stand-alone spreadsheets, which can be run and modified by a user (Nam and Giannelli, 2005).

MOVES Input Data Requirements

Input files for an emission analysis in MOVES are in the .xls format (Microsoft Excel spreadsheets). These input files for the project level analysis include the following (Table 81):

- Link Information (Link volume, length, grade).
- Link Sources (Type and percentage of vehicles).
- Meteorology (Temperature and humidity).
- Age Distribution of Vehicles.
- Fuel Supply and Formulation.

Table 81: Input Data Requirements for MOVES (MOVES, 2011)

Project Level Analysis		
Data Item	**Description**	**Source**
Link	Roadway link characteristics	User defined
Link Source Type Fraction	Vehicle fleet composition for each roadway link	Users have to calculate the percentage of link traffic volume driven by each vehicle type
Source Type Age Distribution	Vehicle age distribution	MOVES default data
Meteorology	Temperature and humidity	MOVES default data
Fuel Supply and Formulation	Fuel supply parameters and associated market share for each fuel	MOVES default data

Vehicle Types

Vehicle types defined in MOVES are given in Table 82. Note that in MOVES, "long-haul" trucks are defined as trucks for which most trips are 200 miles or more.

Table 82: Vehicle Types for MOVES (MOVES, 2011)

MOVES code	MOVES description
11	Motorcycle
21	Passenger Car
31	Passenger Truck
32	Light Commercial Truck
41	Intercity Bus
42	Transit Bus
43	School Bus
51	Refuse Truck
52	Single Unit Short-Haul Truck
53	Single Unit Long-Haul Truck
54	Motor Home
61	Combination Short-Haul Truck
62	Combination Long-Haul Truck

Pollutant Types

In MOVES, emission levels can be calculated for the pollutant types given in Table 83. Note that there are post-processing codes available from EPA (can be downloaded from http://www.epa.gov/oms/models/moves/tools.htm) to calculate the total amount of Particulate Matter levels (i.e., total amount of PM10 is equal to the sum of pollutants 101 to 107).

Table 83: Pollutant Types for MOVES (MOVES, 2009)

Pollutant ID	MOVES description	Pollutant Abbreviation
1	Total Gaseous Hydrocarbons	HC
2	Carbon Monoxide (CO)	CO
3	Oxides of Nitrogen	NO_x
5	Methane (CH_4)	CH_4
6	Nitrous Oxide (N_2O)	N_2O
90	Atmospheric CO_2	AT CO_2
91	Total Energy Consumption	TotEnergy
92	Petroleum Energy Consumption	PetEnergy
93	Fossil Fuel Energy Consumption	FossilEnergy
98	CO_2 Equivalent	CO2EQ
101	Primary PM10 – Organic Carbon	PM10OC
102	Primary PM10 – Elemental Carbon	PM10EC
105	Primary PM10 – Sulfate Particulate	PM10Sulfate
106	Primary PM10 – Brakewear Particulate	PM10Brake
107	Primary PM10 – Tirewear Particulate	PM10Tire
111	Primary PM25 – Organic Carbon	PM25OC
112	Primary PM25 – Elemental Carbon	PM25EC
115	Primary PM25 – Sulfate Particulate	PM25Sulfate
116	Primary PM25 – Brakewear Particulate	PM25Brake
117	Primary PM25 – Tirewear Particulate	PM25Tire

Emission Level Estimation

In this section, emission factor (HC, CO, NO_x, PM10 Levels, etc.) calculations are given using MOVES, given a set of input links with speed/volume/link type information, and subject to several other non-network parameters (i.e. meteorology, age distribution and fuel related information). Several scenarios have been tested at different speeds for all vehicle types on a typical link (Urban Unrestricted Access: all other urban roads except highways, i.e., arterials, connectors, and local streets) to estimate emission rate vs. speed relationships. Emission rates due to vehicle idling, traffic signals, etc. are also studied extensively.

Estimation Methodology for Moving Vehicles

In order to fit emissions approximation functions for different vehicle types from MOVES output, it is necessary to obtain emission levels for different vehicle types, fuel types, and speed levels. A link characteristics input file is created with speed values of 1 to 10 mph (1 mph increments), and increasing by 5 mph until 80 mph. For lower speeds, the speed increments are specifically selected as 1 mph to capture high emission level changes whereas for higher speeds where the emission changes between speeds are low, they are chosen as 5 mph. In the input file used to generate emissions functions, link distances and volumes are selected as 1 mile and 1 vehicle, respectively, to calculate the unit emission levels per distance and per vehicle (grams/vehicle-mile). This process is repeated for every vehicle type (cars, trucks, and buses) and for diesel and gasoline fuels. MOVES is then repeatedly run to generate emissions estimations for each pollutant. The results for each speed value and for each vehicle type are plotted to fit a curve to the data. For vehicle idling emissions, analysis is conducted with zero speed for each vehicle type. With this analysis, the unit emission levels per hour (grams/hour) are obtained for diesel and gasoline fueled vehicles.

Emission level results from MOVES 2010b are given for four pollutants: CO, NO_x, HC and PM_{10}. Comparison of MOVES results with results from MOBILE, the pre-cursor to MOVES, is also provided. During the comparison with MOBILE, MOVES results for trucks and buses are presented as the average of the available types (sizes/buses/fuel) for simplicity. Similarly, idling results are limited to diesel fuel trucks and buses and gasoline fuel passenger cars. It is important to note that MOVES runs produce grams/vehicle-mile emission levels for moving vehicles, and grams/vehicle-hour emission rates for idle vehicles.

Carbon Monoxide (CO)

Carbon monoxide emissions increase when conditions are poor for combustion, and they pose significant health impacts on people. Figure 80 shows the CO emission levels versus speed estimated from MOVES for different types of diesel and gasoline trucks, respectively. Combination short- and long-haul trucks are estimated to generate the largest CO levels. Figure 81 shows CO emission levels comparisons (MOVES versus MOBILE) for different types of vehicles. Results indicate that for trucks and buses, MOBILE generates similar values as MOVES; however for cars, the CO emission levels are lower from MOVES by about 50%.

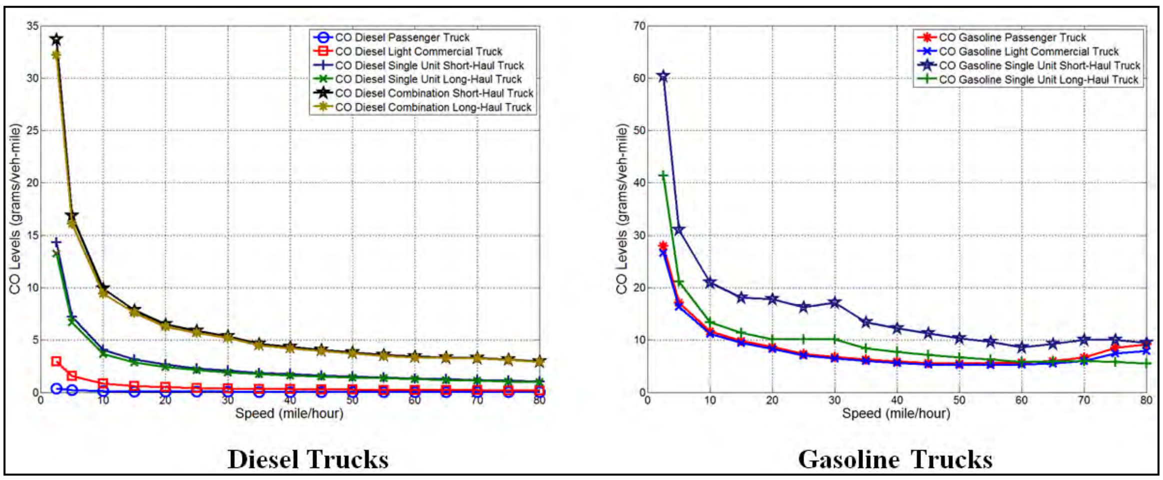


Figure 80: CO Levels from MOVES for Different Types of Trucks

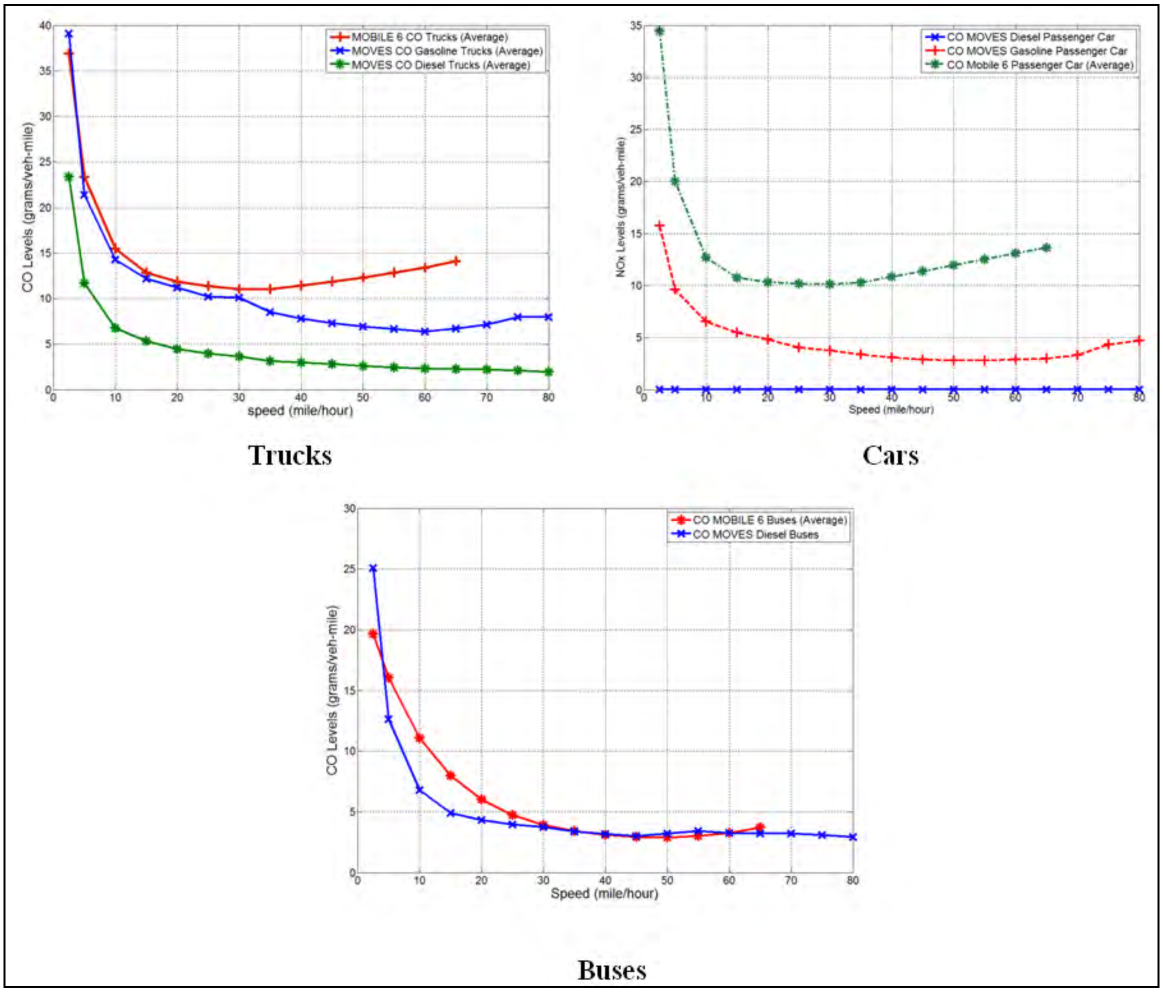


Figure 81: CO Level Comparison for Different Type of Vehicles

Nitrogen Oxides (NOx)

One of the primary sources of nitrogen oxides is motor vehicles, and they have adverse effects on respiratory systems and vegetation. Figure 82 shows the NO_x emission levels versus speed estimated from MOVES for different types of diesel and gasoline trucks, respectively. Results indicate that trucks that have larger sizes and more axles output higher NO_x levels. Figure 83 shows the NO_x emission level comparison (MOVES versus MOBILE6) for different types of vehicles. Comparative results indicate that NO_x results are substantially different between MOVES and MOBILE, especially for lower speed values. NO_x levels for diesel trucks calculated by MOVES show a critical difference, and MOBILE NO_x levels for passenger cars are higher than those of MOVES.

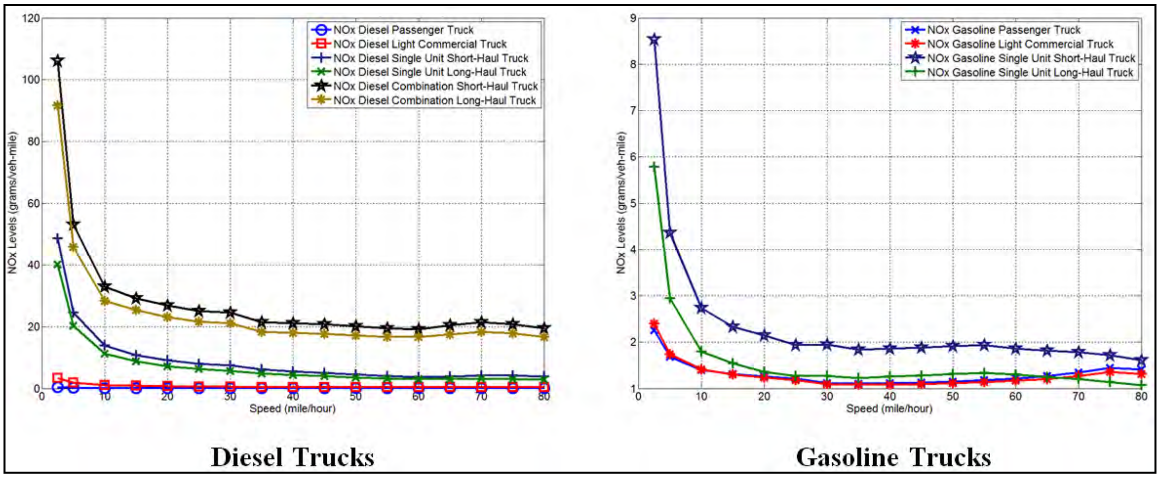


Figure 82: NO_x Levels from MOVES for Different Types of Trucks

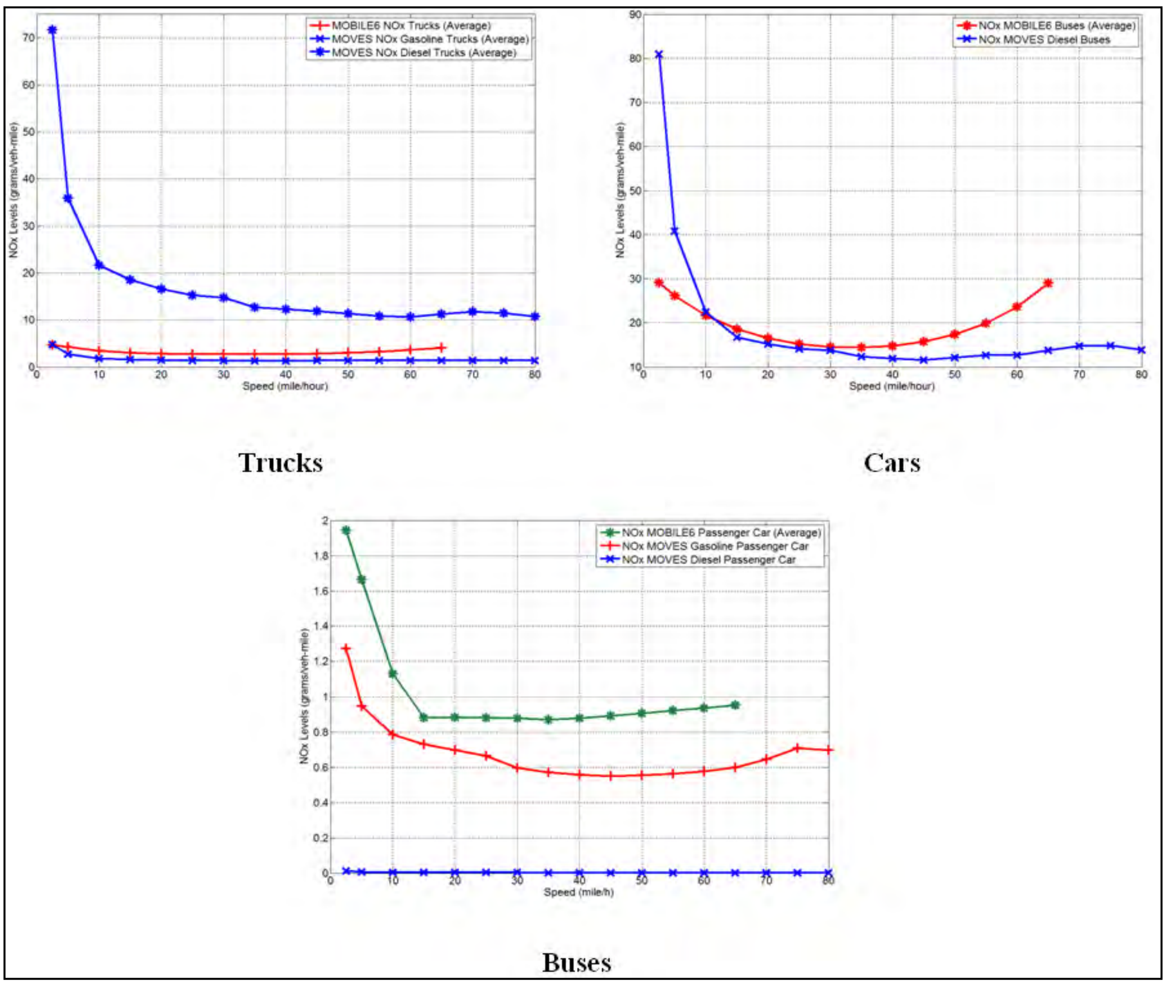


Figure 83: NO_x Level Comparison for Different Type of Vehicles

Hydrocarbons (HC)

Hydrocarbons include many toxic compounds that cause cancer and other adverse health effects. Figure 84 shows the HC emission levels versus speed estimated from MOVES for different types of diesel and gasoline trucks. Similar to other pollutants, short- and long-haul trucks output more HC. Figure 85 shows the HC emission levels comparison (MOVES versus MOBILE6) for different types of vehicles. HC levels appear to be very similar for trucks between MOVES and MOBILE, however, they are significantly different for cars. For buses, the difference is greater at lower speeds.

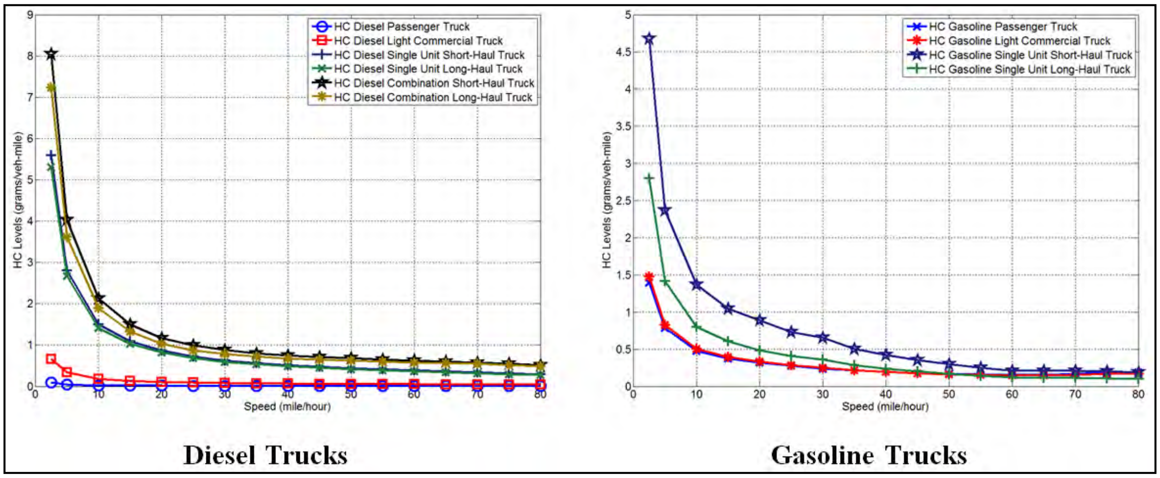


Figure 84: HC Levels from MOVES for Different Types of Trucks

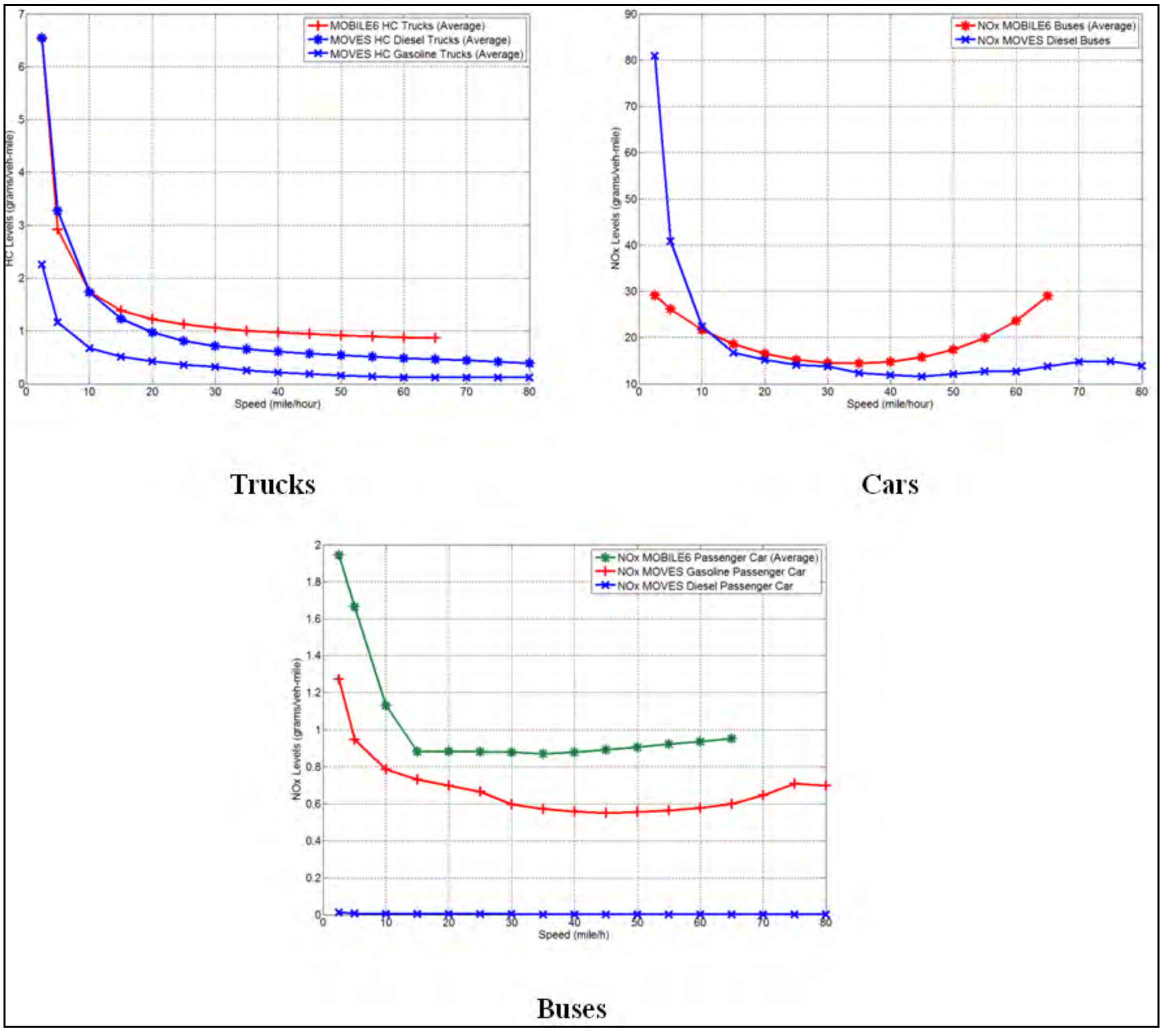


Figure 85: HC Level Comparison for Different Type of Vehicles

Particulate Matter 10 (PM10)

PM_{10} are tiny particles or liquid droplets suspended in the air that can contain a variety of chemical components that are 10 microns in diameter or less. Figure 86 shows the PM_{10} emission levels versus speed estimated from MOVES for different types of diesel and gasoline trucks, respectively. For diesel trucks, combination unit trucks create the highest emission levels. Figure 87 shows the PM_{10} emission levels comparison plots (MOVES versus MOBILE6) for different types of vehicles. Results indicate that PM_{10} estimations are significantly different in MOVES. For all vehicles, MOVES results present significantly higher emission levels.

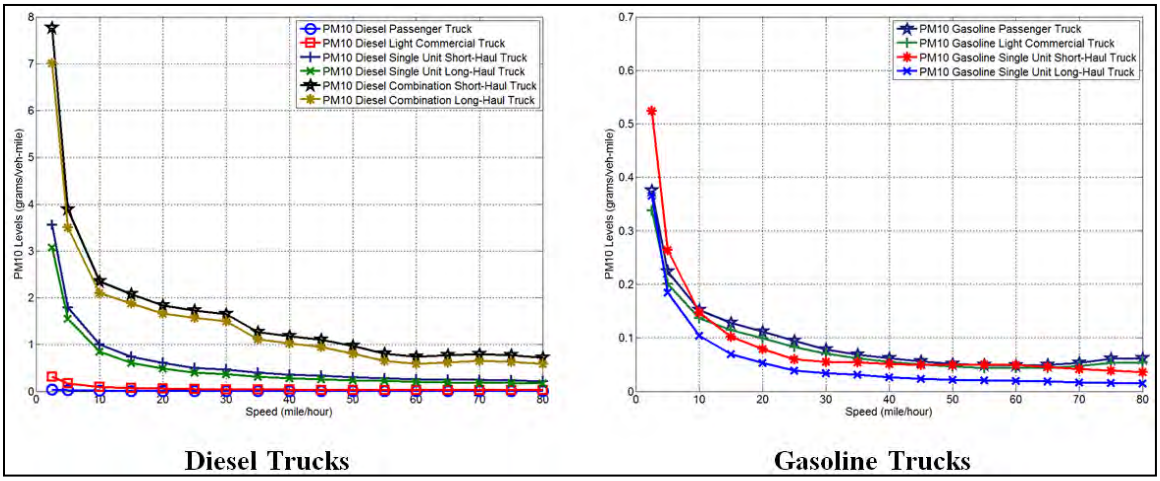


Figure 86: PM_{10} Levels from MOVES for Different Types of Trucks

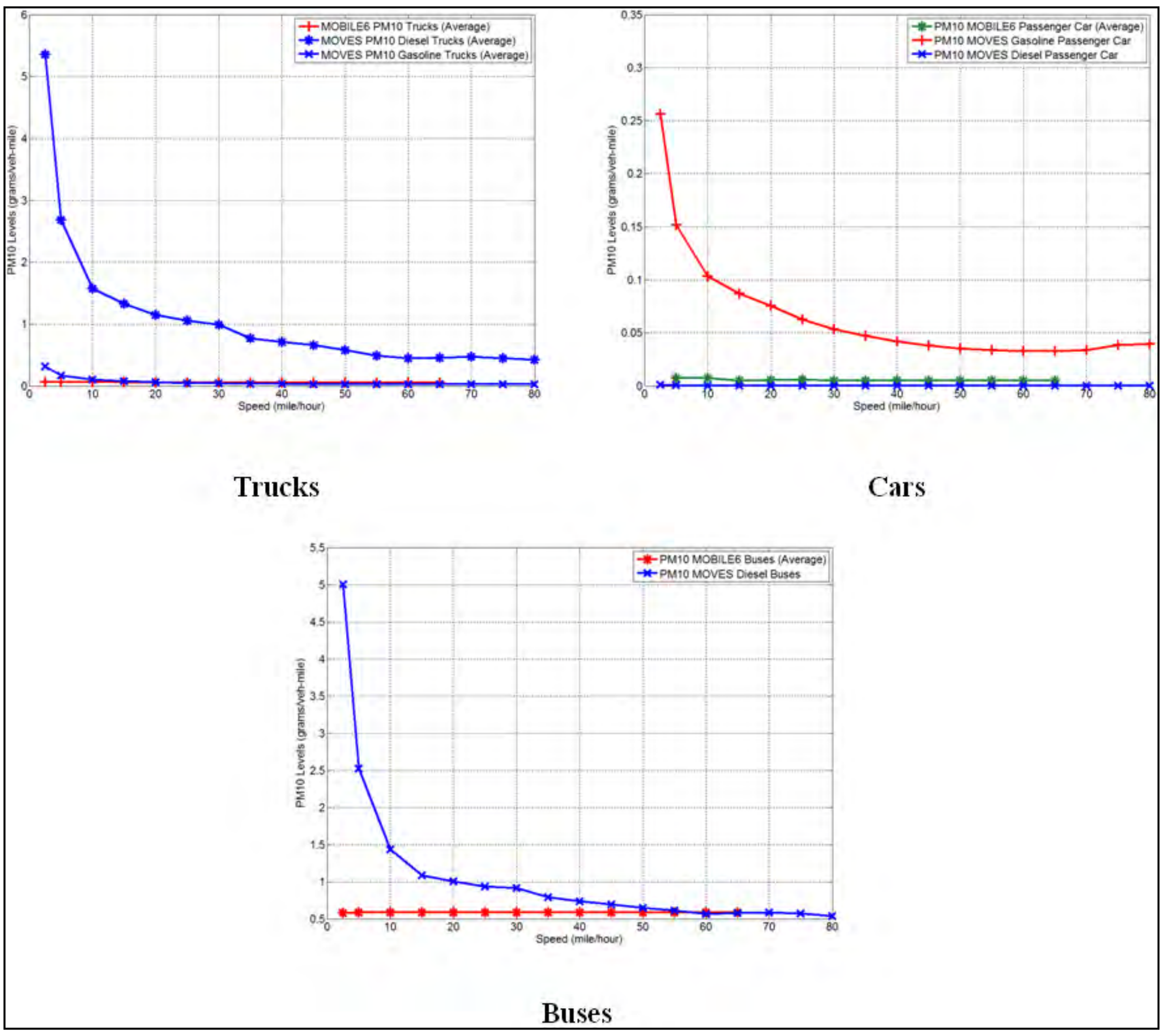


Figure 87: PM_{10} Level Comparison for Different Type of Vehicles

Approximation of MOVES Estimations with Distribution Fits for Moving Vehicles

In this section, distribution fits for the pollutant estimates are generated from MOVES for different vehicle types at several speed values. This method enables offline emission calculations to avoid the long running time of MOVES. Different distributions are tested starting with power and polynomial fits, and the best fit is obtained by an eighth degree Fourier series fit. As an example, Figure 88 shows the Fourier series fit on the CO levels for gasoline passenger cars, diesel trucks and diesel buses. As observed, fits are almost perfect fits on the CO emission levels estimated from MOVES.

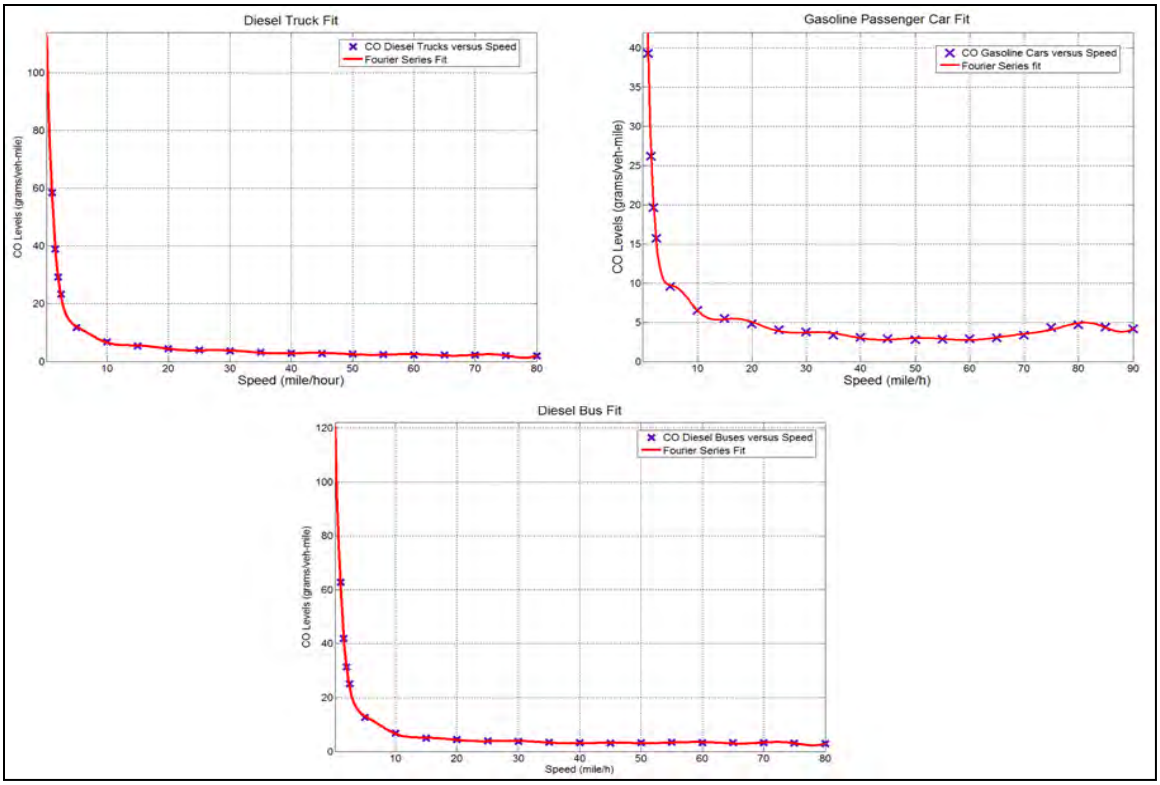


Figure 88: Example of Fourier Series-based Functional Approximations for CO Levels

After a thorough comparative analysis of other pollutants for all vehicle types, the Fourier series is found to best fit all pollutant estimations from MOVES. These formulations are ultimately used to input functions into a software analysis tool, Assist-Me, to calculate emission levels of pollutants for each type of vehicle on a network. Coefficients are estimation for eighth order Fourier series fits (based on sums of sine and cosine functions that can capture even the smallest fluctuations in the emission levels) of all the pollutants for different types of vehicles to fit equation (**32**).

$$\begin{aligned} Emission\ Levels = {} & a_0 + a_1 * \cos(w*V) + b_1 * \sin(w*V) + a_2 * \cos(2*w*V) + b_2 * \sin(2*w*V) \\ & + a_3 * \cos(3*w*V) + b_3 * \sin(3*w*V) + a_4 * \cos(4*w*V) + b_4 * \sin(4*w*V) \\ & + a_5 * \cos(5*w*V) + b_5 * \sin(5*w*V) + a_6 * \cos(6*w*V) + b_6 * \sin(6*w*V) \\ & + a_7 * \cos(7*w*V) + b_7 * \sin(7*w*V) + a_8 * \cos(8*w*V) + b_8 * \sin(8*w*V) \end{aligned} \quad \textbf{(32)}$$

where V is the speed on the roadway link.

Carbon Monoxide (CO)

Table 84 shows the parameter (coefficient) estimation for CO Fourier series fits for different types of vehicles.

Table 84: Parameter Information for CO Fourier Series Fit

	Coefficients			
	Gasoline Trucks	**Diesel Trucks**	**Buses**	**Cars**
a_0	2.07E+13	1.18E+13	1.19E+13	8.67E+12
a_1	-3.20E+13	-1.80E+13	-1.80E+13	-1.33E+13
b_1	-1.90E+13	-1.10E+13	-1.10E+13	-7.87E+12
a_2	1.26E+13	7.21E+12	7.22E+12	5.28E+12
b_2	2.29E+13	1.31E+13	1.32E+13	9.60E+12
a_3	4.26E+11	2.42E+11	3.03E+11	1.88E+11
b_3	-1.50E+13	-8.30E+12	-8.40E+12	-6.10E+12
a_4	-3.30E+12	-1.90E+12	-1.90E+12	-1.40E+12
b_4	5.28E+12	3.01E+12	3.02E+12	2.21E+12
a_5	1.77E+12	1.01E+12	1.03E+12	7.42E+11
b_5	-9.10E+11	-5.20E+11	-5.10E+11	-3.79E+11
a_6	-4.50E+11	-2.50E+11	-2.60E+11	-1.86E+11
b_6	-2.60E+10	-1.50E+10	-1.90E+10	-1.15E+10
a_7	5.21E+10	2.97E+10	2.96E+10	2.17E+10
b_7	3.50E+10	1.99E+10	2.06E+10	1.47E+10
a_8	-1.80E+09	-1.00E+09	-9.90E+08	-7.42E+08
b_8	-3.80E+09	-2.10E+09	-2.20E+09	-1.57E+09
w	0.010578	0.010578	0.010578	0.010578

Hydrocarbons (HC)

Table 85 shows the parameter (coefficient) estimation for HC Fourier series fits for different types of vehicles.

Table 85: Parameter Estimation for HC Fourier Series Fit

	Coefficients			
	Gasoline Trucks	**Diesel Trucks**	**Buses**	**Cars**
a_0	1.16E+12	3.26E+12	3.11E+12	3.89E+11
a_1	-1.80E+12	-5.00E+12	-4.80E+12	-6.00E+11
b_1	-1.00E+12	-3.00E+12	-2.80E+12	-3.50E+11
a_2	7.06E+11	1.99E+12	1.89E+12	2.37E+11
b_2	1.28E+12	3.61E+12	3.46E+12	4.31E+11
a_3	2.44E+10	7.19E+10	7.74E+10	9.00E+09
b_3	-8.10E+11	-2.30E+12	-2.20E+12	-2.70E+11
a_4	-1.90E+11	-5.30E+11	-5.10E+11	-6.30E+10
b_4	2.95E+11	8.30E+11	7.90E+11	9.89E+10
a_5	9.90E+10	2.79E+11	2.68E+11	3.34E+10
b_5	-5.10E+10	-1.40E+11	-1.30E+11	-1.70E+10
a_6	-2.50E+10	-7.00E+10	-6.70E+10	-8.40E+09
b_6	-1.50E+09	-4.40E+09	-4.70E+09	-5.50E+08
a_7	2.90E+09	8.16E+09	7.75E+09	9.71E+08
b_7	1.96E+09	5.55E+09	5.37E+09	6.65E+08
a_8	-1.00E+08	-2.80E+08	-2.60E+08	-3.30E+07
b_8	-2.10E+08	-5.90E+08	-5.70E+08	-7.10E+07
w	0.010578	0.010578	0.010578	0.010578

Particulate Matter 10 (PM10)

Table 86 shows the parameter (coefficient) estimation for PM10 Fourier series fits for different types of vehicles.

Table 86: Parameter Estimation for PM10 Fourier Series Fit

	Coefficients			
	Gasoline Trucks	Diesel Trucks	Buses	Cars
a_0	1.54E+11	2.92E+12	2.45E+12	1.33E+11
a_1	-2.40E+11	-4.50E+12	-3.80E+12	-2.00E+11
b_1	-1.40E+11	-2.60E+12	-2.20E+12	-1.20E+11
a_2	9.37E+10	1.79E+12	1.49E+12	8.11E+10
b_2	1.71E+11	3.22E+12	2.72E+12	1.48E+11
a_3	3.63E+09	4.96E+10	5.38E+10	2.97E+09
b_3	-1.10E+11	-2.10E+12	-1.70E+12	-9.40E+10
a_4	-2.50E+10	-4.60E+11	-4.00E+11	-2.20E+10
b_4	3.92E+10	7.48E+11	6.24E+11	3.39E+10
a_5	1.32E+10	2.49E+11	2.10E+11	1.14E+10
b_5	-6.70E+09	-1.30E+11	-1.10E+11	-5.80E+09
a_6	-3.30E+09	-6.30E+10	-5.30E+10	-2.90E+09
b_6	-2.20E+08	-3.00E+09	-3.30E+09	-1.80E+08
a_7	3.85E+08	7.40E+09	6.14E+09	3.33E+08
b_7	2.64E+08	4.84E+09	4.17E+09	2.27E+08
a_8	-1.30E+07	-2.60E+08	-2.10E+08	-1.10E+07
b_8	-2.80E+07	-5.30E+08	-4.50E+08	-2.40E+07
w	0.010578	0.010578	0.010578	0.010578

Nitrogen Oxides (NOx)

Table 87 shows the parameter (coefficient) estimation for NOx Fourier series fits for different types of vehicles.

Table 87: Parameter Estimation for NOx Fourier Series Fit

	Coefficients			
	Gasoline Trucks	Diesel Trucks	Buses	Cars
a_0	2.38E+12	3.75E+13	3.90E+13	6.70E+11
a_1	-3.70E+12	-5.80E+13	-6.00E+13	-1.00E+12
b_1	-2.20E+12	-3.40E+13	-3.60E+13	-6.10E+11
a_2	1.45E+12	2.29E+13	2.37E+13	4.04E+11
b_2	2.65E+12	4.15E+13	4.33E+13	7.45E+11
a_3	5.80E+10	7.38E+11	9.57E+11	1.91E+10
b_3	-1.70E+12	-2.60E+13	-2.70E+13	-4.70E+11
a_4	-3.90E+11	-6.00E+12	-6.40E+12	-1.10E+11
b_4	6.05E+11	9.57E+12	9.91E+12	1.69E+11
a_5	2.05E+11	3.20E+12	3.35E+12	5.78E+10
b_5	-1.00E+11	-1.70E+12	-1.70E+12	-2.80E+10
a_6	-5.10E+10	-8.10E+11	-8.40E+11	-1.40E+10
b_6	-3.60E+09	-4.50E+10	-5.90E+10	-1.20E+09
a_7	5.94E+09	9.45E+10	9.72E+10	1.65E+09
b_7	4.10E+09	6.31E+10	6.72E+10	1.17E+09
a_8	-2.00E+08	-3.30E+09	-3.30E+09	-5.40E+07
b_8	-4.40E+08	-6.80E+09	-7.10E+09	-1.20E+08
w	0.010578	0.010578	0.010578	0.010578

Emission Levels during Idling

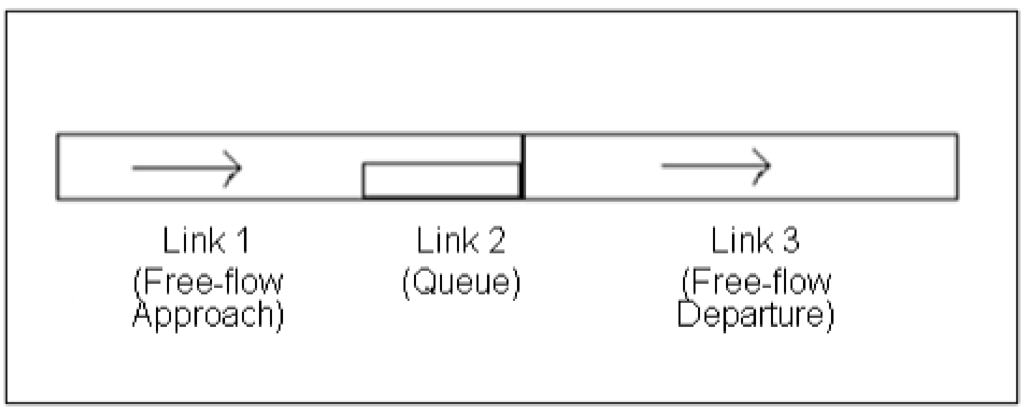


Figure 89: Idling Example

Traffic idling (stopping due to a traffic light, congestion, etc.) is critical for air pollution analysis since idle speeds can create a significant amount of emissions. Idling analysis based on traffic signal analysis is given in an earlier study, which includes the calculation of emission levels based on zero speeds (MOVES, 2011). Emission analysis is conducted within MOVES for zero speed for each vehicle type (cars, trucks, and buses), and the unit emission levels per hour (grams/hour) are obtained for diesel and gasoline fueled vehicles. Results of the analysis can be seen in Table 88 for gasoline-fueled cars and diesel trucks and buses.

Table 88: Emission Levels for Idling

Vehicle Type	Pollutant Levels (grams/veh-hour)			
	CO	NOx	HC	PM10
Cars	24.952	1.693	1.708	0.21
Trucks	21.704	82.071	9.795	4.534
Buses	29.959	138.646	12.457	5.123

These emission levels can be multiplied by the average stop time per vehicle on a roadway link, if available, to calculate the total idling emissions with respect to different vehicle types and pollutants. Large-scale travel demand models that employ equilibrium assignment may not provide stopped time output for traffic; however mesoscopic or microscopic simulation models often calculate this information on a vehicle- by-vehicle basis, and can provide the results as an output for each network link or overall network.

Validity of Approximation Method

The approximation method was developed to provide an alternative to running MOVES. The main problem with using MOVES is the long run time when trying to process anything larger than a simple network with dozens of links. This section describes a scenario-based analysis that uses the output of transportation network models to estimate emissions from MOVES and from Assist-Me, using the fitted approximation functions based on MOVES output.

The methodology is applied to New York Best Practice Model (NYBPM) network. The NYBPM data consisted of four scenarios: AM peak, midday, PM peak, and night. The AM peak was selected as the base scenario to be run in MOVES due to the extensive computational run time for the NYBPM network that consists of 53,399 links, and 39 characteristics for each link, ranging from length, speed, and travel time to number of single occupancy vehicles, trucks, commercial vehicles, and buses. The necessary information was extracted from the transportation network model for the given scenario and used in MOVES. Only one direction of each link for 1-hour (7-8 AM) period was used for the AM peak period, otherwise the number of links would double and processing would take a very long time.

Next, several other scenarios were created to estimate the emission levels focusing on the different parts of the network. While creating the scenarios, the following factors were taken into consideration:

- Goals oriented towards short and long term planning
- Complexity and runtimes
- Network size
- Ease of applicability
- Flexibility

Based on this information, Figure 90 shows the scenario matrix within four quadrants defined by the aforementioned factors. The scenario matrix approach was introduced as a deductive method useful for constructing and describing scenarios where deductive scenario methods were perceived as the most analytical and exhaustive ways of building scenarios from an outside-in perspective.

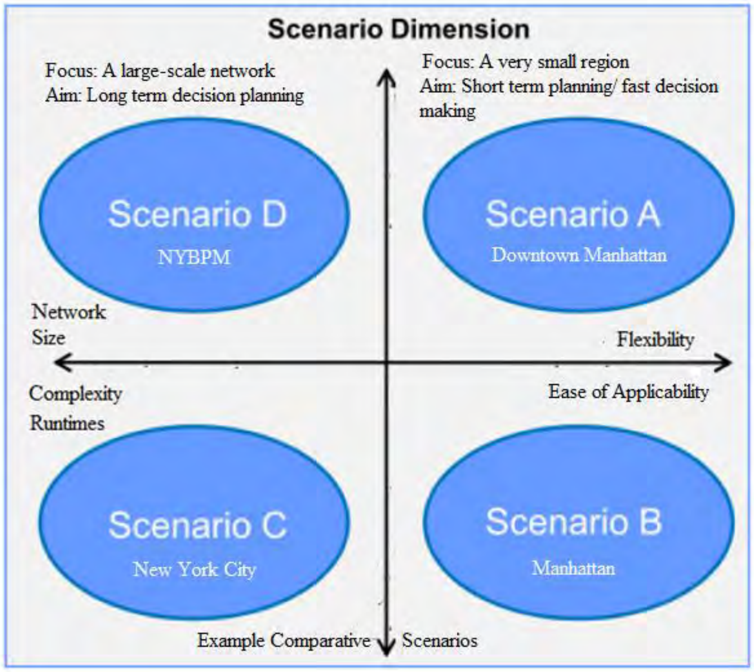
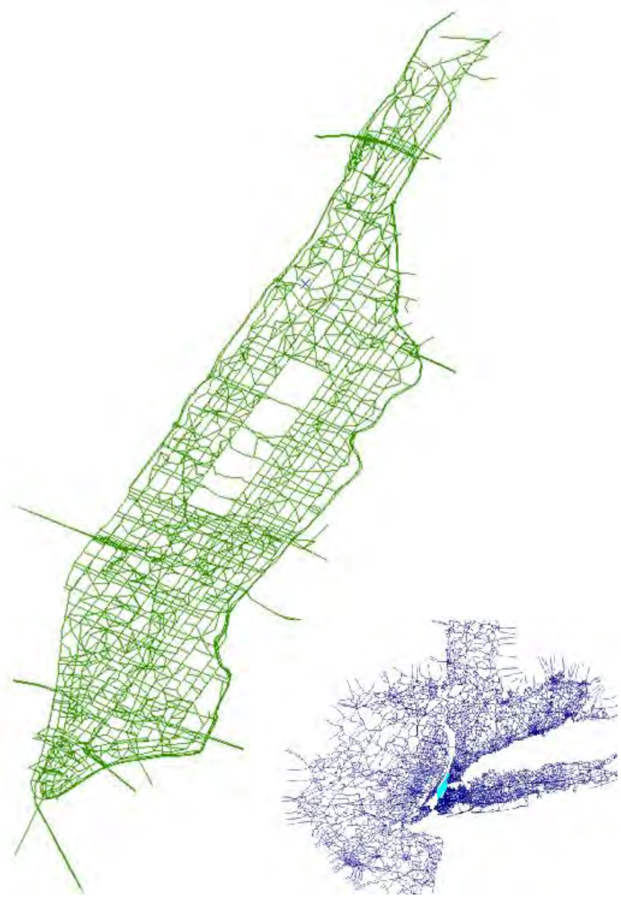


Figure 90: Scenario Matrix (adapted from Van der Heijden, 2005)

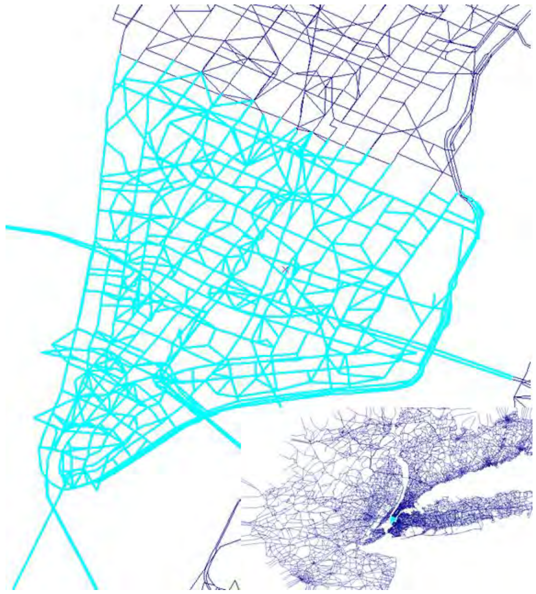
Figure 91 shows the networks considered for these scenarios.

(a)

(b)



(c)



(d)

Figure 91: Networks Used for the Scenario-based Analysis: (a) The Whole NYBPM Network (b) New York City Network (c) Manhattan Network (d) Downtown Manhattan Network

Table 89, on the other hand, lists the critical model-derived parameters of the networks for the scenarios presented in Figure 91.

Table 89: Scenario Network Information

Downtown Manhattan Network		Manhattan Network	
Number of Links	1,166	Number of Links	4,080
Average Speed (m/h)	10.34	Average Speed (m/h)	12.6
Total Flow (veh)	536,497	Total Flow (veh)	2,054,030
Vehicle Type Percentages			
Cars	64.7	Cars	69.1
Trucks	33.3	Trucks	28.1
Buses	1.6	Buses	2.7
New York City Network		**Whole NYBPM Network**	
Number of Links	18,983	Number of Links	53,399
Average Speed (m/h)	15.51	Average Speed (m/h)	20.46
Total Flow (veh)	8,002,407	Total Flow (veh)	21,117,862
Vehicle Type Percentages			
Cars	78.4	Cars	84.9
Trucks	16.7	Trucks	14.2
Buses	4.7	Buses	0.79

Base Scenario Results

For the base case scenario, Table 90 and Figure 92 show the comparison between MOVES and Assist-Me generated approximation function results, and shows that the Fourier series distributions can estimate the pollutant levels successfully without compromising accuracy with a maximum percentage difference of approximately 1.50. This efficient and accurate estimation, here, is especially important for large networks due to the fact that estimation error per vehicle and per mile can lead to very large error values for high traffic volumes and large networks.

Table 90: Emission Level Analysis and Comparison for the NYBPM Network (Base Case Scenario: AM Peak Only)[1]

Vehicle Type	Pollutant Levels (grams)				
	CO	NO_x	HC	PM10	Total
Cars	30,759,076	5,062,936	1,001,514	650,652	**37,474,178**
Trucks	4,777,796	19,583,105	774,237	2,227,880	**27,363,018**
Light Commercial Trucks	2,373,850	189,899	87,453	37,378	**2,688,580**
Buses	200,283	666,039	41,087	105,799	**1,013,208**
Total	**38,111,005**	**25,501,979**	**1,904,291**	**3,021,709**	**68,538,974**
Comparison of MOVES and Approximation Function Results					
	Approximation (grams)	**MOVES (grams)**		**Difference**	**Percent Difference**
CO	38,111,005	38,426,710		315,705	**0.82**
NO_x	25,501,979	25,883,741		381,762	**1.49**
HC	1,904,291	1,931,753		27,462	**1.43**
PM10	3,021,709	3,022,630		922	**0.03**

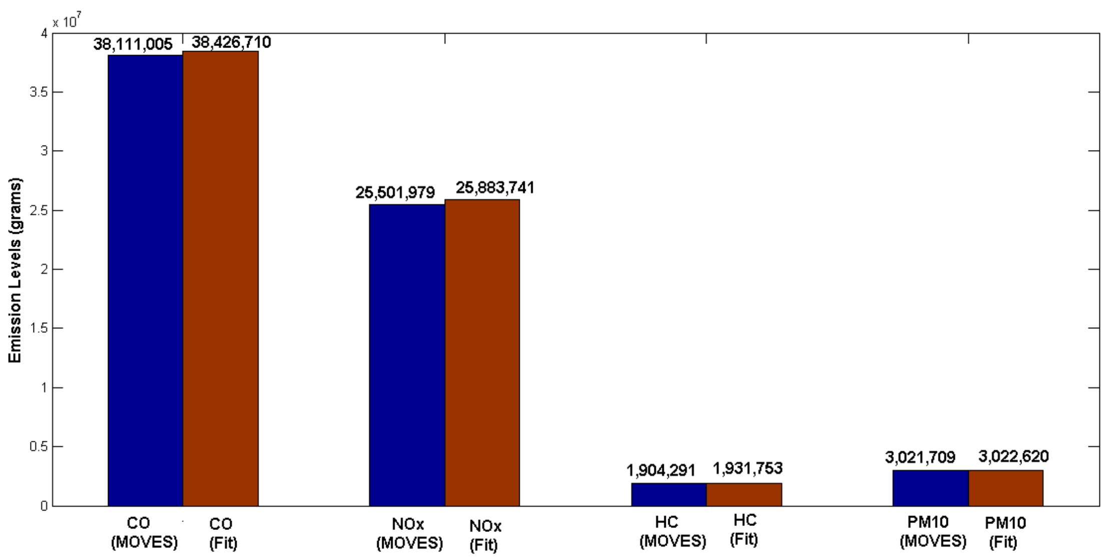


Figure 92: Comparison of MOVES and Approximation Function Results for the NYBPM AM Network

Unfortunately, MOVES takes a very long time to produce results, depending on the number of links and number of chosen pollutants. A hundred links may take as little as thirty minutes to complete, but five thousand links will take up to a week of computation time. Especially certain pollutants, such as PM10, are comprised of sub-pollutants which are codependent on each other which render the computational time even longer. As seen from Table 89, there are 53,399 total links that are processed. The

[1] The network files used in this analysis are available upon request.

computational times for this process, including the pre-processing of transportation network inputs, were about 10 days each for NOx and CO, and almost a month (30 days) each for HC and PM10 (More specifically, analyzing 1000 links in MOVES took approximately 14 hours for one vehicle type and four pollutants). The run time for each individual file changed depending on how many individual links actually had data. For example, for the bus vehicle type, more than half the links had a value of zero because bus use was not detected on those links. Overall, the total run time for the entire network was extensive. Moreover, because there were four vehicle types, each pollutant needed to be run four times. In this case, using one computer would mean that the total calculation time would exceed half a year. The solution to this problem is either to run the program simultaneously on multiple processors/computers, or to find another method that will reduce the computational burden for running MOVES such as the approximation function methodology presented in this paper. Running MOVES for the NYBPM network takes almost a month in computational time, whereas Assist-Me tool can be completed within a matter of hours.

Although the difference between MOVES and approximation function results is negligible (less than 1.50%), a t-test is also used to evaluate if the difference between two results is statistically significant. The null hypothesis is that the difference between the averages of emission level estimates for both methods is zero, and the alternative hypothesis is that they are not zero. Results indicate that the differences between the average emission level estimates of MOVES and the approximations are not statistically significant (T-test @ 95%) for all pollutant types. This indicates that we can accept the null hypothesis and results of MOVES and approximation functions are statistically indifferent for the base case scenario.

Next, we will focus on the results of air pollution analysis for the scenarios created.

Approximation Functions for Different Scenarios

In this step, based on the accurate approximation function results for the base scenario, Assist-Me is run using the MOVES-based approximation functions for several new scenarios created using the New York Best Practice Model (NYBPM) network. The aim of this scenario-based analysis is to indicate the ease of calculating air pollution estimates using the approximation function methodology. A comparison for approximation functions and MOVES run results is also presented for the small networks given in Scenario A and B to make sure that the approximation functions for small networks also successfully represent the MOVES results.

Scenario A

In this scenario, a small network extracted from NYBPM network is considered, namely downtown Manhattan network which consists of 1,166 links (for AM peak period only). This scenario can provide the official with a detailed focus on a specific area (downtown Manhattan) and the opportunity to make decisions in the shortest amount of time possible. Note that, for such a small-scale network, MOVES can still be run efficiently to find the emission levels. Table 91 shows the results of this scenario (with an extra comparison between MOVES and approximation functions to validate the performance of the methodology) where percentage difference is not more than 4.53%, which is for NO_x. According to the result of the t-test conducted for this scenario with the hypotheses defined similarly as for the base case scenario (T-test @ 95%), results of MOVES and approximation functions are statistically indifferent.

Table 91: Comparison of MOVES and Approximation Function Results for the Downtown Manhattan Network

	Approximation (grams)	MOVES (grams)	Difference	Percent Difference
CO	411,786.42	419,403,54	7,617.12	**1.81**
NO_x	248,838.79	260,660.30	11,821.51	**4.53**
HC	24,851.83	25,623.26	771.43	**3.01**
PM10	20,500.93	19,976.18	524.75	**2.63**

Scenario B

In this scenario, a relatively larger network with respect to the one in Scenario A is considered: Manhattan network (4,080 links) for AM peak period only. This analysis can be compared with Scenario A to investigate the effects of air pollution emissions on air quality in the downtown and other parts of Manhattan. One outcome of this comparison would be a decision on changing the truck delivery dates within Manhattan to improve the air quality (Note that approximately 20% of the emissions are due to downtown Manhattan). For this scenario, MOVES results are also obtained for comparison which shows a maximum percentage difference of 2.63% for NO_x, as presented in Table 92. With the null and alternative hypothesis defined as in the base case scenario, the t-test conducted for this scenario (T-test @ 95%) shows that results are not significantly different from each other.

Table 92: Comparison of MOVES and Approximation Function Results for the Manhattan Network

Comparison of MOVES and Approximation Function Results				
	Approximation (grams)	**MOVES (grams)**	**Difference**	**Percent Difference**
CO	1,545,403.98	1552383.31	6,979.33	**0.45**
NO_x	1,002,166.25	1,029,200.83	11,821.51	**2.63**
HC	94,938.08	95,833.90	895.82	**0.93**
PM10	76,725.52	77,668.84	1,393,32	**1.21**

Scenario C

In Scenario C, the complexity increases due to the change in network size where we are focused on the New York City network with 18,983 links for AM peak period only. This will create an opportunity for officials to see the impacts of traffic on air quality with a broader focus on New York City. Since the growth of a transportation network will affect not only social and economic activities, but air quality as well, this scenario analysis can be used to make long term decisions on the environmental sustainability of the New York City network. Table 93 shows the results for this scenario, where the research team presents the approximation function methodology instead of running MOVES, which will require a long run time.

Table 93: Emission Level Analysis for the New York City Network

	Approximation Function Results			
	CO (grams)	Nox (grams)	HC	PM10
AM Peak	7,251,214.00	4220442	379,556.00	**310366**
Midday	10,913,278.00	5,007,078.00	507,396.00	**381009**
PM Peak	9,074,881.00	2,703,514.00	371440	**225598**
Night	5,019,693.00	2,221,810.00	211842	**150389**
Total	32,259,267.00	14,152,845.00	1470233	**1067362**

Scenario D

In this scenario, emission calculations are conducted for the whole NYBPM network and for all periods including the AM peak, midday, PM peak, and night periods. Table 94 shows the analysis results presenting the total emissions for both directions. Note that this analysis lasts a couple of hours with the proposed methodology. Re-running MOVES on our large-scale complex network with 53,399 links per direction, on the other hand, could take up-to several months considering the need to run MOVES for both directions, for four pollutants and four daily periods. This scenario reveals the environmental impacts of the complex NY-NJ metropolitan region, and provides a scientific understanding of the emission levels for forecasting, planning, policy-making and evaluation.

Table 94: Emission Level Analysis for the NYBPM Network

	Approximation Function Results			
	CO	NOx (grams)	HC	PM10
AM Peak	75,876,273.00	51417410	3,782,918.00	**6025177**
Midday	114,858,456.00	63,558,861.00	5,204,769.00	**7336802**
PM Peak	92,454,213.00	32,299,884.00	3615322	**3866394**
Night	55,811,488.00	37,868,814.00	2608763	**3806615**
Total	339,000,430.00	185,144,969.00	15211772	**21034988**

Emissions Analysis based on MTM Model

The emissions analysis procedure was conducted using the US EPA's Motor Vehicle Emission Simulator (MOVES) model.

Simplified Moves Emission Estimation Process

Methodology

The County level analysis of EPA MOVES was used to estimate pollutants based on travel activity outputs from the traffic modeling process, including car and truck volumes, roadway types and speeds, and vehicles miles of travel (VMT) and vehicle hours of travel (VHT).

To facilitate the analysis, MOVES was run in County level to generate a set of emissions rates. These are specific to a year/month, location, pollutant type, source, and time of day. The pollutants for which emissions rates were estimated for New York County were based on the following:

- Vehicle types and fuels: gasoline-powered passenger cars, diesel-powered buses, diesel-powered trucks
- Roadway type: urban unrestricted access (local streets), urban restricted access (highways)
- Time periods: typical hour 8 AM – 9 AM

The pollutants NOx, VOC and CO are precursors of ozone, while CO2E is the cumulative measure of global warming potential of the greenhouse gases carbon dioxide, methane, nitrous oxide and sulfur dioxide. Particulate matter is categorized by size. MOVES produces emission rates for specific speed ranges or "bins" as defined in Table 95.

Table 95: MOVES Speed Bins

Speed Bin ID	Average Bin Speed	Bin Speed Range
1	2.5	speed < 2.5mph
2	5	2.5mph <= speed < 7.5mph
3	10	7.5mph <= speed < 12.5mph
4	15	12.5mph <= speed < 17.5mph
5	20	17.5mph <= speed <22.5mph
6	25	22.5mph <= speed < 27.5mph
7	30	27.5mph <= speed < 32.5mph
8	35	32.5mph <= speed < 37.5mph
9	40	37.5mph <= speed < 42.5mph
10	45	42.5mph <= speed < 47.5mph
11	50	47.5mph <= speed < 52.5mph
12	55	52.5mph <= speed < 57.5mph
13	60	57.5mph <= speed < 62.5mph
14	65	62.5mph <= speed < 67.5mph
15	70	67.5mph <= speed < 72.5mph
16	75	72.5mph <= speed

The following methodology was used for the pollutant estimation process:

1. MOVES were run for New York County for year 2013 (base year) for a typical weekday hour in the analysis month of May. Discrete emission rates were generated by each parameter outlined above for each of the pollutants.
2. Output from the traffic model, hourly volumes, speeds, VHT, and VMT were estimated for each roadway segment in the model roadway network.
3. The MOVES-generated emission rates by vehicle type were then matched to the travel activity output from the traffic model, based on roadway type, and roadway segment speed for each analysis hour. Since the study area almost covered 25 percent of the whole New York County, the County level, analytical framework was chosen to conduct EPA MOVES air quality analysis.
4. The idling emission rates at intersections were not provided in the County level. They were included as part of the moving process. The running exhaust process (process 1) provided the valid basis for emissions estimations on the basis of simulation output.
5. The mass (in tons) of each pollutant was then calculated as follows for each hour:

$$Mass\ of\ Pollutant\ = (ER_{veh\ type,fuel,road\ type})_{speed} \times Link\ Distance \times (Link\ Hourly\ Volume)_{veh\ type,fuel}/907185 \quad \textbf{(33)}$$

   Where $(ER_{veh\ type,fuel,road\ type})_{speed}$ is the speed-specific emission rate (in grams or joules per mile per vehicle) from MOVES, for a specific combination of vehicle type, fuel, and road type during a given hour of the day, which accounts for meteorological factors.

6. Once all of the process emissions were estimated for a given pollutant, the emissions were summed across the analysis hours to determine the total mass of emissions for that pollutant per period – morning and evening. Similarly, the total energy consumption (in joule) was calculated from MOVES rates, and converted to gallons of fuel (gasoline, diesel) from joule units as follows:
   - One gallon of U.S. gasoline = 1.32 x 10^8 joule
   - One gallon of U.S. diesel = 1.46 x 10^8 joule

Analysis Results from EPA MOVES

The data records from the micro-simulation output files exceeded the maximum permitted storage capacity of MS Access files. MS SQL Server database was used to process simulation data output. The Aimsun output files provided link-by-link simulation output. Each link was matched with the corresponding emissions rate on the basis of the vehicle class, roadway types, speed bins, and emission types. The emissions were summarized into the total and individual emissions charts for comparison of the 11 scenarios, ranging from no incentive to a $10,000 incentive, at the incremental rate of $1000 between scenarios.

Daytime Emissions Analysis

The simulation models were able to provide estimation for the on-road traffic congestions at both AM and PM peak periods. The AM model was featured with better estimation of network congestions caused by double-parked trucks with field data. The behavior-based micro-simulation model (BMS) provided the truck demand diversion rate for the destination zones. In the AM peak, the methodology is straightforward to determine the changes of truck demand. In the PM peak, the diversion percentage of reversed truck OD demand was not available from the BMS output. The street networks are also more congested in PM caused by cars exiting Manhattan. Without detailed double-parking data in the PM peak, the AM peak emissions were used as a conservative reference to represent daytime air emissions.

1) Overall emissions in the daytime peak hour

For the comparison purpose, the overall emissions were summarized into Table 96 for all of the vehicle types, roadway classes and emission types. From scenario OTI0K to OTI10K, the overall emissions were reduced from 126.0 tons to 118.8 tons in response to the removal of 256 trucks from the network between 8 AM and 9 AM. The emission reduction rate was 0.028 ton per diverted truck. Between incremental incentive scenarios, the emission reduction rates ranged from 0.012 ton to 0.056 ton depending on the actual output from the replication runs.

Table 96: Daytime Overall Emissions for All Vehicles in the Network

Scenario IDs	Overall Emissions (tons)	Incremental Emissions (ton)	Incremental Truck Demand (trips)	Emissions Reduction (ton) per Diverted Truck
OTI0k	126			
OTI1k	125.4	-0.6	-14	0.043
OTI2k	125	-0.4	-10.5	0.042
OTI3k	124.5	-0.5	-22	0.022
OTI4k	124	-0.5	-19	0.024
OTI5k	123.5	-0.5	-27.8	0.02
OTI6k	123.3	-0.2	-15.3	0.012
OTI7k	121.8	-1.5	-36	0.041
OTI8k	120.3	-1.6	-27.8	0.056
OTI9k	119.6	-0.7	-38	0.017
OTl10k	118.8	-0.8	-46.3	0.017
Total	1,352.20	-7.2	-256.5	0.028

The overall emissions trend was illustrated on Figure 93 for the daytime study hour (8 – 9 AM). The simulation runs were only replicated when it was deemed to be necessary to replace the invalidated results. A consistent tendency can be observed from Figure 93.

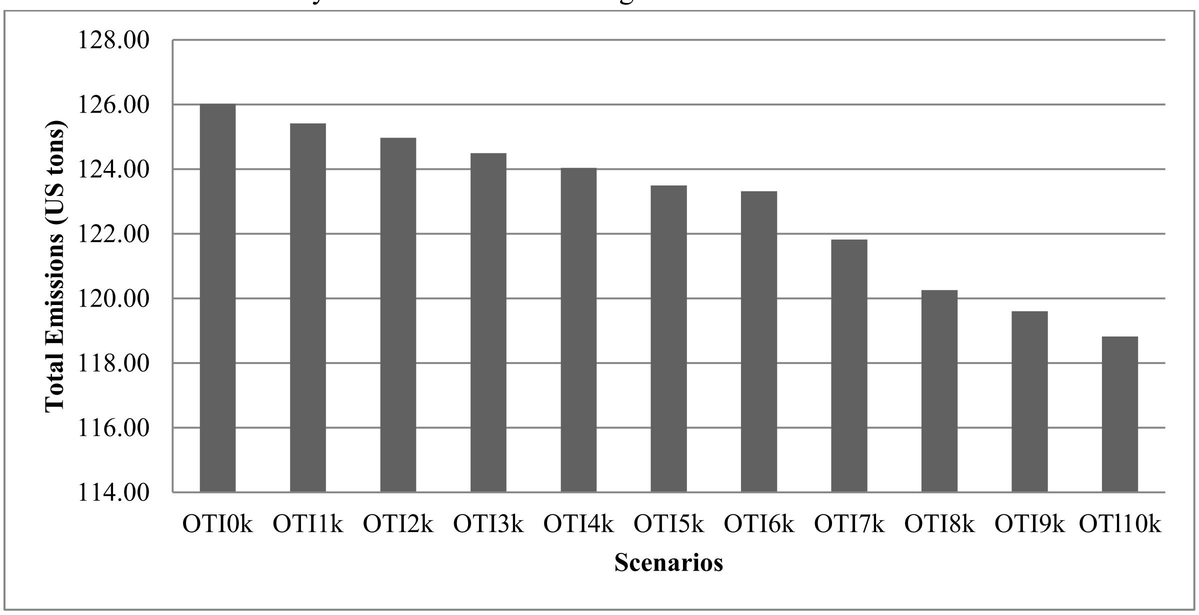


Figure 93: Daytime (8 – 9 am) Overall Emissions for All Vehicles in the Network

Since Midtown Manhattan is an oversaturated network, the network demand exceeds bottleneck capacity on most of the crossings in and out of Manhattan. Due to the capacity limitation of the crossings and bottlenecks approaching these crossings, queuing spillback usually extends five to twenty miles away from Manhattan on the major highways. The midtown micro-simulation network does not include full queuing distances of these crossings, but the entrance approach to the crossings were modeled as the centroid connector link, which feeds traffic demand into the network. The reduction of truck demand would merely permit more autos to enter the network among congested avenues, with spillback queues outside the micro-simulation area. The resulted network performance becomes even more complicated when the induced auto demand has different destinations from the reduced truck demand.

Despite the induced auto demand, the emissions generally displayed a decreasing trend following the incremental amount of incentives.

Due to the limitation of sensitivity in the Midtown area, the model output indicated variation for individual emissions. These individual emission details were illustrated in the charts below.

Nighttime Emissions Analysis

Nighttime emissions were estimated under the assumption that the diverted truck demand in the sampled AM four hour periods will shift to the nighttime ten hours from 8PM to 6AM. Considering the random fluctuation range of micro-simulation analysis, it is assumed that 60%-70% of AM and PM diverted demand would fall in the two-hour analysis period in the nighttime. Generally, the added nighttime hourly truck demand was about 130%-170% of the amount of trucks diverted from the AM period per hour (8 AM – 9AM). Nighttime emissions were summarized for individual scenarios on Table 97.

The total nighttime emissions showed a trend of incremental emissions by the amount of incentives. The total emissions increased from 12.12 tons for no incentives to 12.70 tons for the 10k incentives. Net increase of emissions is 0.58 tons for the overall network in response to addition of 360 trucks. The emissions incremental rate was 0.0016 ton per participating truck in the nighttime hour. In comparison to the daytime emission reduction rate from Figure 94, the average network emissions savings per diverted truck at the daytime hour were up to 0.028 ton/0.016 ton = 17.5 times of the emissions consumptions for the same truck in the nighttime hour.

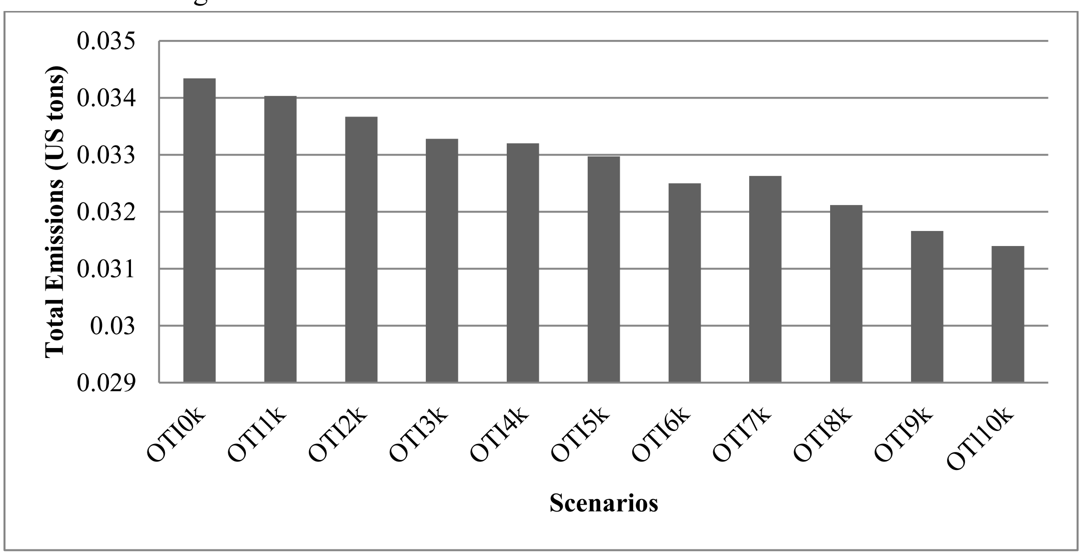


Figure 94: Hydro Carbons (HC) Daytime (8 – 9 am) Peak Hour Emissions

Table 97: Nighttime Overall Emissions for All Vehicles in the Network

Scenario IDs	Overall Emissions (tons)	Incremental Emissions (ton)	Incremental Truck Demand (trips)	Emissions Reduction (ton) per Diverted Truck
OTI0k	12.12			
OTI1k	12.14	0.02	24.9	0.0009
OTI2k	12.22	0.08	14.2	0.0054
OTI3k	12.23	0.01	30.1	0.0005
OTI4k	12.35	0.12	28	0.0043
OTI5k	12.38	0.02	37.3	0.0006
OTI6k	12.47	0.09	21.6	0.0042
OTI7k	12.49	0.02	48.9	0.0004
OTI8k	12.49	0	39.4	0.0001
OTI9k	12.53	0.04	51.5	0.0007
OTI10k	12.7	0.18	64.5	0.0027
Total	136.11	0.58	360.4	0.0016

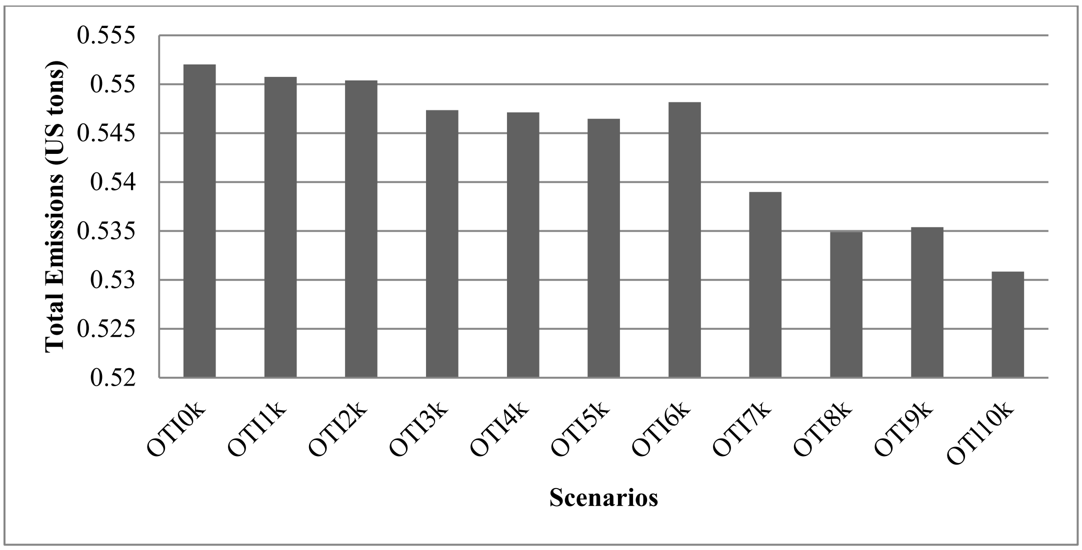


Figure 95: Carbon Monoxide (CO) Daytime (8 – 9 am) Emissions and Peak Hour Emissions

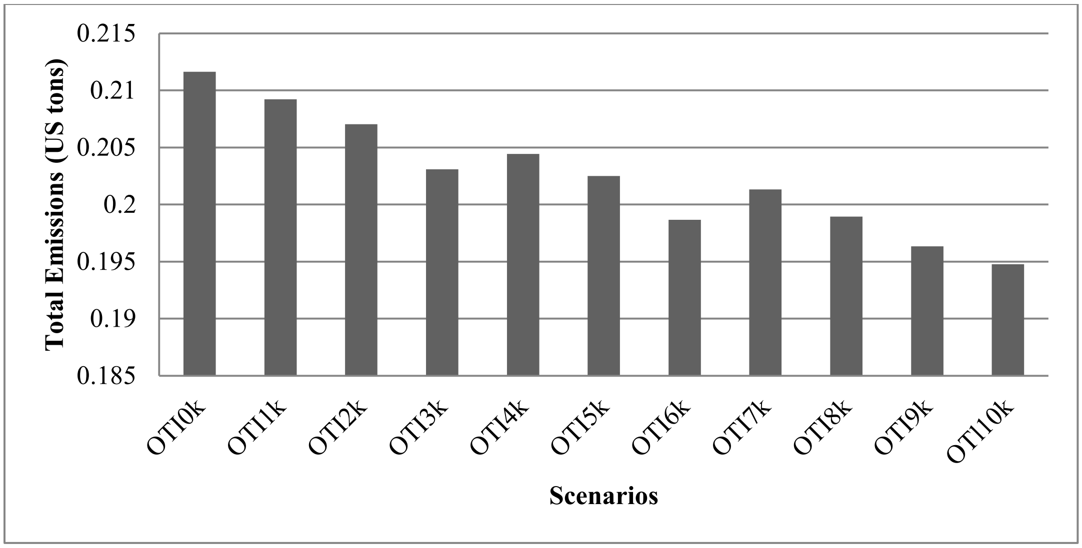


Figure 96: Nitrogen Oxides (NOx) Daytime (8 – 9 am) Emissions and Peak Hour Emissions

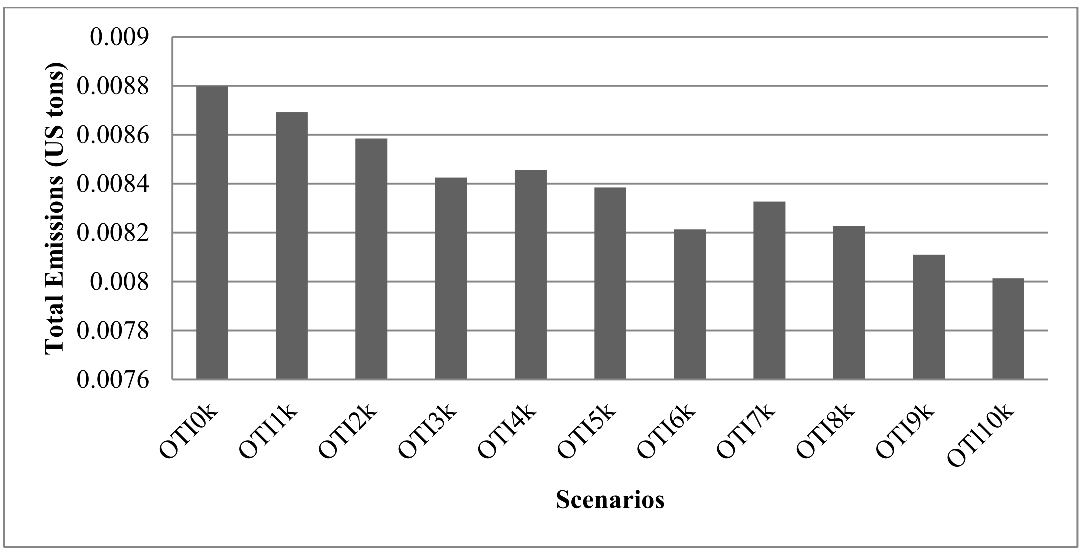


Figure 97: Particulate Matter (PM10) Daytime (8 – 9 am) Emissions

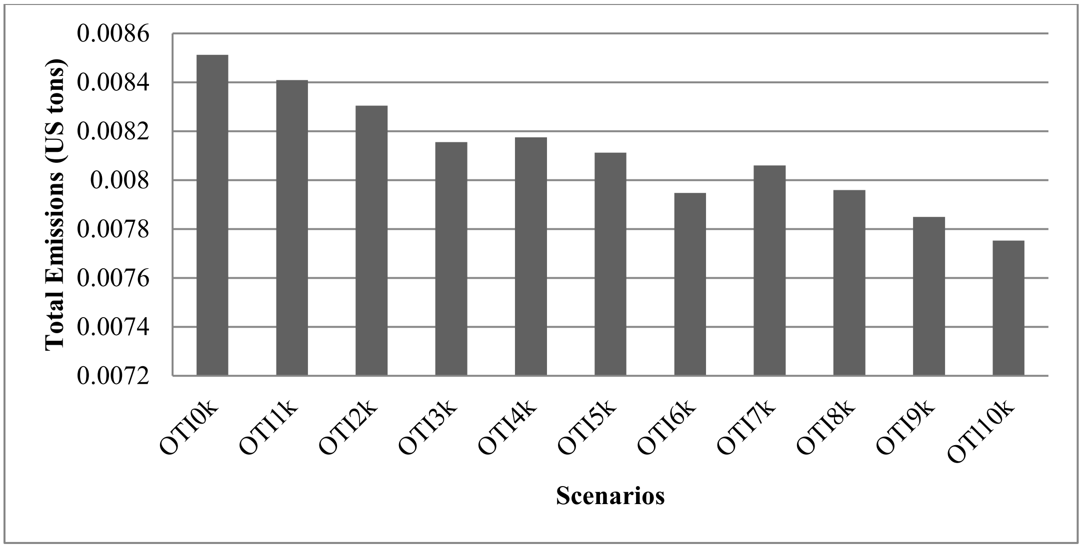


Figure 98: Particulate Matter (PM2.5) Daytime (8 – 9 am) Emissions

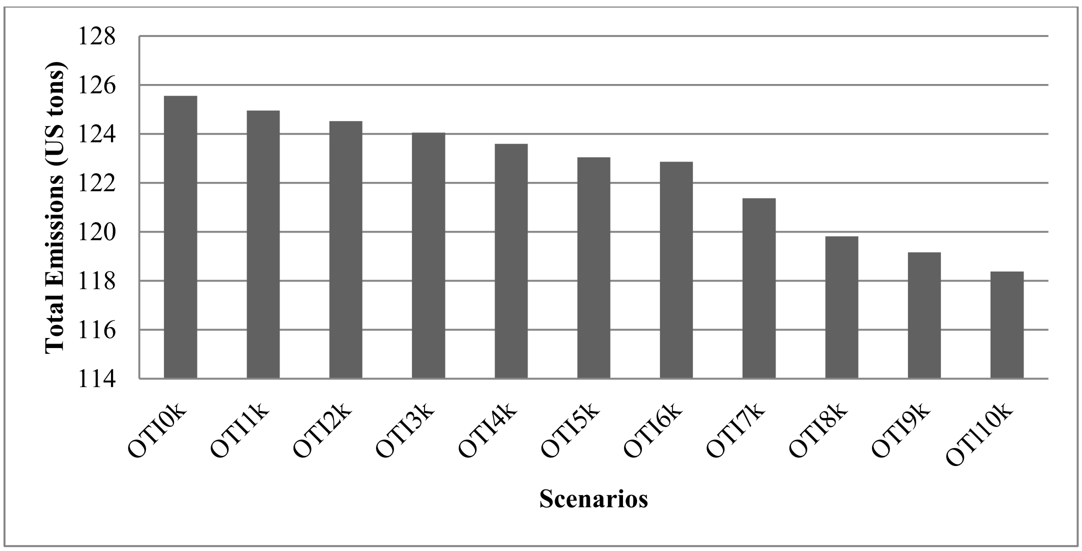


Figure 99: Carbon Dioxide Equivalents (CO2E) Daytime (8 – 9 am) Emissions

The nighttime overall emissions were illustrated in Figure 100.

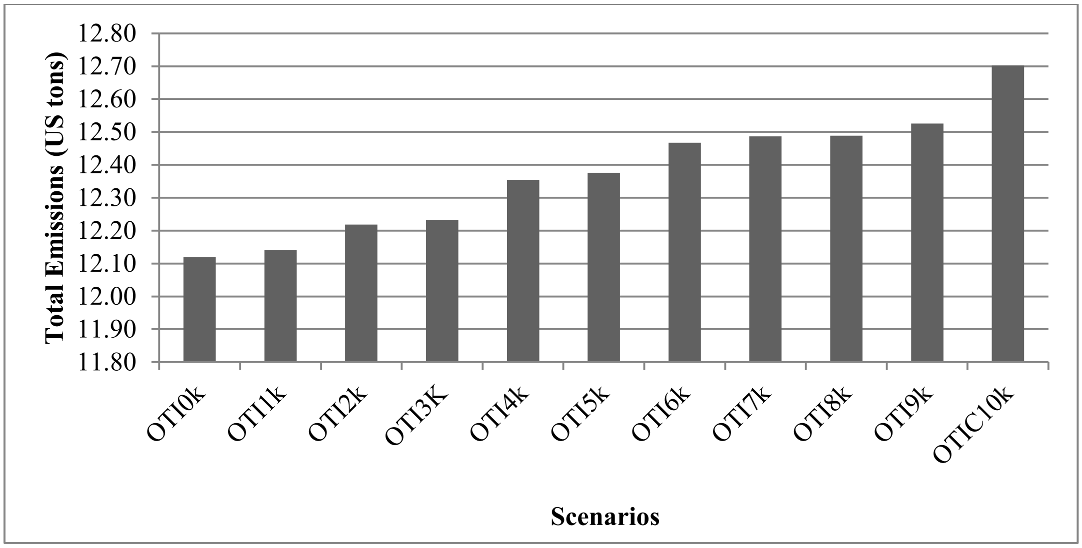


Figure 100: Nighttime (3-4 am) Overall Emissions for All Vehicles in the Network

Due to the limitation of sensitivity in Midtown Manhattan area, the model output indicated variation for individual emissions. These individual emissions details were illustrated in the following figures.

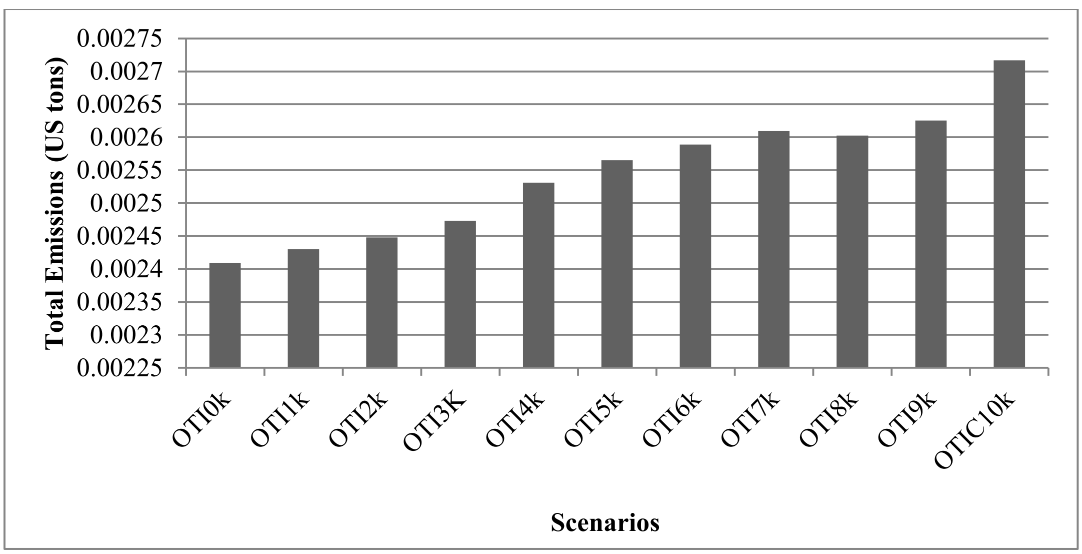


Figure 101: Hydro Carbons (HC) Nighttime (3-4 am) Emissions

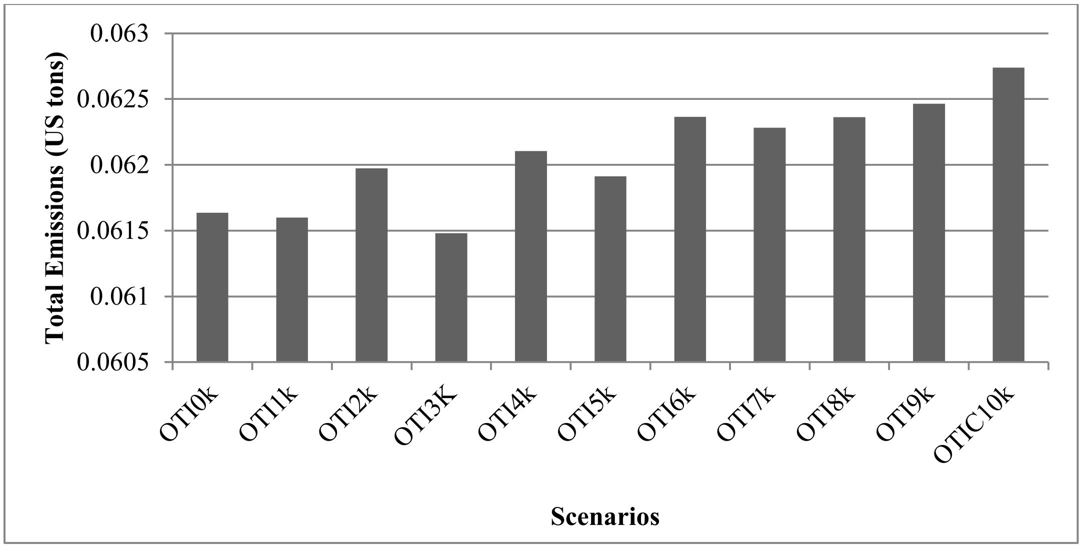


Figure 102: CO Nighttime (3-4 am) Emissions and Peak Hour Emissions

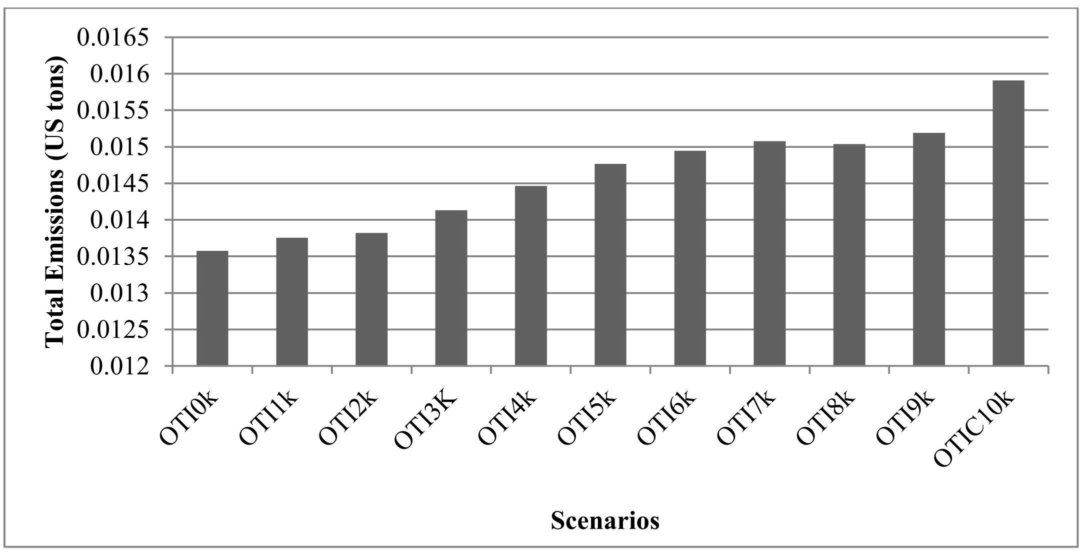


Figure 103: Nitrogen Oxides (NOx) Nighttime (3-4 am) Emissions and Peak Hour Emissions

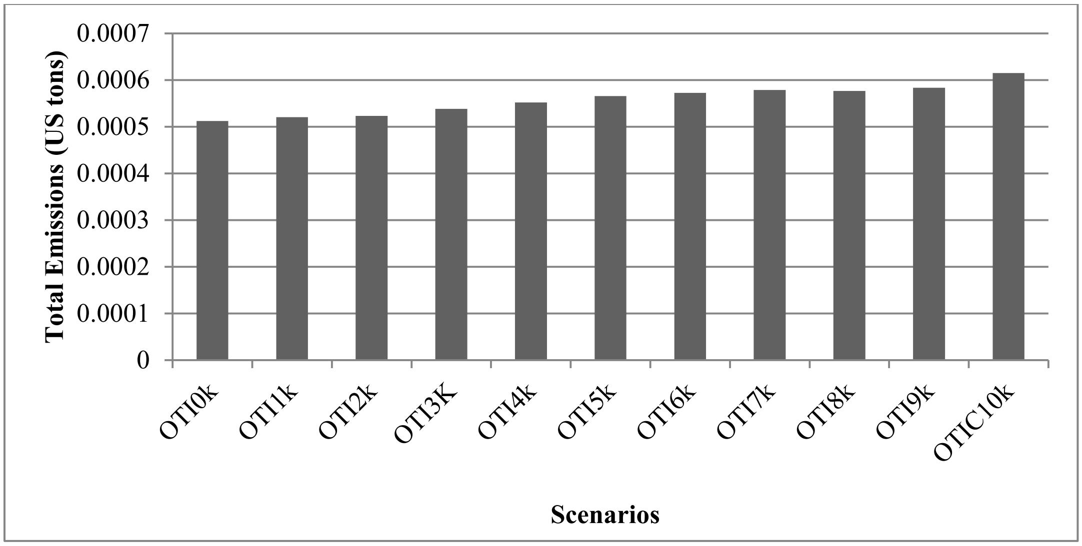


Figure 104: Particulate Matter (PM10) Nighttime (3-4 am) Emissions

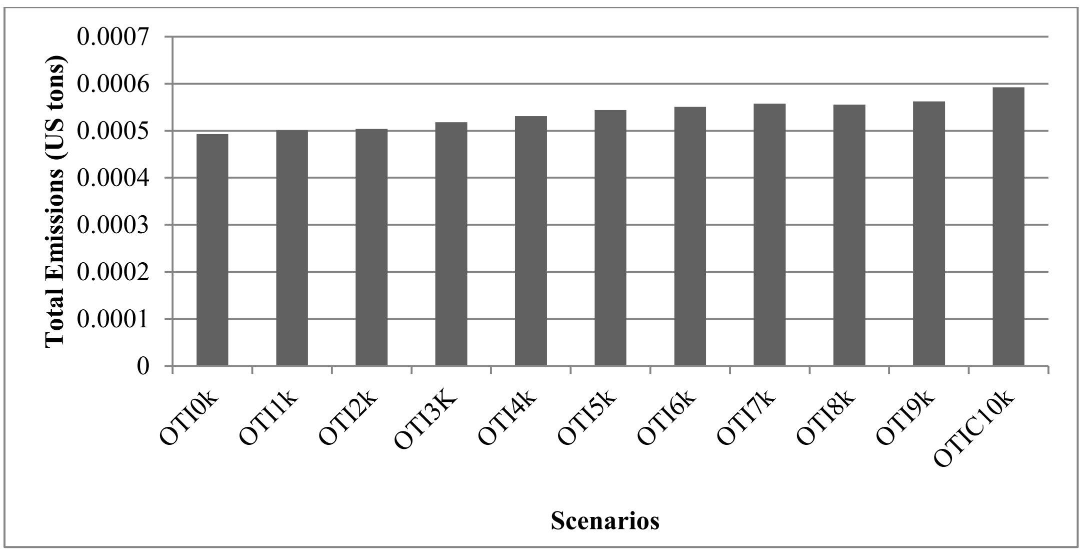


Figure 105: Particulate Matter (PM2.5) Nighttime (3-4 am) Emissions

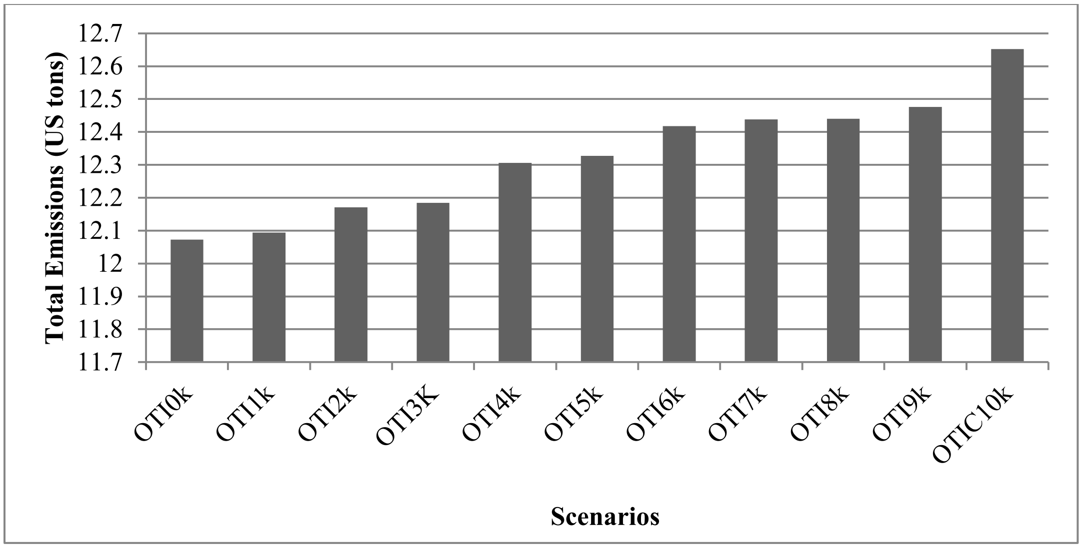


Figure 106: Carbon Dioxide Equivalents (CO_2E) Nighttime (3-4 am) Emissions

In comparison to the daytime emissions, the nighttime emissions displayed a much smaller scale of increment between scenarios. Although only one random run was replicated for the nighttime scenarios, the nighttime emissions formed consistent incremental trends for most of the pollutants and scenarios. The nighttime travel conditions are also less complicated than the daytime travel conditions.

Air Pollution Cost Estimation

A definition of air pollution costs is of utmost importance to be able to quantify the emission levels obtained in the previous sections. For this purpose, we will use the Victoria Transport Policy Institute (2010) study, which thoroughly reviews all of the relevant literature on how to obtain the air pollution costs (Table 98).

Table 98: Review of Existing Air Pollution Studies(VTPI, 2010)

Publication	Costs	Cost value	2007 USD Per Vehicle Mile
CE Delft (2008)	Urban Car	0.0017 – 0.0024 €/km (2000)	$0.003 – 0.004
	Urban Truck	0.106 – 0.234 €/km	0.189 – 0.417
Delucchi et al. (1996)	Light Gasoline Vehicle	$1990/VMT 0.008 – 0.129	0.013 – 0.205
	Heavy Diesel Truck	0.054 – 1.233	0.086 – 1.960
Eyere et al. (1997)	Gasoline Urban	$/VMT 1996 0.030	0.04
	Diesel Urban	0.074	0.098
FHWA (1997)	Automobiles	$/VMT 0.011	0.015
	Pickups/Vans	0.026	0.034
	Diesel Trucks	0.039	0.051
			Per Tonne/Ton
AEA Technology (2005)	NH3/tonne Europe	2005 €19,750	$26,061
	NOx	€ 7,800	$10,293
	PM2.5	€ 48,000	$63,339
	SO2	€ 10,325	$13,624
	VOC's	€ 1,813	$2,392
RWDI (2006)	PM2.5/tonne	2005 Canadian $317,000	$277,359
	O3 total	$1,739	$1,522
Wang, Santini & Warinner (1994), US cities	NOx	1989 $/ton $4,826	$8,059
	ROG	$2,419	$4,040
	PM10	$6,508	$10,868
	SOx	$2,906	$4,853

Using this table, we obtain the cost figures presented in Table 99 for the pollutants, where 2007 values have been adjusted for inflation by the Consumer Price Index with a value of 1.123.

Table 99: Unit Costs for Pollutants

Pollutant	$ per grams (2007 USD)	$ per grams (2012 USD)
CO	0.000501155	0.000543
NOx	0.010293	0.011559039
HC	0.002392	0.002686216
PM10	0.010868	0.012204764

For the NYBPM network, the costs for the NOx pollutant were the highest, followed by CO and PM10, which had much lower but similar values. HC was the lowest cost pollutant, with a value approximately 2% of the total. For comparison, the NOx pollutant costs are 80% of the total. Table 100 provides a breakdown of each pollutant and calculation method.

Table 100: Cost of Pollutants – BPM AM Network

Pollutant	(MOVES) (grams)	(FIT) (grams)	(MOVES) (dollars)	(FIT) (dollars)
CO	38,111,005	38,426,710	20694.3	20865.7
NOx	25,501,979	25,883,741	294778.4	299191.2
HC	1,904,291	1,931,753	5115.3	5189.1
PM10	3,021,709	3,022,630	36879.2	36890.5
Total	68,538,984	69264834	357467.2	362136.5

This section presents an air pollution cost estimation methodology for large-scale transportation networks, and includes a comprehensive comparison with MOVES with respect to different pollutants. The proposed methodology includes an emission level calculation and functional approximation process to allow for more efficient analysis of a relatively large number of scenarios for large transportation networks such as New York City or Los Angeles.

The comparative results of the study can be summarized as follows:

- For large-scale projects, it is extremely time consuming to run large networks and many scenarios using MOVES. Using the approximation functions generated from runs of MOVES for the base case provides a straightforward and efficient approach for emissions estimation.
- Most critically, the approach used in this paper provides a significant decrease in run-times which enables planners and analysts to run multiple scenarios and networks within a narrow time frame. For a real large-scale network of 53,399 links, MOVES run time spanned a couple of months for 4 pollutants with 4 vehicle types on several Intel Core 2 Duo CPU E7500 computers (2.93 Ghz, 3 GB Ram). On the other hand, analysis results can be obtained within a couple of hours including pre- and post-processing from Assist-Me, based on the approximation functions described in this paper. By incorporating the approximation with Assist-Me software, we provide a straightforward and fast approach that can be used for large scale projects or studies with comparative analyses that require estimations from several scenarios. The analysis and comparison of emission level estimates for large-scale networks confirms that using the approximation function method dramatically increases computational efficiency without sacrificing accuracy. The t-test is used to assess whether the emission level estimates from MOVES and approximation function results are *statistically* different from each other. This test (T-test @ 95%) indicates that results of MOVES and approximation functions are statistically indifferent for the base case scenario, Scenario A and B.
- The largest difference between MOVES and approximation function results occur for total NO_x emissions, which itself is less than 1.5%. This analysis demonstrates that the approximation functions can be used without re-running MOVES. Therefore, the scenario-based approach presented in this study provides officials with an efficient way of evaluating the environmental effects of pollutant emission on the air quality and human health. Focusing on different size networks, it is possible to investigate short term and long-term decisions on the transportation network studied.

On-Site Noise Measurements

As discussed before, the delivery or pick-up operations of trucks during the night may raise concerns about the effects of noise on communities. Besides doing comprehensive research about existing policies and initiatives, and formulating a noise policy, the research team conducted on-site noise measurements. These measurements provided insights about the potential noise issues associated with OHD, to analyze initiatives to mitigate them.

The on-site measurements were taken at participating locations during 2012 and 2013, during off-hour operations. The main objective was to measure the noise emitted by the vehicle, and the delivery operations both at the vehicle and at the curb side. In addition to the noise measurements, the team collected pictures and videos of the operations and the premises at the establishment location. The team developed a form to log the on-site visit and measurements (see Table 101).

To conduct the noise measurements, the team used the EXTECH Instruments HD600 digital Datalogging Sound Level Meter. The meter has a range between 30 and 130dB(A), with a 1.4 dB(A) accuracy, and meets ANSI and IEC61672-1 Type 2 standards. Before conducting the measurements, the team met with officials from the Department of Environmental Protection (DEP) to calibrate and validate the measurements of the equipment. The measurements were also compared with the Analog Sound Level Meters used by DEP. This was done during a field visit at a location in Manhattan. The team also received guidance about the operation of the equipment and how to take the measurements.

Table 101: On-Site Noise Data Collection

OHD Program – Implementation Phase: OHD Location Analysis			
Establishment Information			
Location ID:		Type of establishment:	
Establishment name:			
Address:			
Contact information:			
Phone number:			
Email address:			
Physical characteristics of the location			
Hours and days of operations:		Type of building establishment	
Street access:		Ramp:	
On-street parking:		Off-street parking:	
Freight entrance:		Loading dock:	
Video Surveillance:		Double-door:	
Alarm system:		Other systems:	
Google URL:			
Pictures:			
Data Profile:			
Comments:			
OHD Program			
Partial incentive received:		Number of vendors	
Vendor 1 Name:		Provided Code of Conduct:	
Number of deliveries per week RH:		Number of deliveries per week OH:	
OHD schedule:			
Vendor 2 Name:		Provided Code of Conduct:	
Number of deliveries per		Number of deliveries per	
OHD schedule:			
Monitoring plan:			
Site visit ID:		Pre- or Post-OHD	
Date:		Time:	
Analyst:		Purpose:	
Data Collected:			
Pictures:			
Data Profile:			
Comments			

During the on-site visits, the team took measurements at a distance of approximately 15 feet, when possible, from the truck engine, truck lift gate, and/or delivery person conducting the loading, unloading and carrying activities. The noise measurements (noise profiles) were compared with the video footage or pictures taken to be able to isolate and identify the source of noise peaks. Average noise levels during the samples were estimated to compare the results.

Figure 102 shows an example of a noise profile from one of the delivery locations on a commercial street. This specific delivery included a two-axle rigid truck parallel parked in front of the customer's establishment. The truck had an electric lift gate on the back, and the driver used a rolling cart to move the boxed items from inside the truck to the establishment. A metal ramp was used to roll the cart between the street level and the sidewalk. The average noise level during the sample was 69.91 dB(A), reaching a maximum of 89.00 dB(A), and a minimum of 59.90 dB(A). The maximum corresponds to about 19 dB(A) (27% increase) over the average. As shown, the critical sources of noise correspond to the handling of the rolling cart inside the truck's container (due to texture of the floor and the movement of the cart wheels); moving and installing the metal ramp on the street; closing the truck's back door; closing the lift gate; and picking up and carrying the metal ramp. It is important to note that the peaks only lasted a couple of seconds, but are still disturbing. An important source of noise relative to the average levels, identified in more residential locations, is attributable to engine noise, specifically of diesel trucks.

Similarly, Figure 108 shows the noise profile for an OHD in a residential street. The vehicle is also a two-axle rigid truck parallel parked about 20 yards from the building entrance. In this case, the driver does not use a rolling cart, but carries the small package to the destination. The average noise level during the sample was 54.09 dB(A), with a minimum of 46.60dB(A) and a maximum of 73.20 dB(A). There is a significant different in the average noise level from the residential and commercial street cases.

Again, most of the operation falls under the permitted limits, and the peaks only last for a couple of seconds. These results were consistent with the observed noise sources at other locations Appendix 3B contains additional examples). However, the engine noise does go over the limit, and could be perceived by the residents if the driver does not adequately manage the acceleration of the truck.

Figure 107: Example 1: of a Noise Profile of an OHD

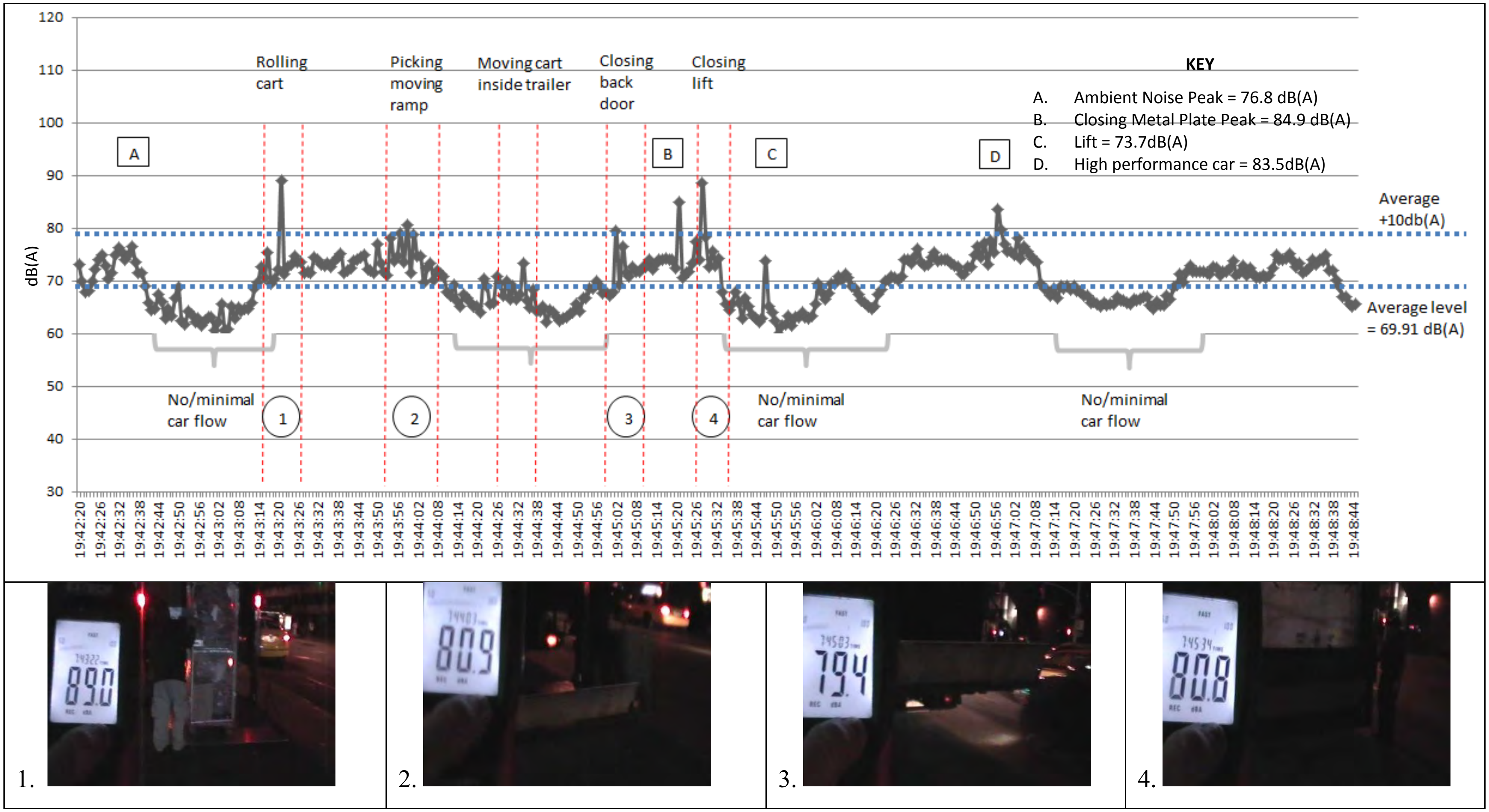
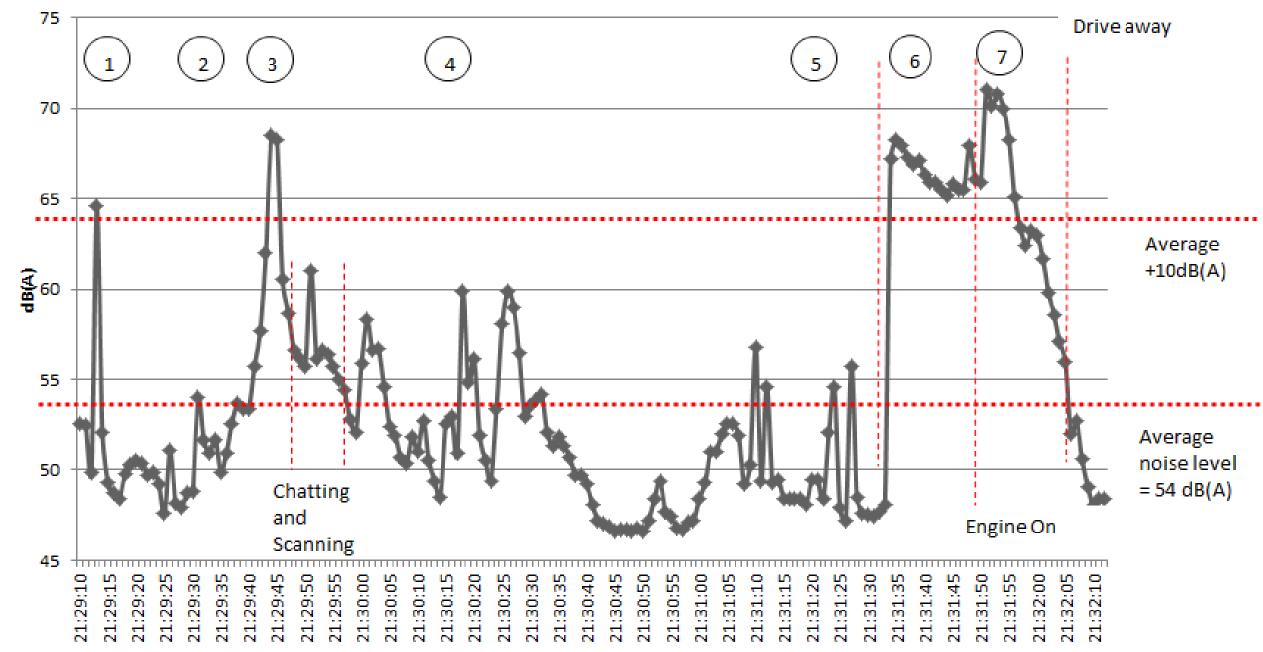
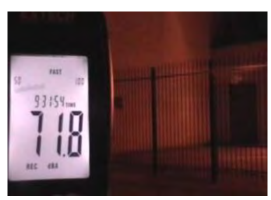


Figure 108: Example 2: of a Noise Profile of an OHD



1.Slamming the door	2. Cargo handling inside the trailer	3. Unloading the cargo	4. Clossing backdoor
			
5.Driver closes front door	6.Engine starts	7.Truck accelerates and drives away	
			

Chapter 2 explained the different policies and measures to mitigate noise impacts. From the examples it is clear that most of the noise issues could be abated with one, or a combination of the discussed measures: low noise truck solutions, truck accessories, cargo handling equipment, noise absorbing materials, and training the staff--both the driver (i.e., driver training programs) and the delivery personnel at the establishment--about noise abatement.

Overall Impacts of OHD on Roadway Users

Quantification of the economic effects of an OHD program on roadway users requires a detailed analysis of the benefits from potential reductions in travel time and other externalities. In this sub-section, the results of the regional network model (BPM) is used to estimate the economic impacts in terms of travel time savings and reductions in externalities such as environmental and safety costs. The results are based on various considerations of value of time, and for each OHD scenario aggregated annual benefits are calculated. For this report, only the benefits to roadway users which can be reasonably estimated from the simulation outputs and potential benefits to carriers are presented.

Value of Time

The value of time (VOT) of roadway users is one of the crucial parameters in assessing the benefits in terms of reductions associated with traffic congestion costs. There are several VOT estimates for the New York City metropolitan area, while most of the studies focusing on valuation of passenger car drivers' time in traffic. Empirical results from travel survey data for EZ-Pass users of Port Authority of New York and New Jersey (PANYNJ) facilities showed that VOT is $16.50/hour during peak periods, and $15.15/hour during off-peak periods (Yanmaz-Tuzel et al., 2011). However these values may be underestimating the VOT for the work-related trips. According to US Bureau of Labor Statistics 2012 data for New York-Newark-Bridgeport area, average hourly wage for all occupations is $27.38 (Bureau of Labor Statistics, 2012). There exist a limited number of VOT estimations for trucks and commercial vehicles for New York City metropolitan area. The two available estimations are $34/hour for light trucks and $55/hour for semi-trailers (Holguín-Veras & Brom, 2008) and an empirical analysis based on the trucker survey for the users of PANYNJ facilities which estimates a VOT of $33.62/hour (Ozbay et al., 2011). Texas Transportation Institute (TTI)'s Urban Mobility Report for 2012 uses $86.81/hour for large trucks (Texas Transportation Institute, 2012). However, this estimation includes other operating costs of trucks in addition to travel time costs. In this report we present results for a range of composite VOT values between $20/hour to $35/hour. Additionally a scenario with different VOTs for cars and trucks ($30/hour and $40/hour, respectively) is also tested.

Cost of Externalities

The estimation of the economic value of the reductions in environmental pollutants was conducted using the approximation methodology presented in this report. Based on previous studies and data collected, functions were developed to estimate the full costs of travel for a highway network with a number of input variables, including distances, speeds, travel times, volumes, and values of time. A software tool, namely, ASSIST-ME (Ozbay et al., 2013), was modified to incorporate new cost functions for crashes and emissions specifically estimated for the Manhattan network. ASSIST-ME was then used in conjunction with the output of transportation planning model, BPM, and to estimate the link costs for all or some links in the network. These costs include vehicle ownership costs, travel time and congestion costs, accident costs, air pollution costs, noise costs, and operating costs. Using this tool, network costs for each of the scenarios simulated in the BPM were calculated. By taking the difference between the costs for each scenario and the base case scenario, the traffic results can be put into monetary terms.

Cost-Benefit Analyses of Scenarios

The benefit estimations are conducted for the road users (passenger cars, buses, and trucks) and carriers. Reductions in travel time, hazardous pollutants and improvements in road safety are considered in the estimations for the OHD scenarios when the truck traffic shifts to the off-hours. Total cost estimation includes congestion costs which depend on the VOT assumptions, operating costs, noise costs, air pollution costs and accident costs. Air pollution costs and accident costs are based on the methodologies presented in the previous sections of this report. It should be noted that since accident cost estimations are performed using Manhattan-specific crash data, we could not generalize the results for the entire BPM network analysis. Therefore safety costs are only included in the economic impact analysis involving Manhattan roadway users.

Table 102 shows the annual benefit estimations for roadway users for different OHD scenarios with various VOT estimations for the entire BPM simulation network. Similarly, Table 103 shows the results for only the Manhattan network. The estimations use a conservative assumption of 250 work days in a year.

Benefits and costs to receivers are not included in the economic analysis in this report. Although the receivers are likely to have increased operating costs for additional staff during off-hours, these costs are assumed to be compensated with financial incentives, or bypassed altogether if policies such as unassisted deliveries are implemented. As mentioned in the Phase I report of the OHD project, there also exist potential benefits to receivers, such as the lower staff idling times since delivery times during off-hours are more accurate compared to other time periods (Holguín-Veras et al., 2010a). However, similar to the economic analysis conducted in the Phase I report, the research team decided to assume that receivers do not receive any economic benefits due to lack of relevant data, and for the sake of being conservative in the cost benefit analysis results.

Table 102: Summary of Economic Impacts: Roadway Users in NYMTC Region

Annual Benefits (millions)[1]						
	Trips Shifted	Composite Value of Time (passenger cars, buses, and trucks)[2]				Cars: $30/hr Trucks: $40/hr
		$20/hr	$25/hr	$30/hr	$35/hr	
$ 1,000	7,058	$ 9.72	$ 12.00	$ 14.27	$ 16.54	$ 14.84
$ 2,000	7,878	$ 10.55	$ 13.03	$ 15.52	$ 18.00	$ 16.68
$ 3,000	8,903	$ 11.88	$ 14.71	$ 17.55	$ 20.38	$ 18.64
$ 4,000	9,958	$ 10.56	$ 13.10	$ 15.63	$ 18.17	$ 17.26
$ 5,000	11,276	$ 14.29	$ 17.56	$ 20.82	$ 24.09	$ 22.41
$ 6,000	12,447	$ 19.69	$ 24.30	$ 28.92	$ 33.53	$ 30.68
$ 7,000	14,380	$ 19.37	$ 24.00	$ 28.63	$ 33.25	$ 30.46
$ 8,000	15,932	$ 19.76	$ 24.48	$ 29.20	$ 33.91	$ 30.67
$ 9,000	18,012	$ 20.47	$ 25.34	$ 30.21	$ 35.08	$ 31.93
$ 10,000	20,560	$ 25.43	$ 31.46	$ 37.49	$ 43.52	$ 39.44

1. Benefits are estimated social benefits based on changes to congestion costs, operating costs, noise costs, and air pollution costs (Annual = Per Day*250). These benefits are calculated for links covered by the 28-county New York Best Practice Model.
2. The benefits calculated depend on the Value of Time estimate used to calculate economic benefits of decreased congestion.

Table 103: Summary of Economic Impacts: Roadway Users in Manhattan

Annual Benefits (millions)[1]						
	Trips Shifted	Composite Value of Time (passenger cars, buses, and trucks)[2]				Cars: $30/hr Trucks: $40/hr
		$20/hr	$25/hr	$30/hr	$35/hr	
$ 1,000	7,058	$ 4.27	$ 5.33	$ 6.38	$ 7.44	$ 6.94
$ 2,000	7,878	$ 4.70	$ 5.83	$ 6.96	$ 8.09	$ 7.56
$ 3,000	8,903	$ 4.98	$ 6.21	$ 7.43	$ 8.66	$ 8.11
$ 4,000	9,958	$ 5.90	$ 7.34	$ 8.78	$ 10.22	$ 9.56
$ 5,000	11,276	$ 7.63	$ 9.43	$ 11.24	$ 13.05	$ 12.07
$ 6,000	12,447	$ 7.13	$ 8.84	$ 10.55	$ 12.26	$ 11.53
$ 7,000	14,380	$ 7.82	$ 9.70	$ 11.58	$ 13.46	$ 12.68
$ 8,000	15,932	$ 10.28	$ 12.76	$ 15.24	$ 17.72	$ 16.52
$ 9,000	18,012	$ 11.17	$ 13.84	$ 16.52	$ 19.19	$ 17.88
$ 10,000	20,560	$ 11.87	$ 14.76	$ 17.64	$ 20.52	$ 19.19

1. Benefits are estimated social benefits based on changes to congestion costs, operating costs, noise costs, accident costs and air pollution costs (Annual = Per Day*250). These benefits are calculated for links covered by the 28-county New York Best Practice Model.
2. The benefits calculated depend on the Value of Time estimate used to calculate economic benefits of decreased congestion.

The number of shifted trips are estimated based on the BMS scenarios and using base case travel demand matrices in NYBPM regional model. Benefits to carriers are estimates based on reductions in the travel time associated with the delivery tour and reductions in customer service times. As a consequence of the faster travel speeds during off-hours, the carriers accrue significant economic benefits. This key component assesses the economic value of the total travel savings to the industry. The GPS data collected during the Phase I OHD study clearly indicate that service times in the off-hours are much shorter than in the regular hours (Holguín-Veras et al., 2010b). The reasons reported for longer regular-hour service times include the need for drivers to: share elevators with building visitors (a major source of delays in large buildings with no cargo elevator), wait for the loading docks to be available, find/wait for store managers to review the shipments and sign the paperwork, coordinate the actual delivery at times when the store staff is busy with other chores, among others. During the off-hours, in contrast, most of these sources of delay are expected to vanish. Consistent with the Phase I study we adopt assumptions of 15 minutes average savings in customer service times, and 48 minutes travel time savings per tour.

Table 104 shows the estimated economic impacts to the carriers. Estimated annual benefits are increasing gradually with increasing amount of tax incentive and assuming higher value of time. Table 105 gives the summary of economic impacts to the receivers and public sector. The analysis is based on the estimated number of participants for each financial incentive scenario. Annual aggregated cost to receivers is assumed to be equal to the yearly total tax incentive amount.

Table 104: Summary of Economic Impacts: Carriers

		Annual Benefits (millions)							
		Average Value of Time for Carriers that Shift to the Off-hours							
Financial Incentive	Trips Shifted	$30	$35	$40	$45	$50	$55	$60	$65
$ 1,000	7,058	$20.93	$24.42	$27.91	$31.40	$34.89	$38.38	$41.87	$45.36
$ 2,000	7,878	$23.37	$27.26	$31.15	$35.05	$38.94	$42.84	$46.73	$50.63
$ 3,000	8,903	$26.41	$30.81	$35.21	$39.61	$44.01	$48.41	$52.81	$57.21
$ 4,000	9,958	$29.53	$34.46	$39.38	$44.30	$49.22	$54.15	$59.07	$63.99
$ 5,000	11,276	$33.44	$39.02	$44.59	$50.17	$55.74	$61.31	$66.89	$72.46
$ 6,000	12,447	$36.92	$43.07	$49.22	$55.38	$61.53	$67.68	$73.83	$79.99
$ 7,000	14,380	$42.65	$49.76	$56.87	$63.97	$71.08	$78.19	$85.30	$92.41
$ 8,000	15,932	$47.25	$55.13	$63.00	$70.88	$78.75	$86.63	$94.51	$102.38
$ 9,000	18,012	$53.42	$62.33	$71.23	$80.13	$89.04	$97.94	$106.84	$115.75
$ 10,000	20,560	$60.98	$71.14	$81.31	$91.47	$101.63	$111.80	$121.96	$132.12

Assumptions:

1. Travel time saved (hours/tour): 0.80
2. Service times savings (hours/delivery): 0.25
3. Days per year: 250
4. Delivery stops/tour: 5.5

Table 105: Summary of Economic Impacts: Receivers and Public Sector

	Trips Shifted	Annual Cost to Receivers (millions)[1]	Public Sector Incentives (millions)[2]
$ 1,000	7,058	($0.50)	$ 0.50
$ 2,000	7,878	($2.20)	$ 2.20
$ 3,000	8,903	($5.14)	$ 5.14
$ 4,000	9,958	($9.93)	$ 9.93
$ 5,000	11,276	($16.20)	$ 16.20
$ 6,000	12,447	($24.33)	$ 24.33
$ 7,000	14,380	($34.90)	$ 34.90
$ 8,000	15,932	($47.06)	$ 47.06
$ 9,000	18,012	($61.41)	$ 61.41
$ 10,000	20,560	($76.07)	$ 76.07

1. Assumed to be equal to the incentive.
2. Calculated by multiplying the number of receivers expected to participate by the incentive amount.

Table 106: Economic Analysis Results for the Entire Network

Financial Incentive	Cost to Receivers	Benefit to Carriers	Benefit to road users[1]	Total Benefits	Total Incentive Costs	Net Benefits	Marginal B/C ΔB/ΔC
$ 1,000	$ (0.50)	$ 27.91	$ 14.84	$ 42.75	$ (0.50)	$ 42.26	-
$ 2,000	$ (2.20)	$ 31.15	$ 16.68	$ 47.84	$ (2.20)	$ 45.64	2.99
$ 3,000	$ (5.14)	$ 35.21	$ 18.64	$ 53.85	$ (5.14)	$ 48.71	2.04
$ 4,000	$ (9.93)	$ 39.38	$ 17.26	$ 56.64	$ (9.93)	$ 46.71	0.58
$ 5,000	$ (16.20)	$ 44.59	$ 22.41	$ 67.00	$ (16.20)	$ 50.81	1.65
$ 6,000	$ (24.33)	$ 49.22	$ 30.68	$ 79.91	$ (24.33)	$ 55.58	1.59
$ 7,000	$ (34.90)	$ 56.87	$ 30.46	$ 87.33	$ (34.90)	$ 52.43	0.70
$ 8,000	$ (47.06)	$ 63.00	$ 30.67	$ 93.67	$ (47.06)	$ 46.61	0.52
$ 9,000	$ (61.41)	$ 71.23	$ 31.93	$ 103.16	$ (61.41)	$ 41.75	0.66
$ 10,000	$ (76.07)	$ 81.31	$ 39.44	$ 120.74	$ (76.07)	$ 44.67	1.20

1. Benefits are estimated by assuming VOT of $30/hour for cars and $40/hour for trucks.

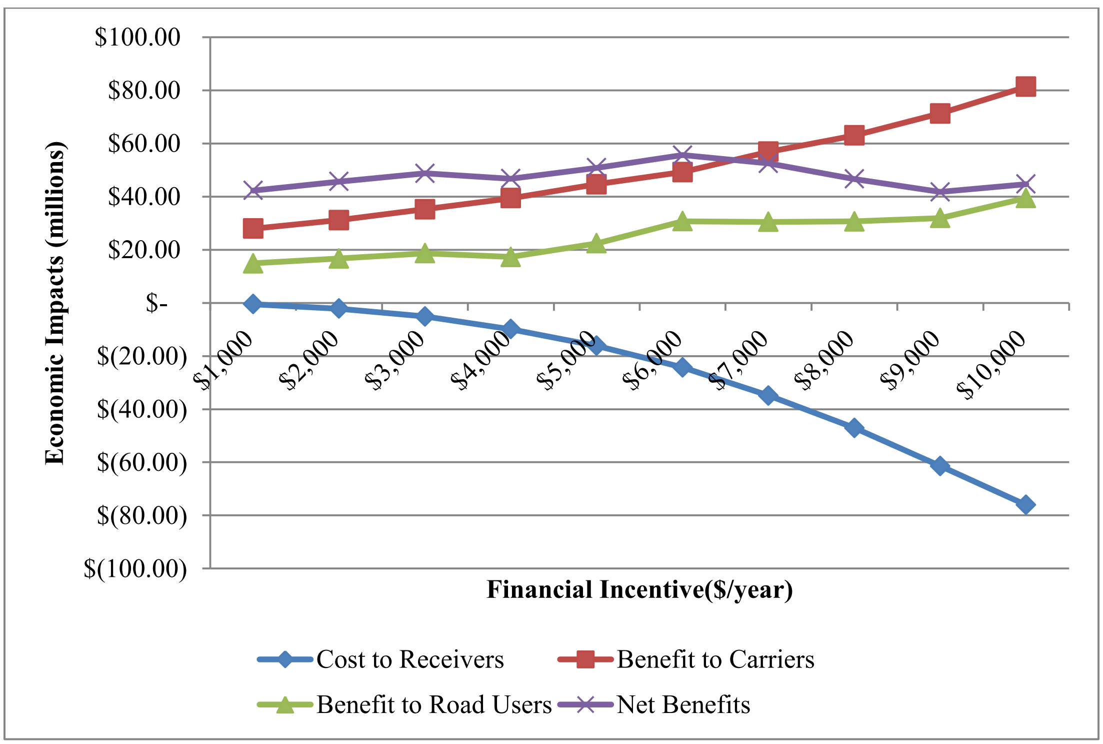


Figure 109: Cost and Benefits for the Entire Network

The summaries of the economic impacts to the stakeholders are shown in Table 106 and Figure 109 for the case where the composite VOT of roadway users is $30/hour, and the average value of time of delivery trucks is $40/hour. As shown, the benefits to carriers and roadway users increase steadily with increased receiver participation in OHD. The cost to receivers, and the consequent associated incentive costs, increase at an accelerating pace due to the effect of the higher incentive amount and the number of establishments that take the incentive. These analyses show that the optimal amount of incentive is about $6,000/year per participant, and beyond this amount net benefits start to decline. Table 106 shows the marginal benefit/cost ratios. This economic indicator measures the ratio of the increase in benefits brought about by a given alternative, with respect to the increase in costs. It is optimal when the marginal benefits equal marginal costs, for a $B / C = 1$. As shown in the table, the marginal benefit to marginal cost ratio for $6,000/year incentive is 1.59 and for $7,000/year incentive is 0.7. This concludes that optimal marginal benefits in the range of $6,000 - $7,000 can be obtained, which is consistent with the net benefit graph shown in Figure 109.

Discussion

The results of this section indicate that the economic benefits associated with increasing off-hour deliveries exhibit diminishing net returns though the incentive costs continue to grow (see Figure 109). The optimal financial incentive amount is about $6,000 per year, depending on the composite value of time. The economic impacts estimated here are the ones associated with reducing truck traffic in the regular hours, and decreasing daytime traffic congestion.

It should be noted that coordinated demand management policies targeting both passenger cars and trucks is critical. As economic theory suggests, induced passenger car demand can be generated to take advantage of the road capacity made available by the trucks that switched to the off-hours. The analysis of such phenomena is beyond the scope of this project, however a comprehensive cost benefit analysis must include all key considerations to quantify the actual benefits of such large-scale projects. The analysis presented in this sub-section only considers a limited number of possible OHD scenarios with several assumptions mainly focusing on the benefits to roadway users. For future research, the findings can be improved with detailed data from carriers and receivers.

In-Depth Assessment of Impacts on Carriers and Receivers

Based on discussion between team members, the team designed the three sets of preliminary survey forms targeting drivers, fleet managers, and receivers, respectively. The forms were then sent to participating carriers for their review and pilot run. Key concerns that arose during the design included: requesting sensitive data, which participants may be reluctant to share; some companies were already (partially) doing OHD prior to this launch; redundant information; and receivers having difficulty differentiating between incidents as a result of using OHD and those due to random events. Based on the feedback from participants, the team refined these three surveys, removing and rephrasing some questions so that the participants could understand the questions more clearly and provide reliable answers.

Survey Design

The final survey forms are presented in Appendix 3.

In order to ensure a reasonable response rate, the team proactively reached out to participants and advertised these surveys. The team also worked with Industry Advisory Group (IAG) members for the project, motor trucking associations, New York City Department of Environmental Protection (NYCDEP), and respective Business Improvement Districts (BIDs) to seek their help on recruiting respondents. In order to make it convenient for respondents to provide their information, the team also made the survey forms available online

Driver survey: https://www.surveymonkey.com/s/DriverOHD;
Receiver Before Survey: https://www.surveymonkey.com/s/ReceiverB;
Receiver After Survey: https://www.surveymonkey.com/s/ReceiverA;
Fleet Manager Before Survey: https://www.surveymonkey.com/s/FleetBefore; and
Fleet Manager After Survey: https://www.surveymonkey.com/s/FleetAfter).

Throughout the project, the team requested various groups to complete both the before and after evaluation surveys. In total, there were five surveys, receiver surveys for both before and after OHD implementation, before and after fleet manager surveys, and a driver survey as indicated by the links provided at the end of the previous paragraph. It was decided that a single driver survey would be sufficient to collect the data that was required for both before and after OHD implementation, as all the information needed could be easily adapted to one convenient survey designed to be completed in approximately 5 minutes. The fleet manager was asked by the team to distribute either a paper survey or the online survey link to the drivers. For the other surveys, the fleet manager, who is the representative for the carrier company, and the receiver were asked to fill out their respective before surveys shortly after initial contact with the team. The surveys were approximately ten to twenty minutes in length. After participating in OHD for several months both the receivers and fleet managers were asked to complete after surveys describing their experiences. For receivers that operated multiple locations, the team requested that the manager at each location complete the surveys.

Impacts on Carriers

Impacts on Drivers

The driver survey received 11 responses from different companies (Lightning Express Delivery Service, Inc.; Safeway Trucking; SYSCO; Magnolia; H&H and The Beverage Works) all of which deliver to New York City. The number of years that the truck drivers have been driving ranges from 8 months to 50 years, with the average years of experience being about 14 years of truck driving, with a standard deviation of approximately 15 years for the 10 drivers that responded.

Of the 11 respondents of the survey, 9 provided information on the type of vehicle that is used during the daytime (6 am – 7 pm); the results are shown in Figure 110. Six drivers use semi-trailers while for the other three, one uses a delivery van, another uses a single-unit truck, and the other selected "other" truck type but did not specify the truck type. For the fuel type used, 7 of the respondents use diesel, but the respondent that selected "other" for vehicle type also selected "other" for fuel type, and one of the respondents that uses a semi-trailer did not provide any information on fuel type.

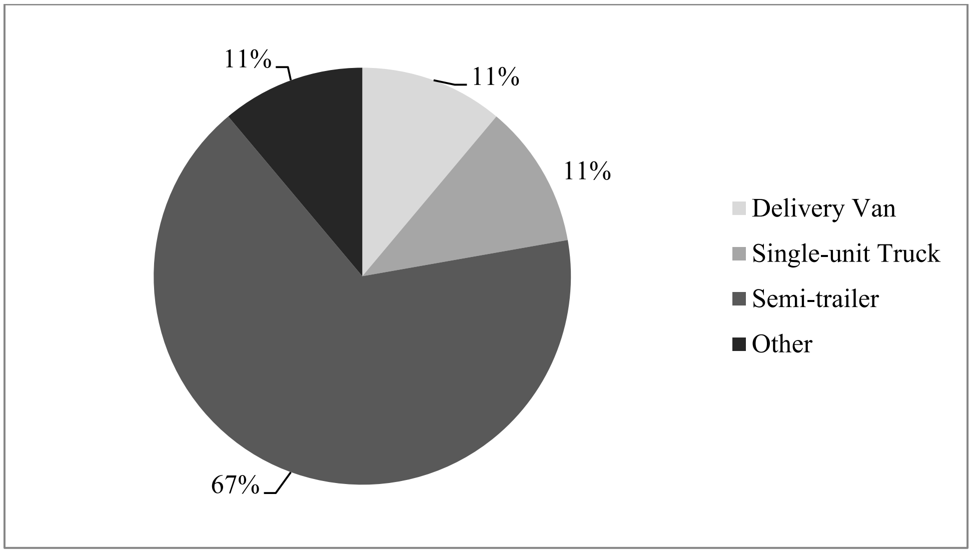


Figure 110: Daytime (6 am – 7 pm) Vehicle Type

The nighttime (7 pm – 6 am) vehicle type usage is shown in Figure 111. Seven of the eleven respondents provided information on nighttime vehicle usage; four use diesel fueled semi-trailers, three of which also use the same vehicle type during the day, while one did not provide daytime vehicle usage. The remaining two respondents use a delivery van and a single-unit truck, both diesel-fueled. These respondents also use the same vehicle type during the daytime. Therefore, none of the respondents indicated a change in vehicle type from day to night.

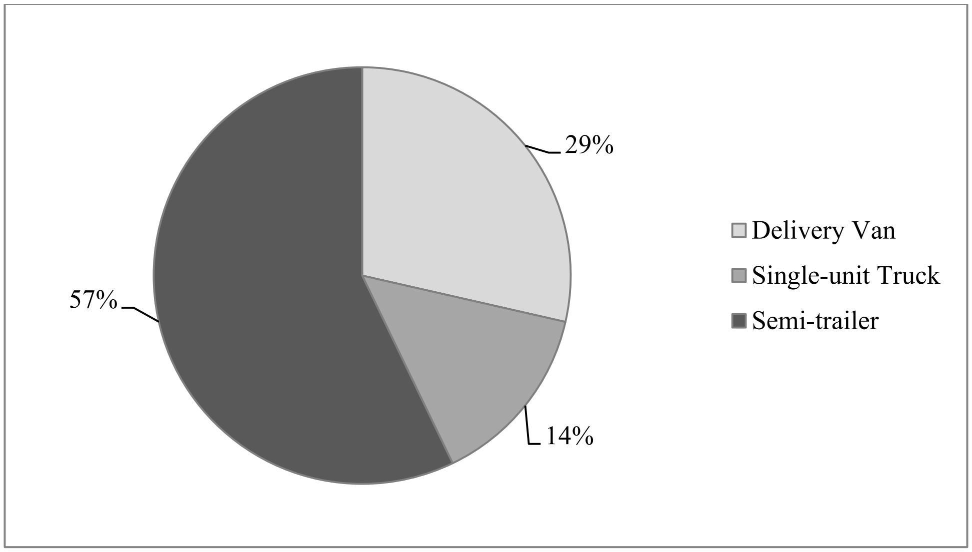
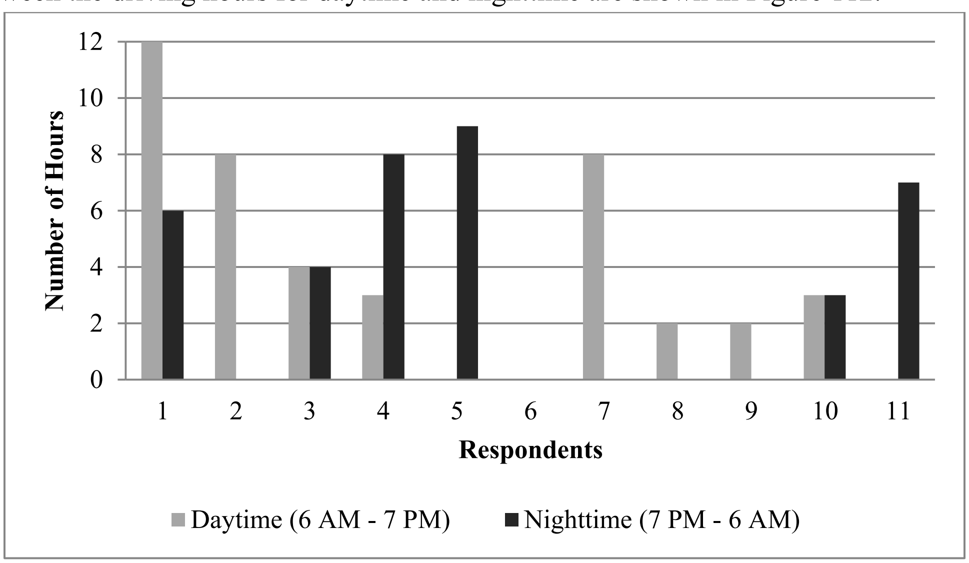


Figure 111: Nighttime (7 pm - 6 am) Vehicle Type

The typical number of hours for a trucker during the day hours ranged from 2 hours to 12 hours. The average for the 8 truck drivers that responded is 5.25 hours, with a standard deviation of 3.65 hours. For the night hours the typical number of driving hours ranged from 3 to 9 hours for the six respondents that replied to this question. The average number of driving hours during the night is 6.167 hours, with a 2.317 hours standard deviation. The comparison between the driving hours for daytime and nighttime are shown in Figure 112.



Note: Missing bars for daytime and/or nighttime values for respondents is due to missing data

Figure 112: Typical Number of Driving Hours in Day

The majority (6 of the 10 respondents) chose the night period (7 pm - 6 am) as their preference for making the deliveries in the New York City, as shown in Figure 113. Three preferred daytime, and one had no preference.

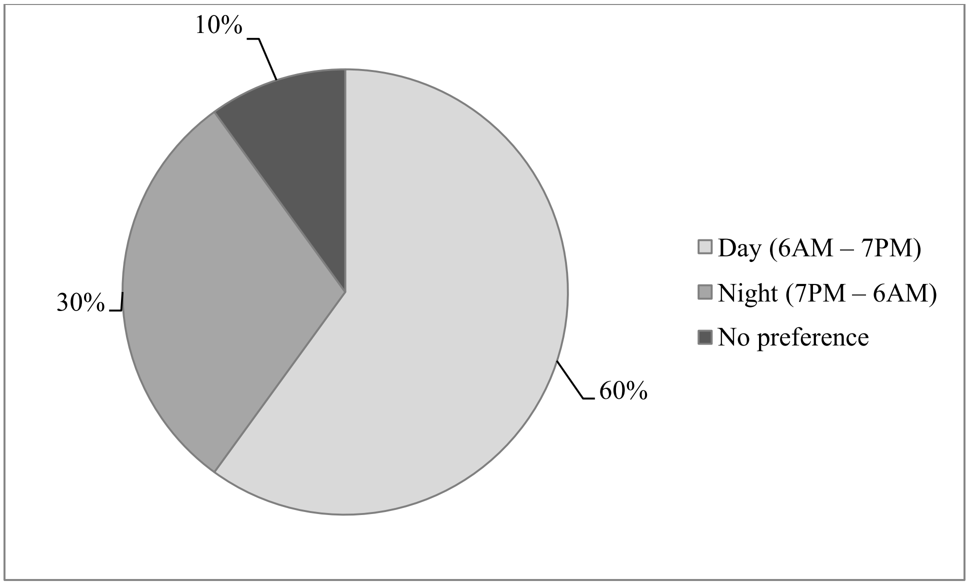
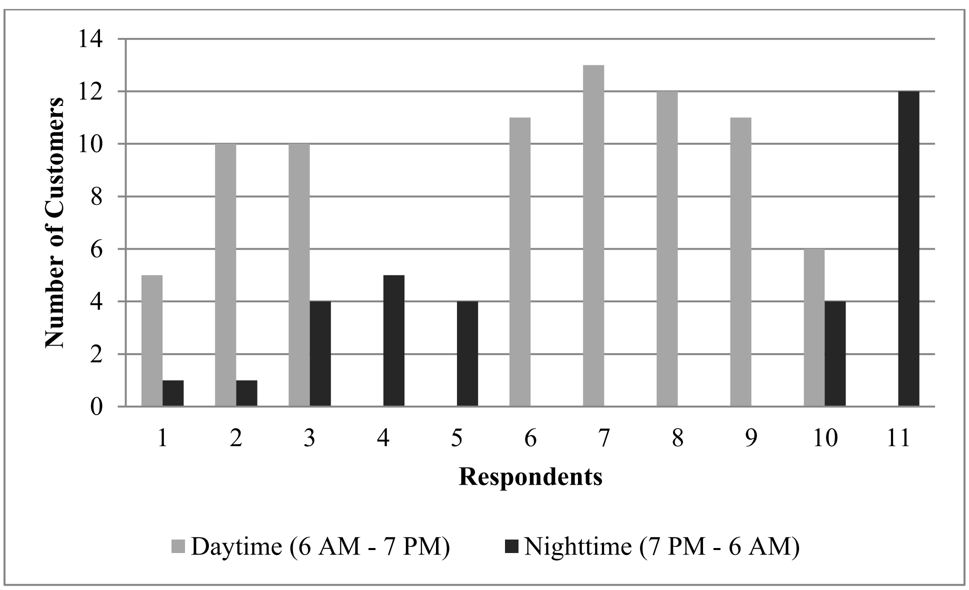


Figure 113: Preferred Time Period for Driving Truck in the City

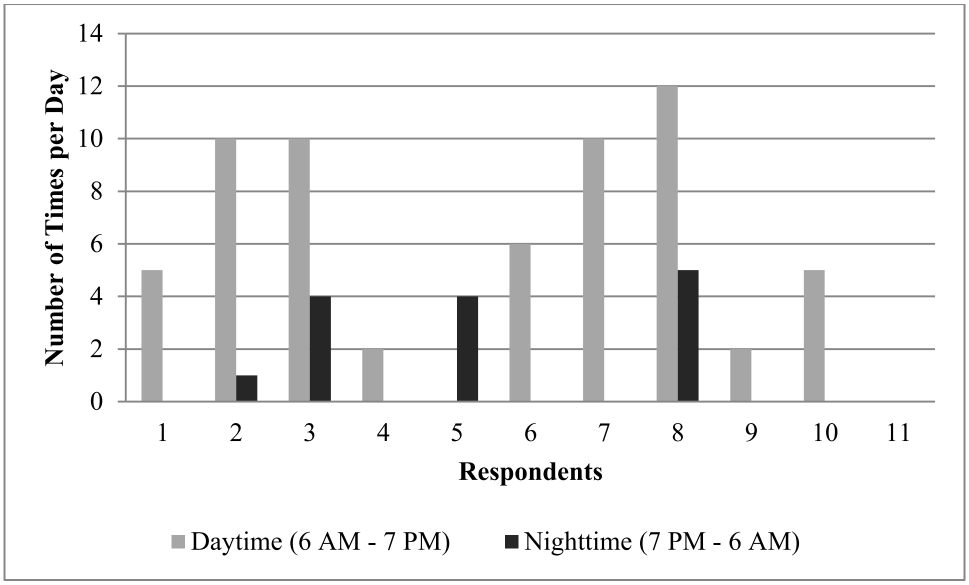
The average number of customers that the driver delivers to in the daytime hours (6 a.m. – 7 p.m.) in a typical day ranges from 5 – 13, with an average of 9.75 and a standard deviation of 2.82. The typical number of customers during the nighttime (7 pm – 6 am) ranges from 1 – 12, with an average of 4.43 customers and a standard deviation of 3.69 customers. Figure 114 shows the comparison between the typical number of customers for both daytime and nighttime. The figure shows that the majority of deliveries are made during the daytime.



Note: Missing bars for daytime and/or nighttime values for respondents is due to missing data

Figure 114: Average Number of Customers in a Typical Day

The number of times per day the driver has to find parking for the daytime hours ranged from 2 – 12. The average number of times is seven (7), with a standard deviation of 3.96. As can be seen by comparing the daytime values in Figure 114 and Figure 115, the values are highly correlated; half of the respondents have to find parking at each stop. The others were close to the number of customers, but a little less, suggesting that at least two stops may be in walking distance of each other. The most significant difference can be seen for respondent 9, that has 11 customers in the daytime period and has to find parking about twice a day. For nighttime the number of time ranges from zero (0) to five (5), with an average of 2.33 and a standard deviation of 2.25. As expected, the number of times the driver has to find parking is less than or equal to the number of customers. The most significant differences for the night period are for respondents 4 and 10 that had 5 and 4 customers, respectively, but had to find parking zero (0) times in the night.



Note: Missing bars for daytime and/or nighttime values for respondents 1, 5, 6, 7, 9 & 11 are due to missing data all others without a bar represent a zero (0) value

Figure 115: Number of Times per Day the Driver Has to Find Parking

Only one of the eleven respondents receives extra compensation for night tours, as shown in Figure 116. The drivers were asked to rate their level of stress when delivering to Manhattan for both daytime and nighttime. The scale that they were asked to select from was 1 through 5, with 1 representing the least stress and 5 representing most stressful. The daytime stress level when delivering in Manhattan for truck drivers ranged from 1 to 5, indicating with the majority (8 of the 11) selecting a stress level of 4 or 5. The average stress level is 4 with a standard deviation of 1.41. For the nighttime the stress level overall is less. The stress level ranged from 2 to 4 with an average stress level of 2.78 and a standard deviation of 0.97. The comparison of the stress level for both time periods is shown in Figure 117.

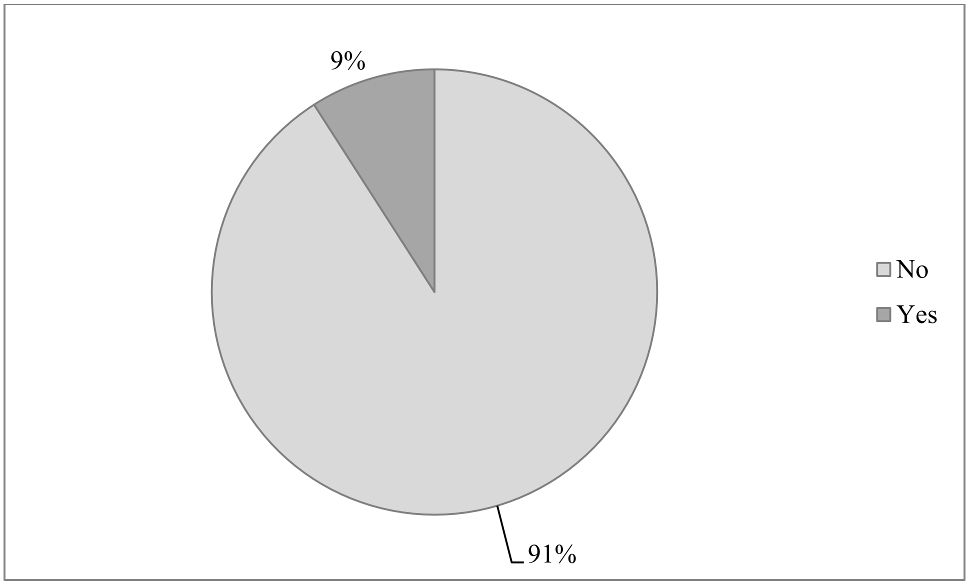
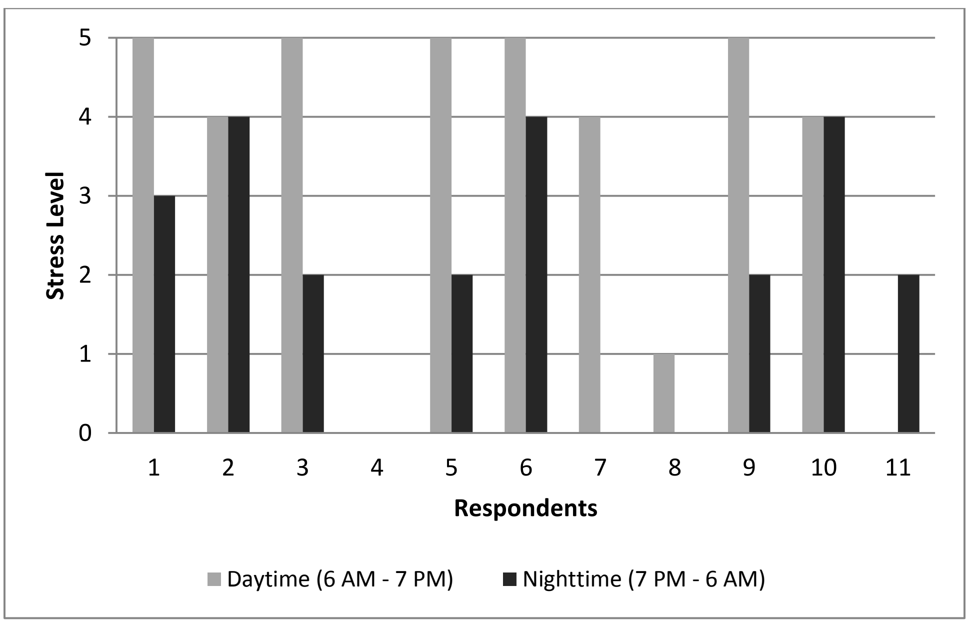


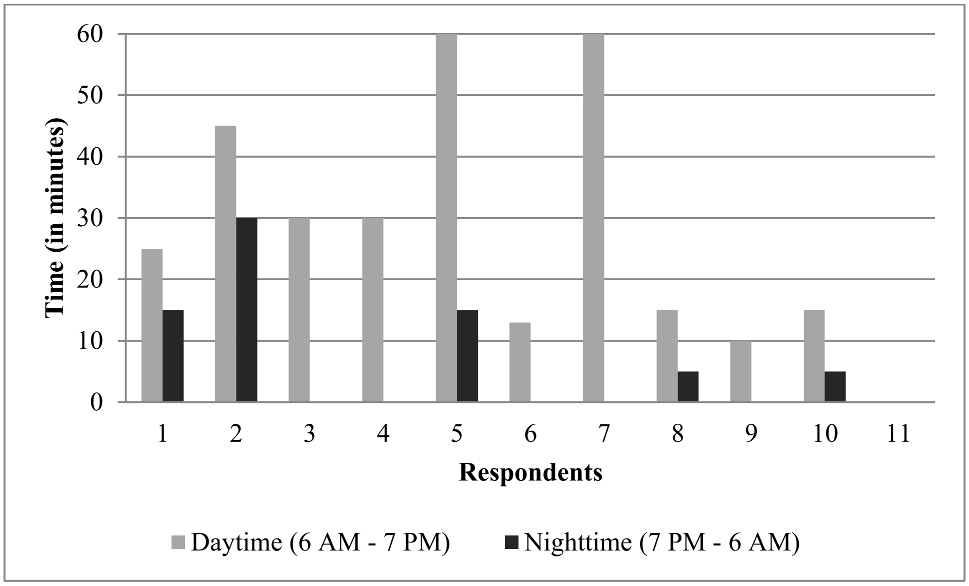
Figure 116: Percent of Drivers that Received Extra Compensation for Night Deliveries



Note: Missing bars for nighttime values for respondents 6 & 7, and daytime values for respondent 11, are due to missing data

Figure 117: Level of Stress Experienced Doing Deliveries in New York City (1being least stressful, 5 being extremely stressful)

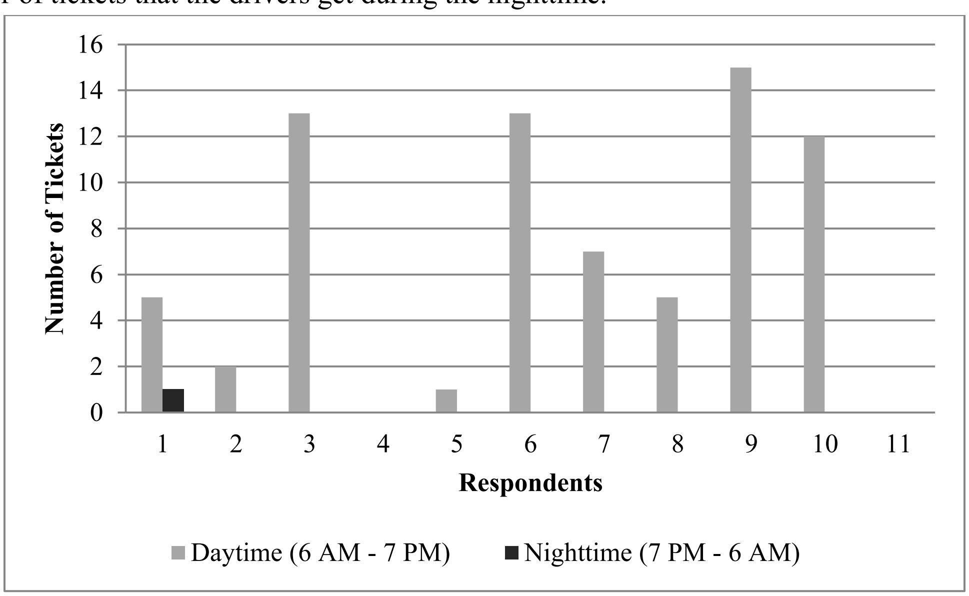
The average time spent finding or waiting for parking at each delivery stop during the daytime (7 am - 6 pm) ranged from 10 minutes to an hour. The average time spent finding or waiting for parking for this sample is approximately half an hour (30.3 minutes) with a standard deviation of 18.82 minutes. For nighttime, the range of waiting time for parking ranged from zero (0) minutes to 30 minutes. The average for the 8 respondents that provided information is 8.75 minutes to find or wait for parking at night, with a standard deviation of 10.6 minutes. The comparison for both time periods is shown in Figure 118; in this case respondents 3 and 4 had a wait time of zero (0) minutes, thus these two were included in determining the average time during the night, but the missing bars for the nighttime for respondents 6, 7 and 9 are due to missing data. The comparison indicates that there is less time spent during the nighttime (7 pm – 6 am) waiting or finding parking. On average, the time spent finding or waiting for parking in the daytime is approximately 3 times more than during the nighttime.



Note: Missing bars for nighttime values for respondents 6, 7 & 9, and daytime values for respondent 11 are due to missing data; all others without a bar represent a zero (0) value

Figure 118: Average Time Spent Finding/Waiting for Parking

The typical number of tickets during the daytime in a typical week ranged from zero (0) to fifteen (15) for one week. The average number of tickets for the sample is 7.3 tickets per week, for the daytime with a standard deviation of 5.56 tickets. For the nighttime the number of tickets received ranged from zero (0) to one (1); therefore having an average of 0.125 tickets with a standard deviation of 0.35. The comparison between both time periods is shown in Figure 119. The number of tickets received during the daytime is over 50 times greater than the number of tickets that the drivers get during the nighttime.



Note: Missing bars for nighttime values for respondents 6, 7 & 9, and daytime values for respondent 11 are due to missing data; all others without a bar represent a zero (0) value

Figure 119: Average Number of Tickets in a Week

Forty percent (40%) of the 10 who responded said they had issues in making their deliveries during the daytime, listing issues such as parking, and accessing delivery area, as shown in Figure 120. The time periods that the issues occurred were 6 am – 8 pm for one of the respondents that mentioned parking as an issue, and another that did not provide information on the specific issue experienced stated that the issue occurred between 6 am – 10 am. For the nighttime, 9 of the 11 respondents provided information. Three (37.5%) of the drivers said they experienced issues at night; these three also stated that they had issues accessing the delivery location during the daytime. The remaining respondent that had issues during the daytime did not provide any information as to whether they had issues during the nighttime.

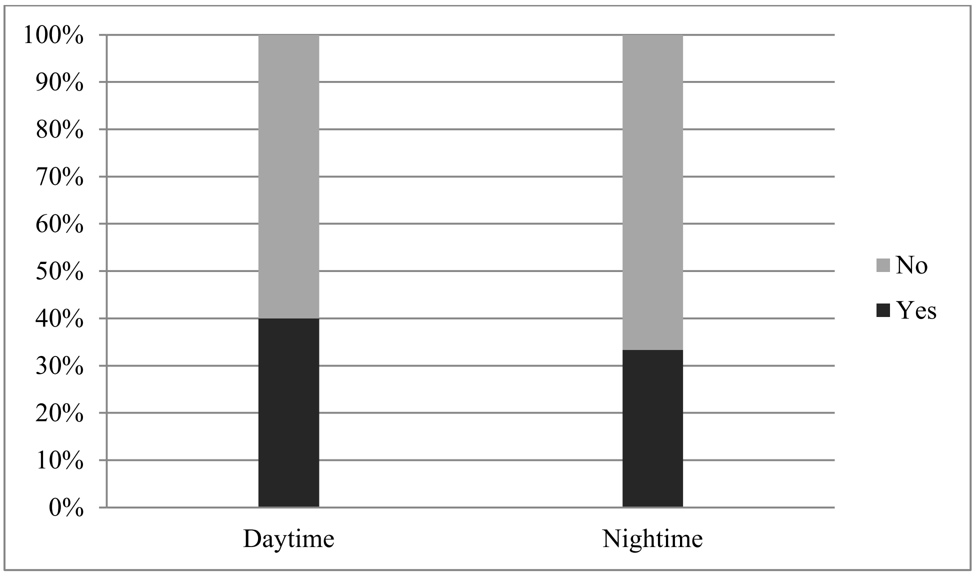
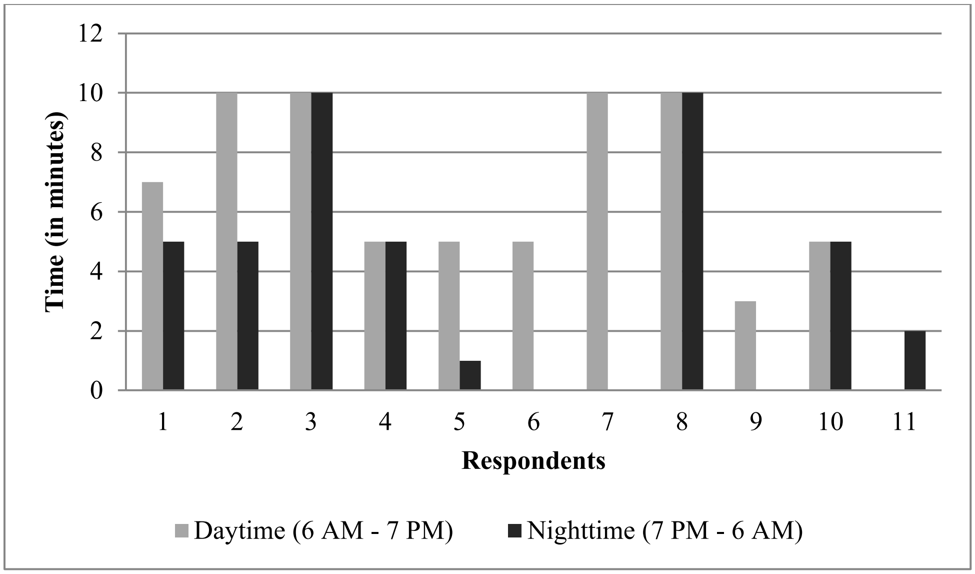


Figure 120: Percentage of Respondents that Experienced Issues in Accessing the Delivery Location

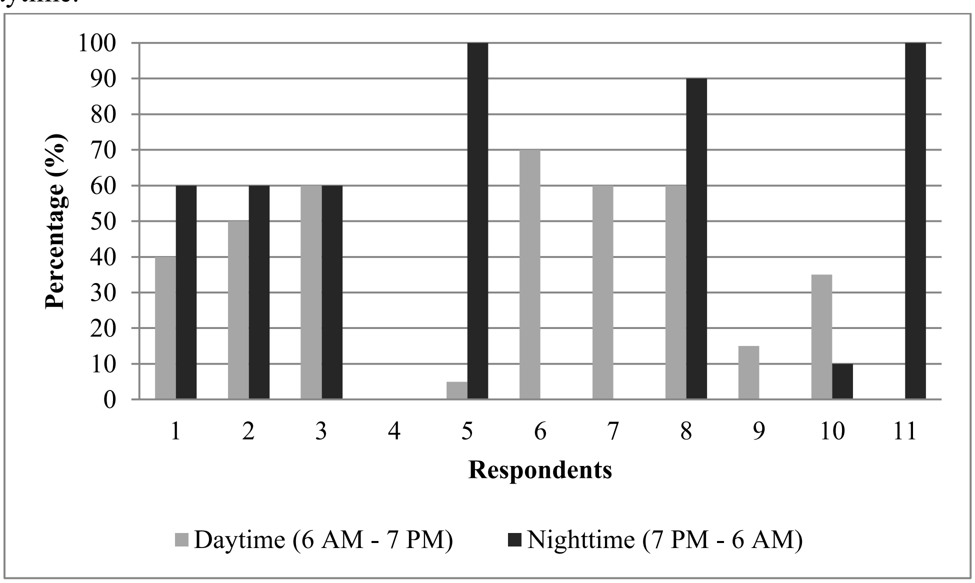
The typical walking distance from the parking spot to the delivery location ranges between 3 - 10 minutes for the daytime hours. The average for the sample is 7 minutes, with a standard deviation of 2.75 minutes. The range for the night hours spreads from 1 minute - 10 minutes. The average walking distance for the nighttime is then 5.375 minutes, with a standard deviation of 3.25 minutes.



Note: Missing bars for nighttime values for respondents 6, 7 & 9, and daytime values for respondent 11 are due to missing data; all others without a bar represent a zero (0) value

Figure 121: Average Walking Distance between Parking and Delivery Location

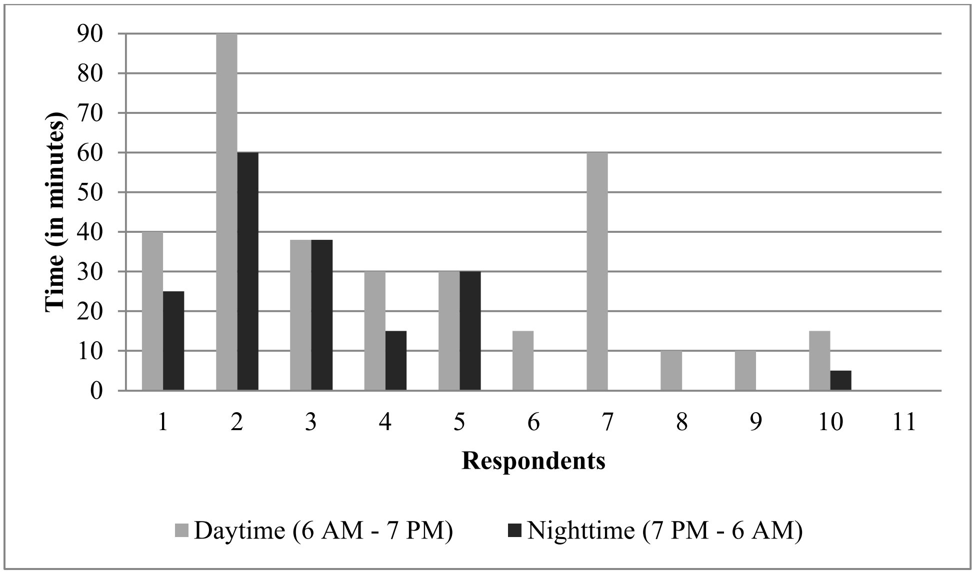
The percentage of times the driver is able to park within 1 block of the delivery location during the daytime ranges from 0% - 70%. The average percentage of times the respondents are able to park within 1 block of the receiver is 39.5%, with a standard deviation of 25.11%. During the night the percent of times the driver is able to park within 1 block of the delivery location ranges from 0 – 100%. The average for the 7 respondents is 60%, with a standard deviation of 38.17%. The comparison between day and night is displayed in Figure 122; it can be seen that on average the drivers are able to park closer to the receiving location more often during the nighttime compared to daytime.



Note: Missing bars for nighttime values for respondents 6, 7 & 9, and daytime values for respondent 11 are due to missing data; all others without a bar represent a zero (0) value

Figure 122: Percentage of Time the Driver Parks within 1 Block from Delivery Location

The average time spent at the loading dock during the daytime is 33.8 minutes, with a standard deviation of 25.32 minutes; while average duration at the loading block during the nighttime provided by the sample is 24.7 minutes, with a deviation of 20.6 minutes. This indicates that the delivery time for night deliveries are on average shorter than those that occur during the daytime, as shown in Figure 123.



Note: Missing bars for nighttime values for respondents 6 – 9, and daytime values for respondent 11 are due to missing data.

Figure 123: Average Time Waiting at Loading Dock

Additional comments from the respondents of the survey indicated that there is a preference for night time deliveries due to less traffic or congestion and better parking which were the factors mentioned most. The only con mentioned has to do with safety. The comment was because of "crazies out at night."

Testimonials about the Impacts on Carriers

Sysco Foods

Sysco is one of the world's largest food distributors. Prior to participating in this program, Sysco had one overnight route; currently, they have 31 routes that leave their warehouse each week in Elizabeth, NJ before 3AM. This represents approximately 18% of their total delivery routes (171 per week) in the NYC metropolitan area shifted to the off-hours. Sysco now has over 200 customers in Manhattan that receive at least some deliveries in the off-hours; they also have keys for approximately 140 unassisted off-hour delivery customer locations.

"Sysco Metro New York was very pleased with the results of the Off-Peak Delivery Project. Along with Rensselaer, we were able to grow from one route to five routes per day with the assistance of a program incentive to our customers. Although the program incentives are not in place anymore, we continue to benefit from the remaining four delivery routes. Given the opportunity to expand upon our four off-peak routes currently in place, along with the use of the Holland Tunnel, Sysco would be able to improve efficiencies in servicing the New York City market area. This would provide a reduction in traffic congestion in the City and in the surrounding areas during regular hours as we make our way back to our facility, reduce fuel consumption due to less miles traveled and traffic congestion, and provide a better quality of life for our employees who deliver in the City and deal with the inability to find locations to make deliveries.

I realized that a window of opportunity to deliver between 11pm and 3am was primarily "unitized" in our field, and was able to convince customers to allow our drivers access to their businesses to make deliveries. This provided the customer, and our company, an advantage. For the customer, their product was ready and waiting for them when they arrived to work, instead of waiting for their delivery throughout the day. The fill rate for product being delivered was nearly 100%, as these were the first orders selected during the night, so there was no issue of us being out of stock on their items ordered. I have received minimal if any complaints in 2 years regarding delivery issues from the accounts participating.
From the company perspective, our drivers are dealing with light traffic at those hours, parking is easier at the customers' locations, resulting in less fuel consumption because we are not sitting in traffic, overtime for our delivery associates is less because they are not tied up in traffic, and we are not receiving parking tickets like we do during the morning hours or 8am on. Year to date we were issued 2.3 million dollars in parking fines in the City. Albeit high, a slight reduction year after year as we move more drivers to an earlier start time. However, our delivery associates receive very few tickets during the early morning hours, compared to after the 7/8am time. If we continue to decrease our ticket expense as a result of deliveries at night, I am sure this would result in more aggressive pricing for our customers. However, we need to continue this reduction and experience this expense reduction over a period of time to insure our costs are decreasing.

----Bobby Heim, Vice President of Operations,

Sysco Metro New York

Wakefern

Wakefern delivers food products to grocery stores within the NYC area. Since NYC grocery stores are typically not open 24 hours, there has been hesitation to accept deliveries in the off-hours. Wakefern has five OHD routes per day, representing approximately 25% of their total daily delivery routes in the NYC metropolitan area. As part of this program, Wakefern, in conjunction with Gristedes Supermarkets, switched four locations to the off-hours. These four stores translate into one complete route driven three times per week. Based on the success of these four stores, Gristedes is going to investigate the logistics of switching additional locations to the off-hours.

Duane Reade Pharmacies

Duane Reade is part of the Walgreen family of companies, with over 250 pharmacies in the New York City area. Duane Reade has pioneered the use of OHD to improve their operations. With approximately 120 of their 160 Manhattan stores receiving OHD on a regular basis, they have realized a 75% reduction in parking tickets and an overnight delivery route approximately 60 minutes faster than their day route.

National DCP (Dunkin Donuts)

National DCP delivers to the 121 Dunkin Donut locations in Manhattan, with about 72 of these locations, or 60%, normally receiving staffed OHD. As routes are expanded, Dunkin Donuts continues to evaluate whether new stores can shift to the off-hours. It is also important to note that during the day deliveries to these locations require smaller trucks, but during the off-hours full size tractor trailers can be used, thereby reducing the number of vehicles entering the city, and improving emissions and congestion.

The Beverage Works (supplier of Red Bull in NYC area)

The Beverage Works has approximately 130 routes in the NY Metro area, each route having 25-35 stops per day. Eager to start shifting deliveries to the off-hours to make their operations more efficient and sustainable, The Beverage Works began by working with CVS to shift 30 of their stores to the off-hours. With a goal to get as many chains in Manhattan shifted to the off-hours as possible, The Beverage Works began by shifting one of their nine daily delivery routes to the overnight hours, and by the end of the project they were able to shift a second route, which represents 22% of their routes in the off-hours. The Beverage Works are continuing to promote the use of off-hour deliveries to their customers and plan on growing the number of routes they have in the off-hours.

Estimates of financial impacts on carriers

For confidentiality and competition reasons, participating carriers would not provide estimates of the project's financial impacts. However, the research reported in Holguín-Veras et al. (2011b) and interviews with drivers indicate that switching a delivery route from regular to off-hours saves on average 2.5 hours. Assuming a value of time of $85/hour, consistent with the estimate produced by the American Transportation Research Institute (Short et al., 2010), one could estimate that for every delivery tour that switched from regular to off-hours carriers save, on average, $212.50 per day or $42,500/year/OHD-tour (assuming 200 days/year).

The parking fines in New York City average about $750/truck-month. Since it is easier for truckers to find legal parking spaces near their delivery locations during off-hours, every OHD route that replaces a regular hour route saves about $9,000/year/OHD-tour in parking fines.

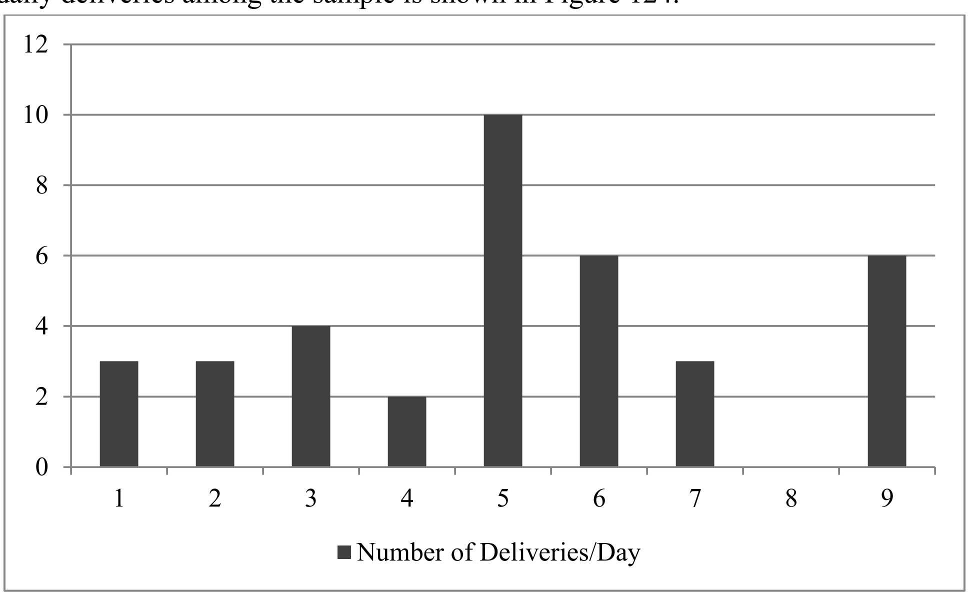
Essentially, the total savings to carriers amounts to about $51,500/year/OHD-tour. It is estimated that approximately 40-50 daily delivery tours in Manhattan have been switched to the off-hours, equaling a total savings to all participating carriers of over $2,250,000 per year.

Impacts on Receivers

Feedback from receivers are collected from the survey and the team's personal interviews, providing both quantitative and qualitative results.

Receiver Surveys -Before

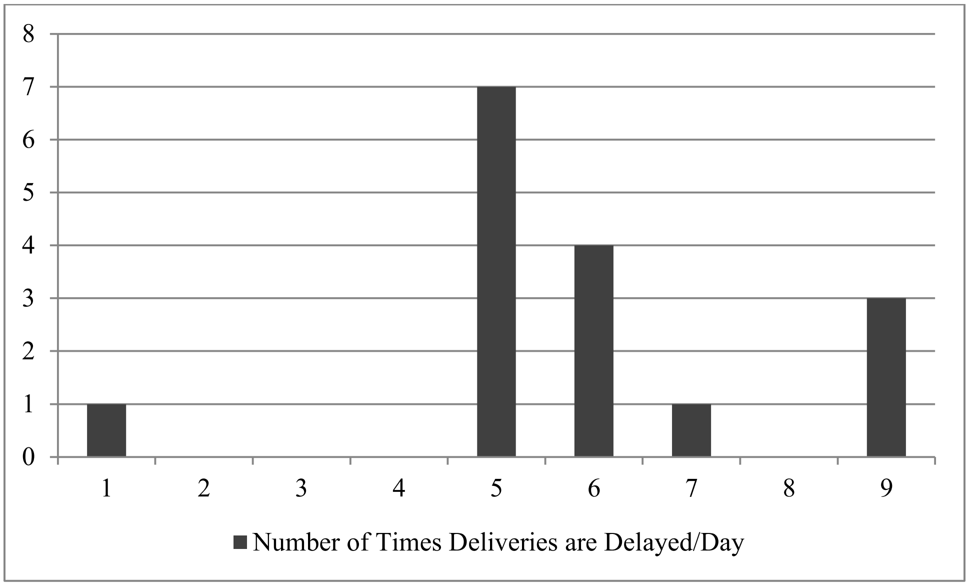
The survey received 9 responses, all from the food industry (specifically, restaurants and bakeries). The typical number of deliveries per day ranged from 2 to 10 deliveries for 8 of the 9 respondents that provided information. The average number of deliveries is 4.625, with a standard deviation of 2.62 deliveries. The distribution of daily deliveries among the sample is shown in Figure 124.



Note: Missing bar for respondent 8 is due to missing data.

Figure 124: Typical Number of Daily Deliveries

The frequency by which deliveries are delayed by at least 30 minutes for the sample ranged from zero (0) to seven (7) times a day, with an average of 2.67 times a day and a standard deviation of 2.58. The distribution of the number of late deliveries within the sample is shown in Figure 125.



Note: Missing bar for respondent 2, 4, and 8 are due to missing data; others without a bar represent a zero (0) value

Figure 125: Typical Number of Times per Day Delivery is Late by at Least 30 Minutes

When asked the number of minutes that the receivers are willing to allow for a late delivery, three (3) of the eight (8) respondents are willing to allow 30 minutes, and another 3 respondents said 60 minutes, while 1 respondent was only willing to allow 15 minutes, and another with the highest allowance of 90 minutes. The distribution of the responses provided by the sample is shown in Figure 126.

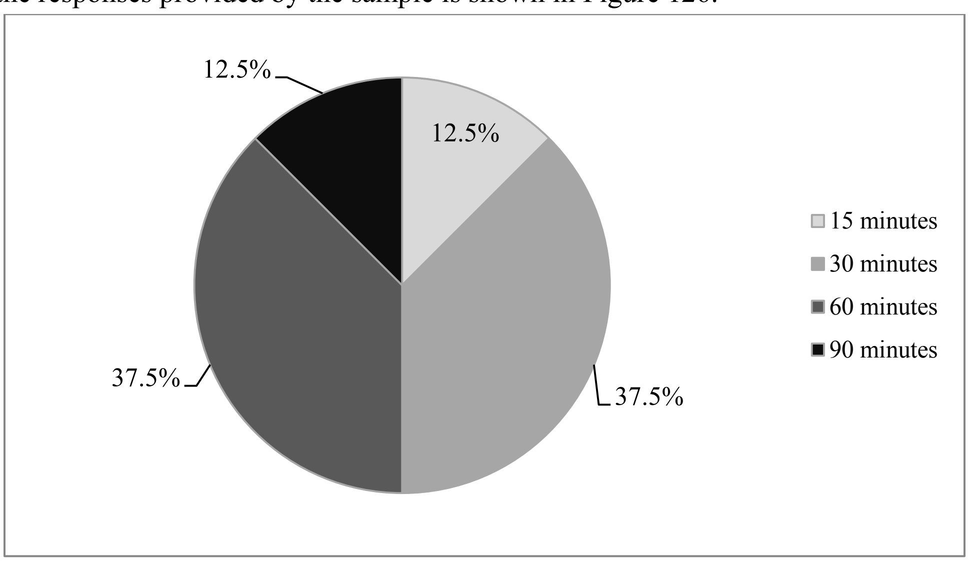


Figure 126: Length of Time the Receiver is Willing to Wait or a Late Delivery

The number of delivery errors—such as receiving wrong items—associated with daytime deliveries that occur in a typical month for the sample, ranged from two (2) to fifteen (15). The sample had an average of 5.86

errors in a month, and a standard deviation of 4.95 errors. The distribution for the sample is shown in Note: ***Missing bar for respondent 5 and 9 are due to missing data***

Figure 127.

Note: Missing bar for respondent 5 and 9 are due to missing data

Figure 127: Number of Delivery Errors in a Month

Eight (8) of the nine (9) respondents provided information on how deliveries enter the store during daytime; the responses are shown Figure 128. The majority (5 respondents) uses the front door, two (2) receivers use a door to the basement, and the other respondent uses the side entrance.

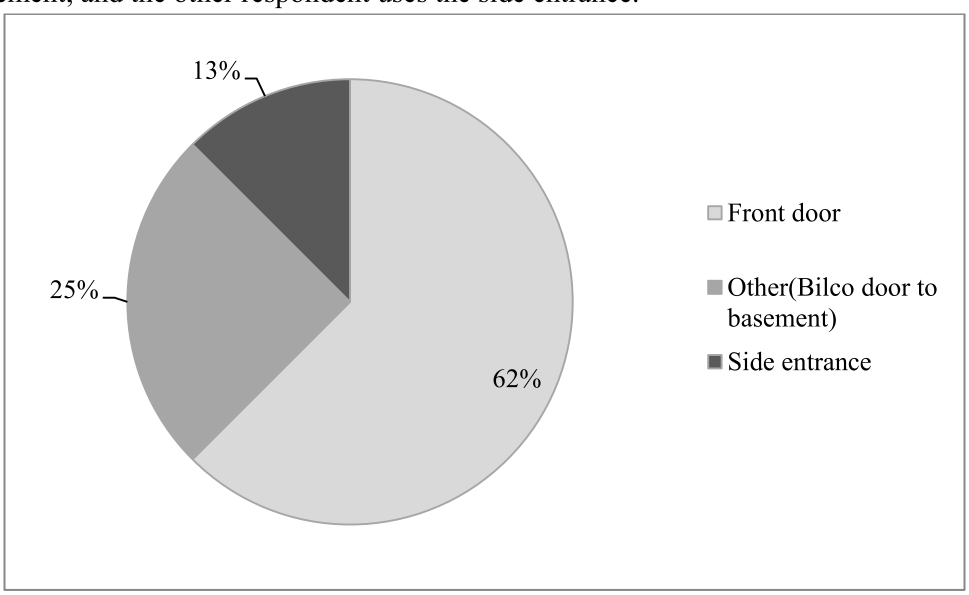


Figure 128: Delivery Entrance to the Store for Daytime Deliveries

The same respondents that answered the daytime entrance also answered for the nighttime delivery. The majority (50%) did not accept off-hour deliveries at the time of the survey. Of those that were already doing

OHD, three (3) respondents use the front door, and one (1) uses the side entrance. For those that accepted OHD they used the same delivery entrance for both day and night deliveries.

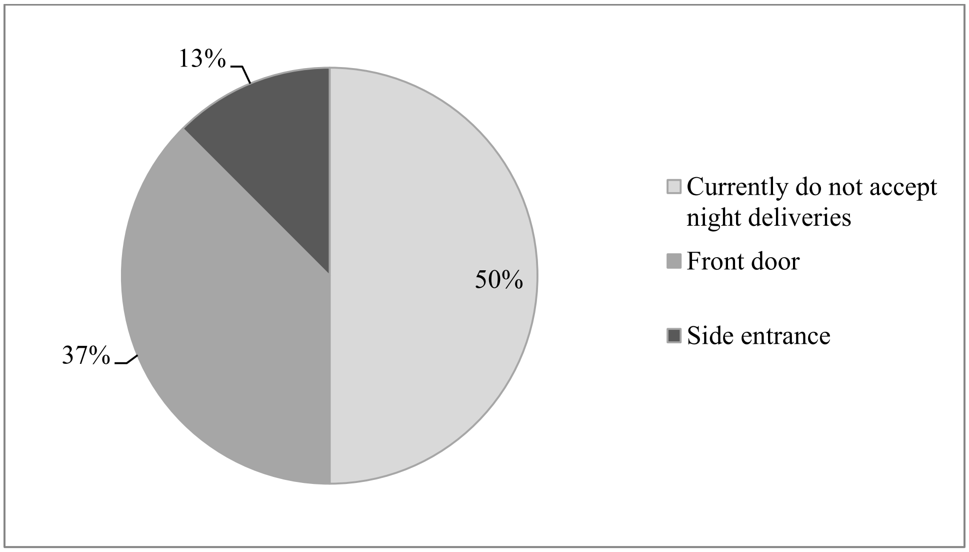


Figure 129: Delivery Entrance to the Store for Nighttime Deliveries

Of the four receivers in the sample that are currently doing off-hour deliveries (OHD), the number of OHD deliveries ranged from 1 – 2 per day, with an average of 1.5 deliveries and a standard deviation of 0.58 deliveries. This distribution among the sample is shown by "OHD" in Figure 130. Two of the respondents receive the deliveries without the use of staff; this is referred to as unassisted off-hours deliveries (UOHD). The number of UOHD per day for the sample is shown in Figure 130.

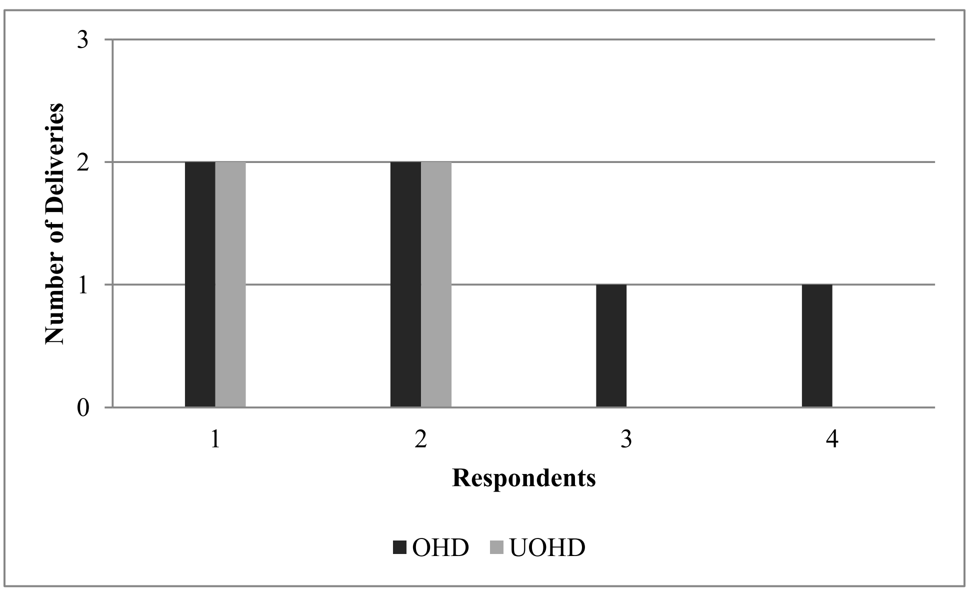


Figure 130: Number of Off-Hour Deliveries (OHD) and Unassisted Off-Hour Deliveries (UOHD)

For those that do UOHD, the driver uses a key to enter the establishment and leaves the delivery while for those that do staffed OHD, the staff accepts the delivery. When asked in a typical week how many of the OHD arrive late, one responded that an average of one delivery per week is late, while 2 other respondents were "not sure."

Receiver Surveys –After

After the switch to off-hour deliveries, the receivers completed a survey to provide information on their experience and opinions towards OHDs. Eleven (11) receivers responded to the survey; the sample was comprised mostly of food sector establishments, specifically restaurants and grocery stores and a hotel. The entire sample indicated that they have a positive impression of OHDs; six (6) of the eleven indicated very favorable while the other five indicated favorable, as shown in Figure 131.

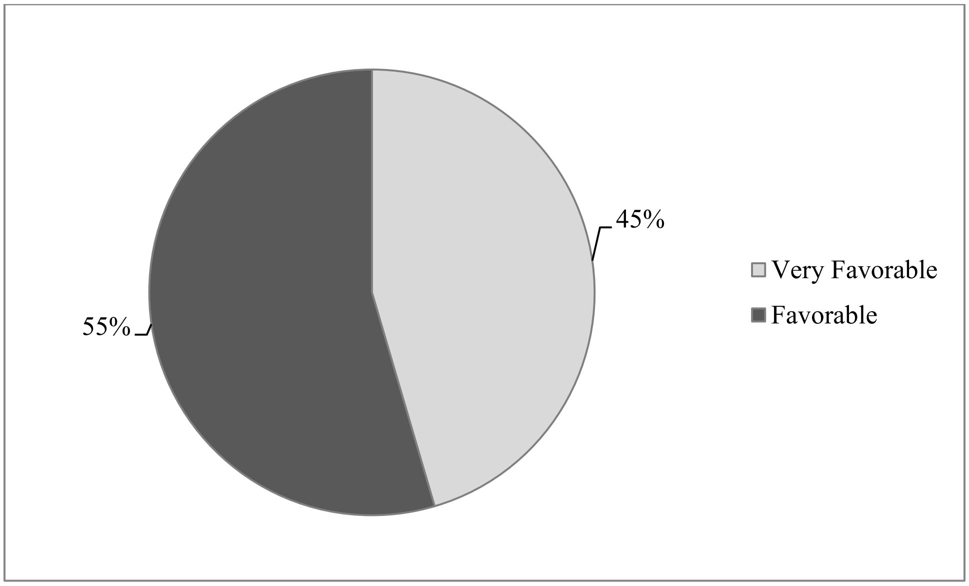


Figure 131: Receivers' Impression of Off-hour Deliveries (OHD) After Test Run

The majority (8 of the 11 respondents) saw some kind of change to their operations, while the other 3 receivers said they experienced no changes in their operations, as shown in Figure 132. Two of the receivers that experienced drastic changes indicated that they had significant time savings, less waiting around for late deliveries, and less having to receive products at inopportune times.

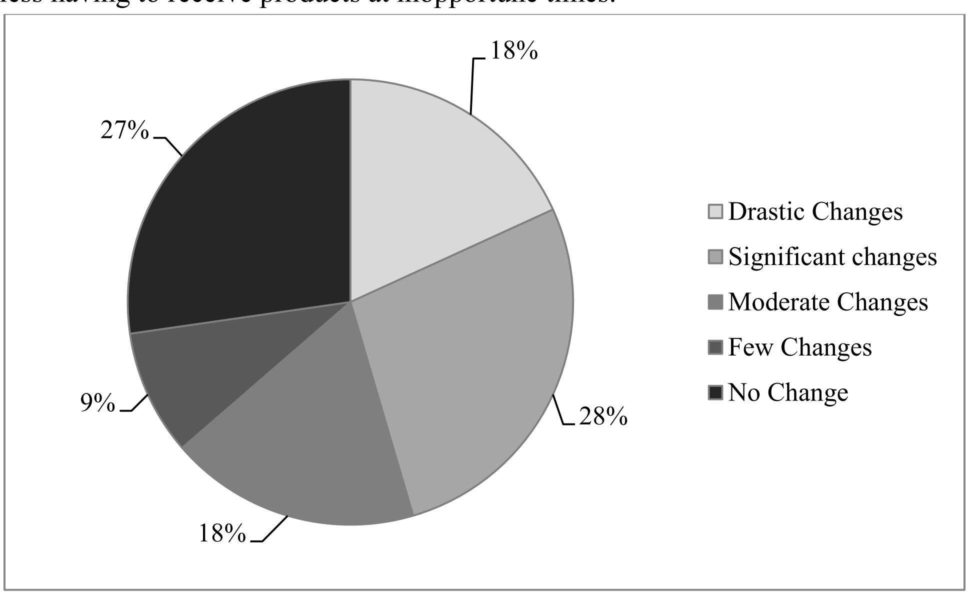
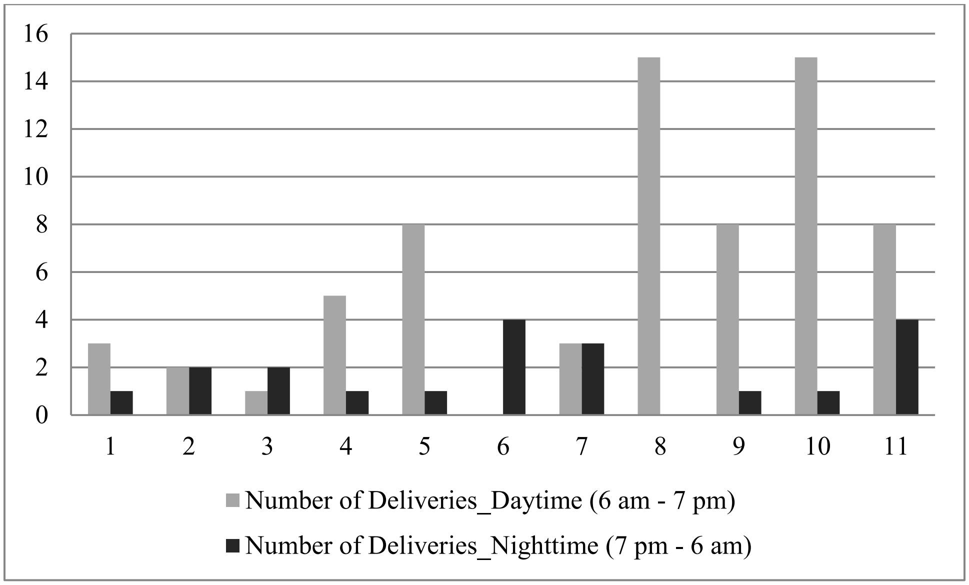


Figure 132: Effects of Off-hour Deliveries on Receivers' Operations

The average number of daytime (6 am – 7 pm) deliveries for the sample is 6.80 deliveries per day, with a standard deviation of approximately 5 deliveries. There is an average of 2 night deliveries for the sample, with a standard deviation of 1.25 deliveries. A comparison of the distribution of daytime and nighttime deliveries for the sample is displayed in Figure 133.



Note: Missing bars for respondent 6 and 8 are due to missing data.

Figure 133: Typical Number of Deliveries Received Per Day

The number of OHDs that arrive late within a typical week ranged from zero (0) to three (3). The majority of the sample (7 of the 11 respondents), as shown in Figure 134, had zero late OHD in a week. Three (3) respondents had one (1) late OHD per week, while 1 respondent had up to 3 late deliveries per week. The sample has an average of 0.55 late OHDs in a week, with a standard deviation of 0.93 deliveries per week.

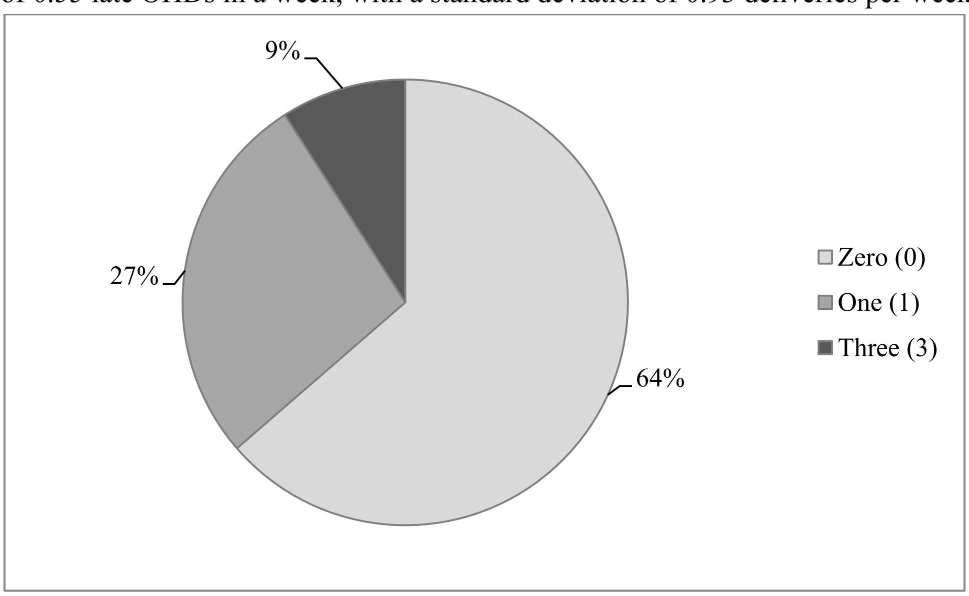


Figure 134: Typical Number of Off-hour Deliveries (OHD) that Arrive Late in a Week

The number of errors (such as receiving wrong items) that the receivers in the sample typically experience, ranges from zero (0) to seven (7) within a month. The average for the sample is 2.64 occurrences of errors, with a standard deviation of 2.34. Shown in Figure 135 are the proportions of the sample by number of times errors occurred within a month.

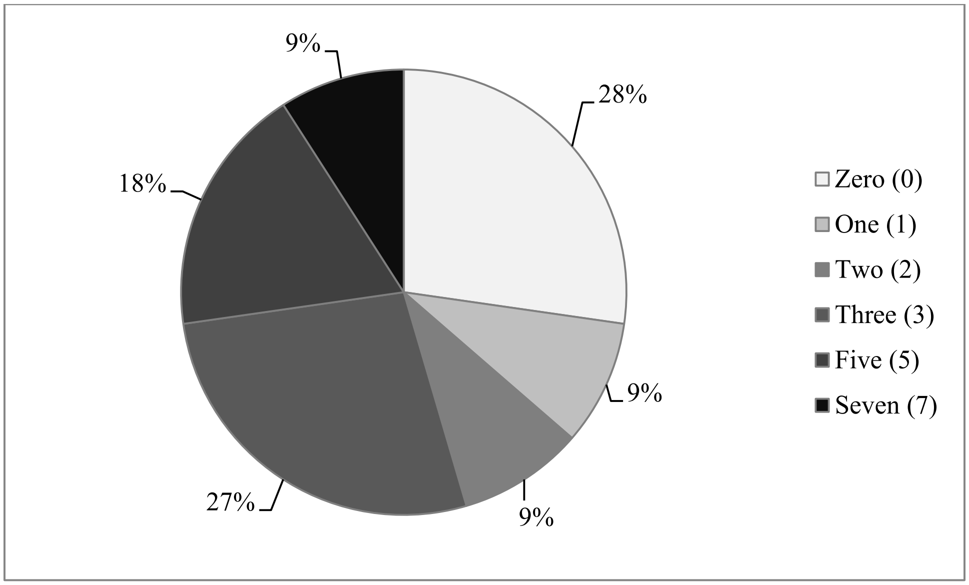


Figure 135: Typical Number of Delivery Errors for Off-hour Deliveries (OHD) in a Month

The majority of the sample (10 of the 11 respondents), indicated that they experienced time savings as a result of switching some of their deliveries to the nighttime (see Figure 136). Four (4) of the receivers responded positively to realizing cost savings due to OHDs, as shown in Figure 137; while the other seven responded that they did not experience any cost saving.

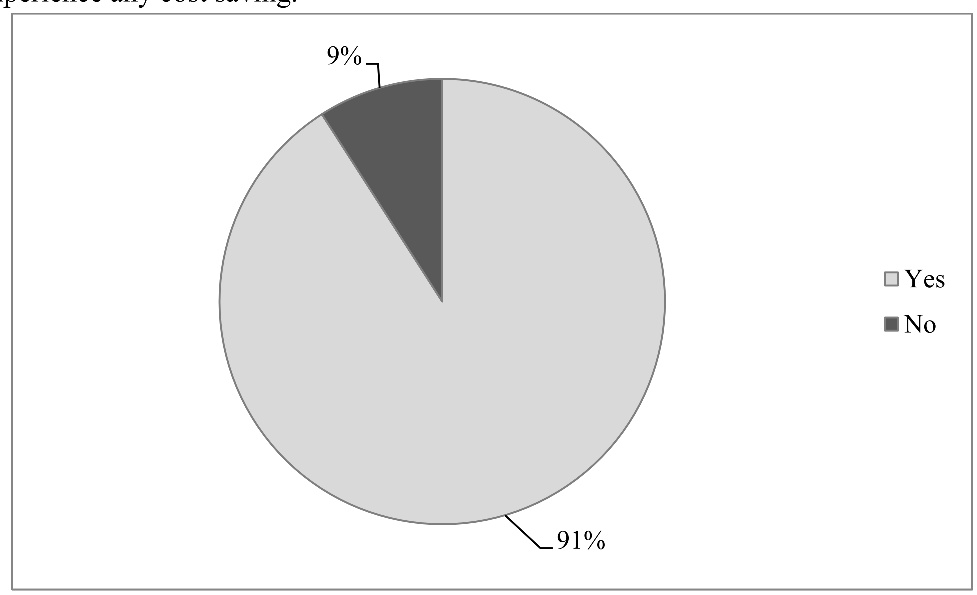


Figure 136: Noticed Time Savings from Off-Hour Deliveries (OHD)

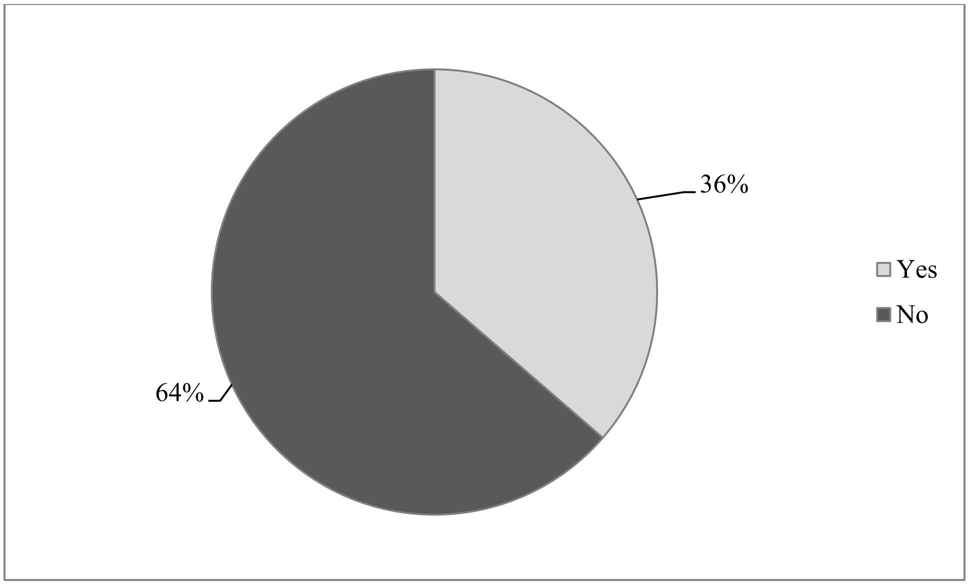


Figure 137: Noticed Cost Savings from Accepting Off-Hour Deliveries (OHD)

Seven (7) of the eleven (11) respondents (which accounts for 64% of the sample) receive their deliveries through the front or the side door; while the rest of the receivers use the loading dock or the basement entrance. Only thirty-six percent (36%) provided the drivers with keys to access their buildings to drop off night deliveries, while the majority had staff on hand to let the driver in, as shown in Figure 139.

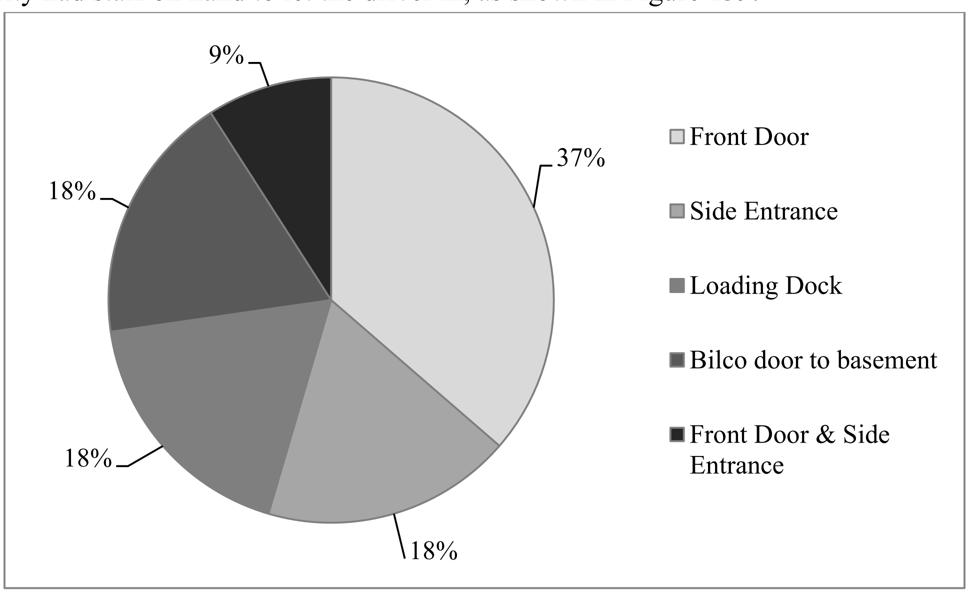


Figure 138: Delivery Entrance for Off-Hour Deliveries (OHD)

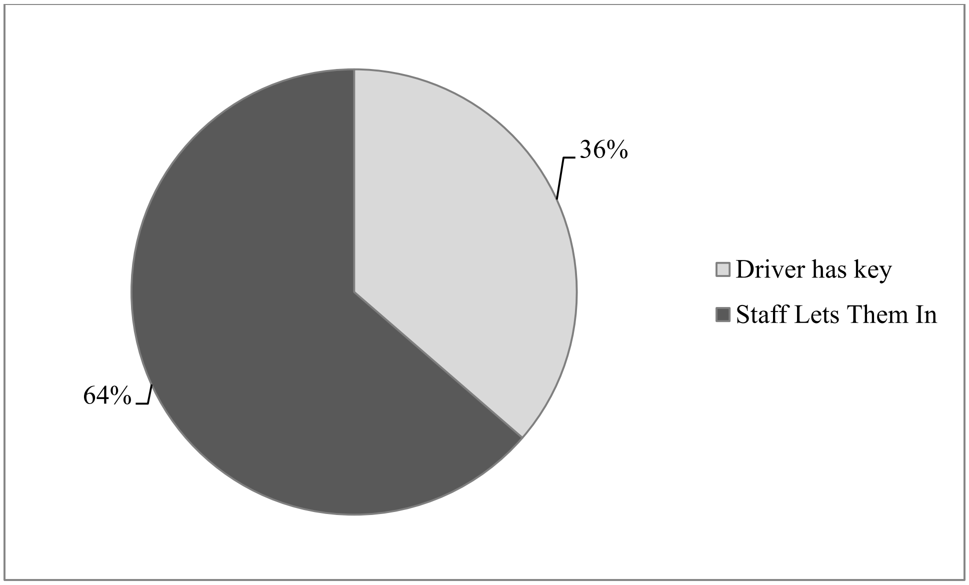


Figure 139: Driver Access to Building for Off-Hour Deliveries (OHD)

100% of the sample of receivers did not receive any discount from the carriers to do night deliveries. One (1) of the eleven (11) receivers incurred extra costs for doing OHD, as shown in Figure 140. This respondent incurred expense was due to that the receiver chose to do staffed-OHD which resulted in an additional 10 – 15 hours of labor costs.

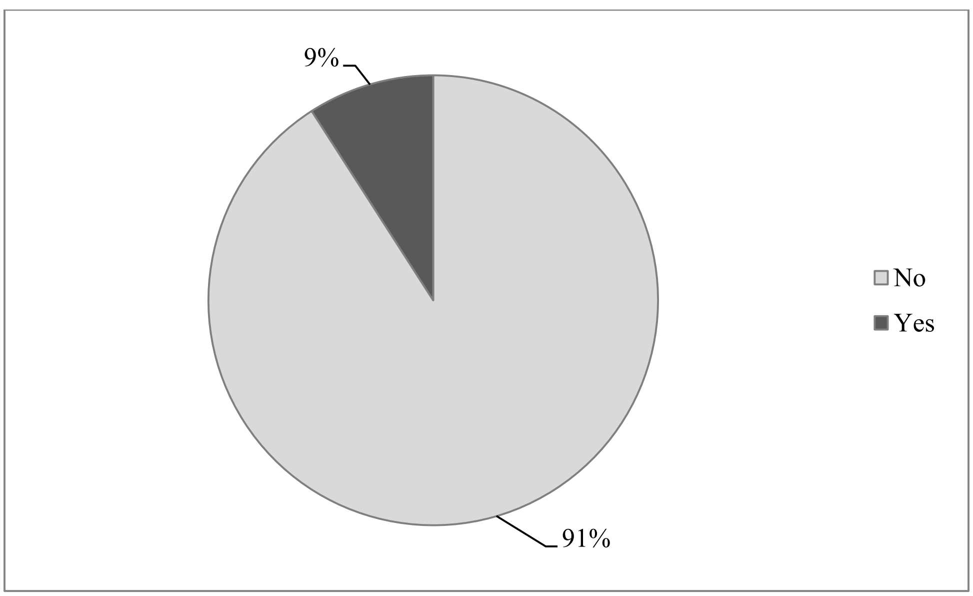


Figure 140: Were Costs Incurred to Participate in Off-Hour Deliveries (OHDs)

100% of the receivers in the sample responded positively to continuing to receive off-hour deliveries after this project. The respondents provided additional comments on their opinions towards OHDs. Among the comments some expressed that they had a positive experience. One indicated that prior to the switch they "were concerned about security issues but those turned out to be unfounded." Two others expressed that doing OHDs resulted in increased store operations efficiency. One specified that they "are able to stock shelves earlier and avoid interrupting our customers with products in the aisles." One negative that was mentioned was that they are not able to catch errors until they come in in the morning; but aside from this issue the respondent still was in favor of OHD.

Testimonials about the Impacts on Receivers

Waldorf Astoria

The Waldorf Astoria enrolled in the OHD program to improve the sustainability of their operations. Although only one location, it is an iconic New York City building, intent on improving the city environment and livability by becoming a role model in the implementation of sustainable business practices. The management at the Waldorf saw the benefits of off-hour deliveries right away, and was excited about the program. The Waldorf was able to quickly shift some of their deliveries to the off-hours, and made other physical changes to the building, such as adding an auxiliary refrigeration unit, to allow for additional off-hour deliveries. The conversations at the Waldorf inspired internal corporate discussions with the eighteen other Hilton-branded hotels in the NYC metro area regarding off-hour deliveries and other sustainability practices that they could implement.

Whole Foods Market:

"Whole Foods Market Union Square has enjoyed the ability to take deliveries in overnight, serve our customers better and enhance our commitment to the environment through more efficient trucking operations." **--Mary Snow Thurber, Director of Receiving**
Whole Foods Market Northeast Region

CVS Pharmacies

After The Beverage Works approached CVS to shift deliveries to the overnight hours at some of their Manhattan locations, 17 stores were shifted, and once this initial round was deemed a success, an additional 16 locations followed. CVS has also begun to accept OHD from other vendors.

Just Salad, LLC

Just Salad, LLC is a healthy fast food company with 11 locations currently in NYC, and many more planned for the tri-state area in 2014. Just Salad requires its three largest distributors to make off-hour deliveries.

"Our locations will continue to receive "night drops," even though this program has ended, as our managers now favor the dependability of night drops vs late daytime deliveries. Thanks again for the program."

"The Off-Hours Delivery Program… [is] a win-win, as business owners and citizens will both realize real immediate benefits"

-- *Nick Kenner,* Managing Partner
Just Salad, LLC

As the team worked with carriers and shippers to implement OHD, an unexpected hurdle was discovered. In some instances, a company's sales staff was not advertising the program because of the perception that, should delivery errors arise, their customers were going to call them very "early in the morning" to complain. Obviously, in anticipation of what they perceived as a possible negative impact on them from OHD, sales people were not inclined to advertise or push for the program. The transportation department, the immediate beneficiary of OHD, could not comprehend the lack of collaboration from the company's own sales people. To resolve the issue, the team decided to offer a small incentive to the sales people for every receiver that they enrolled in the program. This led to a significant increase in enrollment. It is essential that the sales personnel, who are the people dealing directly with the receivers, be in full support of the OHD effort. In the future, it may be possible for some larger companies to offer an incentive to their sales team to promote off-hour deliveries. Since the shipper would have lower operating costs when making OHDs, they may be able to provide a higher commission to the sales people for all deliveries or accounts they switch to the off-hours. This would have to be investigated on a case-by-case basis by each company, but it is a potential mechanism for shippers to increase the amount of off-hour deliveries.

Impacts on Public Sector

The OHD project has transformed NYCDOT's relations with the freight industry and the private sector. The OHD project has clarified the potential that exists for paradigmatic change when public and private sector and academic partners work collaboratively to find solutions to freight issues. The institutional support for, and commitment to, the OHD program--now branded "NYC deliverEASE--is made clear by these and other factors: 1) the adoption of OHD as part of NYC's Sustainability Plan (PlaNYC); 2) the Award ceremony organized by NYCDOT to honor the project participants; 3) the creation of an Industry Advisory Group that provides ongoing input to the city on freight matters; and 4) by conservative estimate, the NYCDOT investment of more than $700,000 of staff time and actual expenses in support of the program.

In March 2012, the NYCDOT Commissioner sent letters to other public agencies seeking their support for OHD. Agencies with the ability to offer incentives, both financial and other, were briefed about the public benefits of expanding their incentive programs in support of OHD. In July 2013, NYCDOT met with NYC Economic Development Corporation to discuss options for tax subsidies or other financial incentives that could be developed to incentivize receivers to shift some of their deliveries to the off-hours. Also, in July 2013, $500,000 was obligated by NYCDOT to support the expansion of OHD. NYCDOT will use these funds to help participants shift to the off-hours, and to fund a quiet truck demonstration project with private sector participation. NYCDOT also submitted a proposal to the New York State Energy Research and Development Authority (NYSERDA) to advance work related to reducing the noise associated with OHD. NYSERDA provided $112,500 in funding to NYCDOT, offering partial assistance to help purchase and evaluate noise reduction equipment to be used in OHD.

The Off-Hour Deliveries (OHD) program has been profoundly influential and impactful, domestically and internationally. The OHD program:

1) has been officially adopted by the City of New York as a feature of its sustainability plan; the first research project incorporated into NYC transportation policy.
2) led to the creation of a grant program, jointly funded by the Federal Highway Administration and the Environmental Protection Agency, to foster OHD programs in other cities. Orlando, Florida and Washington, DC were selected as the first recipients, and are actively developing their own versions of OHD programs.
3) has caught the attention of both public and private sector representatives from multiple US cities, including Boston, Atlanta, Chicago, and Seattle.
4) is being advanced internationally.
   London: The City of London is collaborating with RPI and NYCDOT to promote OHD there.
   Sao Paulo, Brazil: After the RPI team made a presentation in July, 2013 about the NYC OHD program, business groups organized a follow-up meeting—attended by over 200 companies—to urge the government to create an OHD program.

Toronto and Montreal, Canada: Public and private sector representatives from these cities have asked RPI to provide them with additional information about the NYC OHD project.

Summary of Findings

The research team used a wide range of data collection and assessment approaches to evaluate the impacts of the OHD implementation. Overall, the benefits of OHD are evidenced in almost all aspects.

OHD effectively contributes to congestion reduction in the study area: without considering induced traffic, each diverted (i.e., shifting from daytime to off-hour delivery) truck reduces the network-wide VHT by at least 6.2 hours in the day, while only increasing it by 0.07 hours for the entire network during night. The network-wide VHT reduction in the daytime is 88 times of the VHT increment at nighttime.

OHD also benefits the communities through reduction of air pollutants. Each diverted truck reduces the network-wide emissions by 0.028 ton per hour in the daytime, while increases them by a mere 0.0016 ton per hour during nighttime. The noise measurement at multiple delivery sites suggests that noise caused by most of the delivery operation falls under the permitted limits, and the peaks only last for a couple of seconds. However, the engine noise does go over the limit, and could be perceived by the residents if the driver does not adequately manage the acceleration of the truck. In the long term, noise control devices and driver training may be necessary, especially for OHD in residential locations. In terms of safety concerns, it is found that each 1% increase in truck volume is related to a 0.235% increase in non-severe truck crash occurrence rate, and a 0.273% in severe crashes in daytime. The numbers are 0.238% and 0.281%, respectively, for night time. Based on simulation of different OHD participation rates, it can be concluded that the off-hour delivery program does not increase the risk of truck-involved crashes significantly.

As expected, OHD enhances productivity of participating carriers by reduction of travel time. The GPS data analysis indicates that if deliveries are shifted from Midday and PM to Night period, 93% of the analyzed trips can be performed with shorter travel times. This is consistent with the findings in Chapter 5 which also indicate that OHD can help improve delivery efficiency: it reduces delivery service times and travel times between the warehouse and the stops. As a result, OHD helps dramatically reduce fuel consumption and emission rates (by over 20% in general). For deliveries on roads with significant traffic disruptions such as toll roads or urban arterials, the reductions can be over 50%.

An overall analysis of all social benefits show that the optimal amount of incentive is about $6,000/year per participant, when the net benefit (after deducting the incentives) is about 55.6 million dollars per year.

In addition, according to the survey analysis on drivers and fleet managers, carriers also benefit from several other aspects: The average time spent finding or waiting for parking at each delivery stop is reduced from 30.3 minutes in daytime to 8.75 minutes in nighttime. The typical number of tickets changes from 7.3 tickets per week to 0.125. The typical walking distance from the parking spot to the delivery location reduces from 7 minutes to 5.375 minutes. The percentage of times the driver is able to park within 1 block of the delivery location increases from 39.5% to 60%. The average time spent at the loading dock decreases from 33.8 minutes to 24.7 minutes. For driver stress level (1 representing the least stressful and 5 representing most stressful), the average stress level reduces from 4 in the daytime to 2.78 in the nighttime. As one of the participating carriers indicates, as 75% of their deliveries are shifted to off-hours, they have realized a 75% reduction in parking tickets and an overnight delivery route approximately 60 minutes faster than their day route.

Most receivers also observe benefits from participating in OHD. According to the survey, on average, the participants receive 5 deliveries during daytime hours, and 2 during off-hours every day. For daytime, frequency of deliveries that are delayed by at least 30 minutes is 2.67 times per day. In contrast, the number of OHDs that arrive late is only 0.55 per week (about 0.08 per day), presenting a dramatic improvement in the reliability of delivery time. The number of delivery errors averages 5.86 errors per month (out of approximately 150 deliveries per month). The number of errors made during OHD is 2.64 per month (out of 60 deliveries per month), comparable to the rate of errors during day time. Overall, most participating receivers indicated that they experienced time savings as a result of switching to OHD and confirmed the increased store operations efficiency because they “are able to stock shelves earlier and avoid interrupting customers with products in the aisles.” All survey respondents are willing to continue to receive off-hour deliveries after this project.

For the public sector, the OHD program has been profoundly impactful both domestically and internationally. The OHD program has been officially adopted by the City of New York as a feature of its sustainability plan. Locally, the OHD project has fostered the collaborative relationship between NYCDOT with other public agencies, such as NYC Economic Development Corporation and New York State Energy Research and Development Authority (NYSERDA), who worked with NYCDOT to provide support, both financial and other, to the OHD program. It also transformed NYCDOT’s relations with the freight industry and the private sector, greatly enhancing its public image. The success of the NYC OHD project also led to the creation of grant program, jointly funded by the Federal Highway Administration and the Environmental Protection Agency, to foster OHD programs in other cities. Orlando, Florida and Washington, DC have been selected as the first recipients. Other cities, including Boston, Atlanta, Chicago, Seattle, London, Sao Paulo, Toronto and Montreal have also shown great interest in developing their own OHD programs.

CHAPTER 7 - CONCLUDING REMARKS AND NEXT STEPS

The United States Department of Transportation's (USDOT) Research and Innovative Technology Administration (RITA) sponsored project, Integrative Freight Demand Management in the New York City Metropolitan Area: Implementation Phase successfully demonstrates how the freight industry, public agencies and the research community can work together to increase the reliability of goods movement within New York City while improving its citizens' quality of life. Although this is technically the implementation phase, it should be noted that the term launch phase may be more appropriate since a proper and successful implementation of an off-hour delivery program requires a sustained effort over a long period of time. After all, the program aims at transforming entire supply chains, which requires profound modifications of business practices. The implementation phase followed the previously completed pilot phase (RITA Integrative Freight Demand Management in the New York City Metropolitan Area project, 2010) which was also a great success (Brom et al., 2011; Holguín-Veras et al., 2011b). This last chapter of the final report provides concluding remarks that are intended to sum up the chief experiences and lessons learned from the Off-Hour Delivery (OHD) project. The chapter also provides suggested next steps identified by the team as important to ensure the ongoing success of the OHD program in the New York metropolitan area.

For these reasons the OHD project is widely acknowledged as one of the most impactful and business-friendly public sector freight initiatives to date:

1. The project could influence large numbers of deliveries (up to 20-40% of truck traffic), with tremendous economic impacts. OHD's focus is urban deliveries, which dwarf all other freight trips; deliveries to restaurants in Manhattan alone attract and produce more truck trips daily than do the Ports of New York and New Jersey. The OHD program in NYC is expected to produce economic savings of \$100-\$200/million per year, and reductions of: 202.7 metric tons (t)/year of CO; 40t/year of HC; 11.8t/year of NOx; and 69.9 kg/year of PM_{10} (Holguín-Veras et al., 2011b). Not surprisingly, *Time Magazine* identified the OHD project as one of "10 Ideas that Make a Difference" (TIME, 2013).
2. The OHD program increases economic competitiveness, reduces congestion and environmental pollution, and increases sustainability, quality of life, and livability. Local, state, and federal programs also geared towards these outcomes could be used to foster OHD, such as programs from the Small Business Administration, Housing and Urban Development, Environmental Protection Agency, and US Department of Transportation.
3. By removing the interferences produced by freight deliveries, OHD programs facilitate the implementation of other sustainability initiatives, such as Bus Rapid Transit systems, bike lanes, and enhanced pedestrian walkways that also need curb space.
4. The OHD project has dramatically confirmed the potential of public-private sector and academic cooperation in solving urban congestion. The program's business-friendly nature has won the enthusiastic support of the private sector (Journal of Commerce, 2009; 2010; Wall Street Journal, 2010).
5. This project has changed freight policy at regional, national, and international levels. NYC adopted OHD as part of its sustainability plan (City of New York, 2011), and the Federal Highway Administration and the Environmental Protection Agency created a program to replicate the OHD program in cities throughout the US (Federal Highway Administration, 2012). The first grants from this federal program were awarded to Orlando, Fl. and Washington, DC. Chicago, Boston, Atlanta, London, and Sao Paulo have also expressed interest in OHD programs.
6. The OHD program confirms the viability and potential of the emerging field of freight demand management by demonstrating that changing receivers' behavior leads directly to changes in carriers' operations, while policies that target carriers do not necessarily result in broader changes, in the supply chain, the urban

freight system, or the environment. Supported by thorough research, as well as the NYC project's pilot and implementation experience and data, the OHD concept is transferable and adaptable, and its implementation now facilitated for cities around the world.

Among the many critical factors that combined to support the project's success, these are important to highlight:

- The research conducted previous to this phase. The team's path-breaking research clearly indicated that, in direct contrast to prevailing wisdom: (1) receivers are the ones who primarily dictate delivery times; (2) carriers travel in the congested (and more expensive) hours of the day because they must respect the wishes of their customers (the receivers); and, (3) receivers in the food and retail sectors (that produce about 60% of the deliveries) would be willing to switch to the off-hours in response to financial incentives.
- The willingness of the United States Department of Transportation's Research and Innovation Technology Agency to fund a research project, with an implementation phase, in the midst of a financial crisis. Without this courageous decision the OHD program could not have taken place.
- The leadership exhibited by the NYCDOT, particularly its Freight Office, in deciding to implement what at the time was an untested research idea.
- The private sector's willingness to collaborate with research institutions and the public sector in a city where there was no precedent for such collaboration.

In addition to the fortuitous combination of success factors listed above, the project encountered numerous challenges, including:

- The 2009 Wall Street financial crisis; while the impacts were felt primarily in the OHD pilot phase, lingering effects were felt in the (project and) the city's economy for years to come.
- Super Storm Sandy; the impacts brought project activities to a halt for months.
- The lack of precedent for this level of cooperation between the public and private sectors in urban freight matters. The NYCDOT's Freight Office had to make a massive effort to ensure that key representatives of the private sector would be willing to collaborate with the OHD project.
- Private sector inertia; the OHD project required that participating establishments change their operational practices. The actual implementation of those changes, even for businesses that were committed to change, took a lot of coordination and prodding from the project team.
- Leadership turnover; with relative frequency, the leadership of companies already committed to OHD changed. The team frequently had to 'resell' the program to new leadership, which translated into delays.
- Skepticism; some decision makers and agencies--both in the private and public sector—had difficulty believing that the public sector could play any role in influencing the behavior of the receivers of supplies.

The Off-Hour Delivery (OHD) project produced a number of important and unexpected findings, including that:

- Unassisted OHD are a valid option for many receivers. The 2009 pilot test indicated that the receivers that implemented unassisted (not staffed) OHD remained in the program, while those that were using staffed OHD bowed out once they could no longer use the financial incentive to pay for off-hour staffing. From the surveys conducted in the second phase, it is estimated that 32% of all receivers have a vendor that they would trust to make OHD unsupervised. The goal of future OHD efforts is to ensure that these receivers agree to unassisted OHD.

- Numerous receivers agreed to unassisted OHD without incentives. Apparently, because of “word of mouth” from other receivers, several companies (e.g., Sysco, Duane Reade, CVS, Dunkin Donuts) reported increases in the numbers of receivers that requested OHD without asking for the financial incentive. This is very encouraging, because it highlights the potential network effects produced by dissemination of OHD among the private sector. If economic and operational benefits for receivers (and carriers) drive their continued participation, initial incentives may become less necessary as word about the program, and participant experience, spreads.
- Internal carrier dynamics can foster or hamper implementation of OHD. In one notable instance, a vendor/carrier that was extremely happy with OHD experienced problems attracting new receivers to the program. The internal research conducted indicated that the company’s sales staff was not advertising the program because of the perception that, should there be delivery errors, their customers were going to call them “early in the morning” to complain. Obviously, if the sales people felt they might be negatively impacted by OHD, they would not be inclined to advertise the program. The transportation department, the immediate beneficiary of OHD, could not comprehend this lack of collaboration from the company’s own sales people. To resolve the issue, the team decided to offer an incentive to the sales people for every receiver that they enrolled in the program. This led to a significant increase in enrollment. It is essential that the sales staff, the people who deal directly with the receivers, be in full support of the OHD effort.
- The influence of the real estate sector. The real estate sector controls much of the commercial property in large metropolitan areas such as Manhattan, and greatly influences how business is conducted. For instance, if a lease agreement specifies restrictions to deliveries, this could negatively affect the use of strategies like off-hour deliveries. Often the real estate sector is open to improving their policies and environmental profile, and will join forces with the implementation team towards a more business-friendly environment.
- Impacts on driver safety and satisfaction. The perception exists that drivers prefer not to work during the off-hours, or that they feel unsafe working this shift. The surveys conducted indicate that this is a myth; many drivers prefer off-hour to regular-hour shifts. Some of the reasons cited include: the time saved in completing the delivery routes (typically 2-4 hours) which increases the effective pay, the less stressed driving environment, and the possibility of having more time to spend with small kids in the afternoon hours.
- Engagement of unions is important. There is a perception that unions representing drivers, elevator operators, laborers and many others are unwilling to make changes to their contracts, and that they will oppose OHD. This was not found to be the case in the OHD program. In fact, a number of companies participating in the program have union workers, and they were amenable to operating in the off-hours.

These are some of the many important tactics and practical suggestions derived from the team’s experience with the OHD project’s implementation phase:

- Find ‘signature’ chains or businesses to be the participant leaders. Well recognized companies often serve as role models to others companies in the industry. For example, a small company might resist participating unless they see an industry leader already involved. Once an icon business participates, smaller companies are more likely to recognize the benefits and see less risk involved.
- Focus on developing incentives. The incentive structure is critical, and if it has to be changed, mid-project, this could cause confusion and a lack of confidence among participants and potential participants. Before even recruiting participants, it is essential to completely understand, and be confident in, how the incentives are structured.

- Engage community stakeholders once there is a clear plan. Likewise, it is necessary to have the overall program structure defined prior to getting the stakeholders engaged. While early stakeholder engagement is of utmost importance, if stakeholders are brought into the process before there is clear direction, their assistance and involvement could be jeopardized.
- Define an effective marketing strategy. The business community must be aware of a program, and understand its benefits before they will interact with the project team or participate in the project. A brand name that is easy to remember increases the likelihood that people will recognize the name and relate it to something they have heard or seen. A marketing strategy helps facilitate the work of implementation; name recognition, or any prior awareness of the program opens doors, eases doubts, and makes initial contacts easier. Having a participating signature chain or icon business already a member further enhances people's identification with the program.

A project of this length, scope and complexity yields multiple insights as it evolves. With the launch phase now completed, these are some of the key lessons learned most worthy of note:

- Behavior changes are imperative to improve the overall performance of the urban freight industry. Since the path to sustainability entails behavior change, a thorough understanding of behavior is essential. Academic research can provide the tools and resources to model and identify the best ways to induce changes for the better, and the right combination and amounts of incentives/penalties to use.
- Self-interest must be acknowledged and accounted for. A key to success are policies that benefit most, if not all, key players. These will be policies that all those involved will fight for, and ones that will have a better chance of lasting. Policies that impose costs on some stakeholders will inevitably be challenged.
- Stakeholder collaboration is essential. No one agent could solve freight issues singlehandedly; unilateral solutions do not work in complex systems. The public sector regulates and manages the infrastructure, the private sector operates the system, and academia conducts research to find solutions. Communities enjoy the benefits of consuming and producing freight, and also suffer the impacts of the traffic generated. Since all players control a different piece of the system, collaboration is the only way to a more sustainable system, or progress. However, proper stakeholder engagement requires considerable effort: constancy over time, development of trust, transparency of actions and purpose, patience, two-way communication, and the ability to change course based on the input received.
- As the creators of freight demand, receivers are the key to behavior change. By specifying delivery times, receivers define when the vendors/carriers travel and how supply chains operate. However, receivers may be dedicated to the status quo, and unaware of their influence. Public sector incentives, financial and non-financial, are needed to motivate receivers to act in favor of sustainable practices.
- Incentives are needed to engage receivers as agents-of-change. In addition to the one-time cash incentives offered in the implementation phase, there is a wide range of possible incentives—financial and non-financial--that could be offered to receivers in exchange for agreeing to accept off-hour deliveries.
- High-level support is needed. Enacting large-scale change relatively quickly requires a clear message from civic leaders stating the need to change practices, and a path to do so. High-level decision makers should be involved, working in concert with private/public sector. Broad-based campaigns with multi-stakeholder support involving trade groups and associations, leading private companies, and as many high-profile advocate groups as possible. Convincing one receiver at a time is a slow process; 'critical mass' can help the morale and project implementation.

- Switching to OHD is a process, not a quick decision. When designing and implementing an off-hour delivery program, it is important to accept that most private sector companies cannot immediately switch to making deliveries in the off-hours. The NYC implementation process confirmed the importance of developing a working relationship with all of the parties involved, including the carriers, shippers and receivers, and maintaining contact with them on a regular basis. Even when all of the parties involved appear ready to make the shift, it might not be physically possible for some reason such as lease agreements, union contracts, or physical barriers within the building. The right balance of patience and persistence must be applied to not deter anyone, maintain interest, overcome obstacles, and achieve success.
- Multiple public agencies and groups may need to play a role. Most transportation agencies focus on traffic issues, not necessarily the operational ins and outs of the businesses that generate the freight traffic. Moreover, there are other agencies that already have incentive programs in place with similar sustainability goals that could be re-tooled to include OHD. For example, there are: economic development agencies that routinely provide incentives to new companies; federal agencies that manage federal programs for sustainability and environmental improvements; non-profit organizations such as the Leadership in Energy and Environmental Design (LEED) program that could include OHD-friendly building designs as part of its qualifiers. Leading important urban business sectors, such as real estate, hospitality and entertainment, as well as environmental and sustainability groups and companies could help support OHD and sustainable delivery practices.

The project team's chief conclusion is that the Off-hour Delivery (OHD) program is a win-win solution that benefits carriers, receivers, and urban communities at ***all*** hours, enhancing quality of life, economic development, and environmental sustainability. It is a program that is implementable, even in complex institutional environments and with relatively small amounts of funding, and one that is bound to transform the relation between public and private sectors as both sides learn how to work together in the solution of such complex issues. The team is enthusiastic about the potential of such an important and path-breaking project.

REFERENCES

Assured Lock Tool and Supply (2011). "Combination Key Keepers." Posted: Retrieved 30 October 2011, from http://www.locksmithtoolandsupply.com/store/merchant.mvc?Screen=CTGY&Store_Code=PLT&Category_Code=KC-PB.

Augereau, V. and L. Dablanc (2007). An evaluation of recent Pick-Up Point experiments in European Cities: the rise of two competing models? Paris, France, INRETS.

B&H Photo and Electronics Corp. (2011). "Surveillance Video." Posted: Retrieved 10/09/11, from http://www.bhphotovideo.com/c/browse/Surveillance-Video/ci/3496/N/4293342959.

Bai, S., D. Eisinger and D. Niemeier (2009). MOVES vs. EMFAC: A Comparison of Greenhouse Gas Emissions Using Los Angeles

County Transportation Research Board"s 88th Annual Meeting. Washington, D.C.

Barth, M., F. An, T. Younglove, G. Scora, C. Levine, M. Ross and T. Wenzel (2000). Comprehensive Modal Emission Model (CMEM), version 2.0 user's guide. University of California, Riverside.

BESTUFS (2007). Good Practice Guide on Urban Freight Transport. University of Westminster. BESTUFS http://www.bestufs.net/.

Bishop, C. M. (2006). Pattern recognition and machine learning. New York, NY, USA, Springer Science+Business Media, LLC.

BrickHouse Security (2011a). "Biometric Door Locks." Posted: Retrieved 2 October 2011, from http://www.brickhousesecurity.com/keylessdoorlock-electronicbiometric-fingerprintlock.html.

BrickHouse Security (2011b). "Fingerprint Door Locks." Posted: Retrieved 2 October 2011, from http://www.brickhousesecurity.com/fingerprint-door-lock.html.

Brom, M., J. Holguín-Veras and S. Hodge (2011). "Off-Hour Deliveries In Manhattan, New York City: Experiences Of Pilot Test Participants." Transportation Research Record **2238**: 77-85. 10.3141/2238-10

Bureau of Labor Statistics (2012). "Occupational Employment Statistics." Posted: Retrieved September 17, 2013, from http://www.bls.gov/oes/current/oes_35620.htm#00-0000.

Caliper Corporation (2010). "What TransCAD users should know about new static traffic assignment methods." Posted: from http://www.caliper.com/press/what_transcad_users_should_know_about_traffic_assignment.pdf.

Cambridge Systematics (2007). Increase Cost of Parking in the Manhattan Central Business District (CBD). Technical Memorandum prepared for New York City Economic Development Corporation and the New York City Department of Transportation. https://www.dot.ny.gov/programs/repository/Tech%20Memo%20on_Parking.pdf.

City Council of Chicago (2001). "Article VII. Noise and Vibration Control." Posted: Retrieved January 11, 2012, from http://www.nonoise.org/lawlib/cities/chicago/.

City Council of Chicago (2010). Article XXI. Environmental Noise and Vibration Control. Chicago, Illinois, American Legal Publishing Corporation. **Municipal Code of Chicago**.

City Council of Houston (1997). "Noise and Sound Level Regulation." Code of Ordinances City of Houston Texas. Posted: Retrieved January 11, 2012, from http://www.nonoise.org/lawlib/cities/houston.htm.

City Council of Los Angeles (1982). "Los Angeles City Noise Ordinance Information." Ordinance No. 144.331. Posted: Retrieved January 11, 2012, from http://www.tract7260.org/CrimePages/CRM20050101_05.htm.

City of New York (2011). "PlanNYC: A Greener, Greater New York: Update 2011." Posted: Retrieved 5/1/11, from http://nytelecom.vo.llnwd.net/o15/agencies/planyc2030/pdf/planyc_2011_planyc_full_report.pdf.

Colruyt Group (2011). "The Colruyt Group develops a hybrid truck." Posted: Retrieved 20 July 2011, from http://www.colruytgroup.be/colruytgroup/static/energiebeleid-hybride_e.shtml.

Cortes, C. and V. Vapnik (1995). "Support-vector networks." Machine Learning **20**(3): 273 - 297. 10.1023/A:1022627411411

Daimler AG (2011). "Making deliveries with the Econic NGT and the "environmental angel"." Posted, 18 July 2011, Retrieved 20 July 2011, from http://media.daimler.com/dcmedia/0-921-656149-1-1409409-1-0-1-0-0-1-12639-0-0-1-0-0-0-0-0.html?TS=1311168453056.

Dhollandia (2012). "DH-SK(S).20 1500-2000kg." Posted: Retrieved 25 November 2013, from http://www.dhollandia.com/IS/en/8/Products#/cat/3.
Domencich, T. and D. McFadden (1975). Urban Travel Demand: A Behavioural Analysis. Amsterdam, Noth-Holland.
Du, J. and L. Aultman-Hall (2007). "Increasing the accuracy of trip rate information from passive multi-day GPS travel datasets: Automatic trip end identification issues. ." Transportation Research Part A **41**(3): 220-232.
Ehmke, J., S. Meisel and D. Mattfeld (2012). "Floating car based travel times for city logistics." Transportation Research Part C **21**
(1): 338-352.
Environmental Protection Agency (2011). "Noise Pollution." Posted, July 19, 2011, Retrieved January 17, 2012, from http://www.epa.gov/air/noise.html.
Environmental Protection Agency (EPA) (2012). Motor Vehicle Emission Simulator (MOVES): User guide for MOVES2010b. http://www.epa.gov/otaq/models/moves/documents/420b12001b.pdf.
European Parliament and Council of the EU (2001). Directive 2001/43/EC of the European Parliament and of the Council of 27June 2001, Amending Council Directive 92/23/EEC Relating to Tyres for Motor Vehicles and Their Trailers and to Their Fitting. 2001/43/EC. The European Parliament and The Council of the European Union, Official Journal of The European Communities. **L 211/25**.
European Parliament and Council of the EU (2002). Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002, Relating to the Assessment and Management of Environmental Noise. 2002/49/EC. The European Parliament and The Council of the European Union, Official Journal of The European Communities. **L 189/12**.
Federal Highway Administration (2012). "Federal Grant Opportunity Request for Applications (RFA): Off Hours Freight Delivery Pilot Project." Posted: Retrieved July 1, 2012, from http://apply07.grants.gov/apply/opportunities/instructions/oppDTFH61-12-RA-00016-cfda20.200-cidDTFH61-12-RA-00016-instructions.pdf.
Finlay, H. (2008). Noise abatement and night deliveries. Engineering, Dublin Institute of Technology. **Masters**.
Fischetti, T. (2011). Interview with Virtual Doorman representative regarding components and costs. Troy, NY.
Frappa (2013). "Neway Silent Green." Posted: Retrieved November 12, 2013, from http://www.frappa.com/en/green-solutions/neway-silent-green.
Frito-Lay (2012) Leading the Charge in California, Frito-Lay Rolls out Growing Fleet of All-Electric Delivery Trucks.
Gelman, A. (2004). Bayesian Data Analysis. Boca Raton, Fla., Chapman & Hall/CRC.
Gevaers, R. (2011). Selected Quotes from Roel Gevaers 8/22/2011 - PIEK Programme in Belgium. Antwerp.
Goevaers, R. (2010a). PIEK: Low Noise Equipment, Off Peak Hours Transport. Transportation Research Board.
Goevaers, R. (2010b). PIEK: Low noise solutions Night time deliveries. Sustainable Urban Goods logistics Achieved by Regional and local policies (SUGAR), Barcelona, Spain.
Goevaers, R. (2011). Low Noise Trucks. R. P. I. Department of Civil Engineering.
Greaves, S. and M. Figliozzi (2008). "Collecting commercial vehicle tour data with passive global positioning system technology: issues and potential applications " Transportation Research Record 158-166.
Guardian Security Entrance (2011). "Access Control Vestibules." Posted: Retrieved 20 July 2011, from http://www.guardiansecureentrance.com/accesscontrol.html.
Haldex (2010) Magazine, The Customer Magazine of Haldex Europe. Strength in Stillness **Autumn/Winter 2010**, 4-5
Hao, P., X. Ban., K. Bennett, Q. Ji and Z. Sun (2012). "Signal Timing Estimation Using Intersection Travel Times." IEEE Transactions on Intelligent Transportation Systems **In press**.
Holguín-Veras, J. (2006a). Potential for Off-Peak Freight Deliveries to Congested Urban Areas Rensselaer Polytechnic Institute. http://www.rpi.edu/~holguj2/OPD/OPD_FINAL_REPORT_12-18-06.pdf.
Holguín-Veras, J. (2006b). Potential for Off-Peak Freight Deliveries to Congested Urban Areas Albany, NY, Rensselaer Polytechnic Institute.

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. (2009). Urban Delivery Industry Response to Cordon Pricing, Time-Distance Pricing, and Carrier-Receiver Policies International Transportation Economics Conference. Minneapolis, MN.
Holguín-Veras, J. (2011). "Urban Delivery Industry Response to Cordon Pricing, Time-Distance Pricing, and Carrier-Receiver Policies in Competitive Markets." Transportation Research Part A **45**: 802-824.
Holguín-Veras, J. and M. A. Brom (2008). Trucking Costs in a Metropolitan Area: A Comparison of Alternative Estimation Approaches. Annual Meeting of the Transportation Research Board, Washington, DC.
Holguín-Veras, J. and M. Jaller (2012a). "Freight Trip Generation and Business Size." Transportation Research Record **(in review)**.
Holguín-Veras, J. and M. Jaller (2012b). "Parking Requirements in New York City." Transportation Research Record **(in review)**.
Holguín-Veras, J., M. Jaller, L. Destro, X. Ban, C. Lawson and H. Levinson (2011a). "Freight Generation, Freight Trip Generation, and the Perils of Using Constant Trip Rates." Transportation Research Record **2224**: 14. 10.314112224-09
Holguín-Veras, J., M. Jaller, I. Sánchez-Díaz, J. Wojtowicz, S. Campbell, H. Levinson, C. Lawson, E. Powers and L. Tavasszy (2012a). NCHRP Report 739 / NCFRP Report 19: Freight Trip Generation and Land Use. Transportation Research Board of the National Academies. National Cooperative Highway Research Program / National Cooperative Freight Research Program **NCHRP REPORT 739/NCFRP REPORT 19.** T. R. B. o. t. N. Academies. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_739.pdf.
Holguín-Veras, J., C. Lawson, M. Jaller, I. Sanchez, S. Campbell, H. Levinson and E. Levine-Powers (2012b). NCFRP 25: Freight Trip Generation and Land Use: Final Report.
Holguín-Veras, J., G. List, A. Meyburg, K. Ozbay, R. Paaswell, H. Teng and S. Yahalom (2001). An Assessment of Methodological Alternatives for a Regional Freight Model in the NYMTC Region. New York City Metropolitan Transportation Council (NYMTC). N. Y. C. M. T. C. (NYMTC). http://www.nymtc.org/data_services/freight_model/files/Final_Report_053001.PDF.
Holguín-Veras, J., K. Özbay, A. L. C. d. Cerreño and S. Gandhi (2005a). Evaluation Study of Port Authority of New York and New Jersey's Time of Day Pricing Initiative: Final Report. New Jersey Dept. of Transportation. http://www.state.nj.us/transportation/refdata/research/reports/FHWA-NJ-2005-005.pdf, http://www.rpi.edu/~holguj2/PA/index.html.
Holguín-Veras, J., K. Ozbay, A. Kornhauser, A. Shorris and S. Ukkusuri (2010a). Integrative Freight Demand Management in The New York City Metropolitan Area. United States Department of Transportation.
Holguín-Veras, J., K. Ozbay, A. L. Kornhauser, M. Brom, S. Iyer, W. Yushimito, S. Ukkusuri, B. Allen and M. Silas (2011b). "Overall Impacts of Off-Hour Delivery Programs in the New York City Metropolitan Area." Transportation Research Record **2238**: 68-76.
Holguín-Veras, J., K. Ozbay, A. L. Kornhauser, A. Shorris and S. Ukkusuri (2010b). Integrative Freight Demand Management in the New York City Metropolitan Area. http://transp.rpi.edu/~usdotp/OHD_FINAL_REPORT.pdf.
Holguín-Veras, J., N. Pérez, B. Cruz and J. Polimeni (2006a). "Effectiveness of Financial Incentives to Off Peak Deliveries to Manhattan Restaurants." Transportation Research Record **1966**: 51-59.
Holguín-Veras, J., J. Polimeni, B. Cruz, N. Xu, G. List, J. Nordstrom and J. Haddock (2005b). "Off-Peak Freight Deliveries: Challenges and Stakeholders' Perceptions." Transportation Research Record **1906**: 42-48.
Holguín-Veras, J., M. Silas and J. Polimeni (2008a). An Investigation into the Attitudinal Factors Determining Participation in Cooperative Multi-Carrier Delivery Initiatives. Innovations in City Logistics IV. E. Taniguchi and R. Thomson, Nova Science Publishers**:** 55-68.
Holguín-Veras, J., M. A. Silas, J. Polimeni and B. Cruz (2007). "An Investigation on the Effectiveness of Joint Receiver-Carrier Policies to Increase Truck Traffic in the Off-Peak Hours: Part I: The Behaviors of Receivers." Networks and Spatial Economics **7**(3): 277-295. 10.1007/s11067-006-9002-7

Holguín-Veras, J., M. A. Silas, J. Polimeni and B. Cruz (2008b). "An Investigation on the Effectiveness of Joint Receiver-Carrier Policies to Increase Truck Traffic in the Off-Peak Hours: Part II: The Behaviors of Carriers." Networks and Spatial Economics **8**(4): 327-354. 10.1007/s11067-006-9011-6
Holguín-Veras, J. and E. Thorson (2003). "Modeling Commercial Vehicle Empty Trips with a First Order Trip Chain Model." Transportation Research Part B **37**(2): 129-148.
Holguín-Veras, J., Q. Wang, N. Xu, K. Ozbay, M. Cetin and J. Polimeni (2006b). "Impacts of Time of Day Pricing on the Behavior of Freight Carriers in a Congested Urban Area: Implications to Road Pricing." Transportation Research Part A: Policy and Practice **40**(9): 744-766.
Holguín Veras, J., R. Marquis, S. Campbell, J. Wojtowicz, X. Wang, M. Jaller, S. Hodge, S. Rothbard and R. Goevaers (2013). "Fostering the Use of Unassisted Off-Hour Deliveries: Operational and Low-Noise Truck Technologies." Transportation Research Record **(in print)**.
Holguín Veras, J., C. Wang, I. Sánchez-Díaz, S. Campbell, S. D. Hodge, M. Jaller and J. Wojtowicz (2014). "Fostering Unassisted Off-Hour Deliveries: The Role of Incentives." Tranportation Research Part A: Policy and Practice **(in print)**.
Jaller, M., J. Holguin-Veras and S. D. Hodge (2013a). "Parking in The City: Challenges For Freight Traffic." Transportation Research Record **(in print)**.
Jaller, M., X. Wang and J. Holguín-Veras (2013b). Large Traffic Generators: Opportunities for City Logistics Initiatives. 92nd Annual Meeting of the Transporation Research Board, Washington, D.C.
Journal of Commerce (2009). New York Delivers at Night. Journal of Commerce. **10(35):** 4A.
Journal of Commerce (2010). "New York to Expand Off-Peak Truck Program." Journal of Commerce. Posted, July 2, 2010, Retrieved July 3, 2010, from http://www.joc.com/trucking/new-york-expand-peak-truck-program.
Katers, N. (2012). "Renault Trucks Delivering All-Electric Refrigerated Trucks to Nestle Switzerland." Greener Ideal. Posted, 20 July 2012, Retrieved 8 November, 2012, from http://www.greenerideal.com/vehicles/0720-renault-trucks-all-electric-refrigerated/.
Lawson, C., J. Holguín-Veras, I. Sánches, M. Jaller, S. Campbell and E. Powers (2012). "Estimation of Freight Trip Generation Based on Land Use." Transporation Research Record **(in print)**.
Maher, M. and I. Summersgill (1996). "A comprehensive methodology for the fitting of predictive accident models." Accident Analysis and Prevention **28**(3): 281-296.
McCormack, E. and M. Hallenbeck (2006). "ITS devices used to collect truck data for performance benchmarks." Transportation Research Record **No.1957**: 43-50.
McCormack, E., X. Ma, C. Klocow, A. Curreri and D. Wright (2010). Developing a GPS-based truck freight performance measure platform. Washington State Department of Transportation (TRAC)
Transportation Northwest (TransNow). **WA-RD 748.1**
TNW2010-02. http://www.wsdot.wa.gov/research/reports/fullreports/748.1.pdf.
Miaou, S. and H. Lum (1993). "Modeling Vehicle Accidents and Hihway Geometric Design Relationships." Accident Analysis and Prevention **25**(6): 689-709. DOI:10.1016/0001-4575(93)90034-T
MotorTrader.com (2008). "Noise is no longer an issue." Posted: Retrieved 17 October, 2011, from http://www.motortrader.com/motor-trader-tv/noise-is-no-longer-an-issue/.
Nam, E. and R. Giannelli (2005). Fuel consumption modeling of conventional and
advanced technology vehicles in the Physical
Emission Rate Estimator (PERE). Environmental Protection Agency. **EPA420-P-05-001.**
http://www.epa.gov/otaq/models/ngm/420p05001.pdf.
Nemoto, T. (2004). An Experimental Cooperative Parcel Pick-up System Using the Internet in Central Business District of Tokyo. Logistic Systems for Sustainable Systems. E. Taniguchi and R. Thompson, Elsevier**:** 309-320.
New York City Department of City Planning (2011). MapPLUTO.
New York City Department of Transportation (2012). "Park Smart." Posted: Retrieved July 20, 2012, from http://www.nyc.gov/html/dot/html/motorist/parksmart.shtml.
New York State Thruway Authority (1998). Commercial Vehicle Survey Final Report. New York State Thruway Authority.
Noise Abatement Society "Silent Approach Campaign." Posted: Retrieved 20 July 2011, from http://noiseabatementsociety.com/campaigns/silent-approach/.

Noisetek (2011). "Products." Posted: Retrieved 21 September 2011, from http://noisetek.fi/en/tuotteeten.html.
NYC Department of City Planning (2011). Parking Best Practices: A Review of Zoning Regulations and Policies in Select US and International Cities. Transportation Division.
NYC Department of Environmental Protection (2007). New York City Noise Control Code - Title 24 Chapter 2. Subchapter 3**:** 13.
Ogden, K. W. (1992). Urban Goods Movement: A Guide to Policy and Planning. Brookfield, VT, Ashgate Publishing Company.
Ozbay, K., B. Bartin, S. Mudigonda and S. Iyer (2013). ASSIST-ME: Postprocessing Tool for Transportation Planning Model Output. 92nd Annual Meeting of Transportation Research Board. Washington, DC.
Ozbay, K., E. Morgul, F., S. Ukkusuri, S. Iyer and W. Yushimoto (2011). Mesoscopic Simulation Evaluation of Dynamic Congestion Pricing Strategies for New York City Crossings. Transportation Research Board, 90th Annual Meeting, Washington D.C.
Ozbay, K., O. Yanmaz-Tuzel and J. Holguín-Veras (2006). "Evaluation of Impacts of Time-of-Day Pricing Initiative on Car and Truck Traffic: Port Authority of New York and New Jersey." Transportation Research Record: Journal of the Transportation Research Board **1960**: 48-56.
Pigou, A. C. (1920). The Economics of Welfare. London, MacMillian and Co., Ltd.
Quak, H. J. (2008). Sustainability of urban freight transport retail distribution and local regulations in cities, Erasmus Research Insitute of Management**:** 1-242.
Raothanachonkun, P., K. Sano, W. Wisetjindawat and S. Matsumoto (2007). "Truck Trip Origin-Destination Estimation Using Commodity-Based Model Combined with an Empty Trip Model." Transportation Research Record **(in press)**.
Rasmusen, E. (2001). Games and Information: An Introduction to Game Theory. Malden, Massachusetts, Blackwell Publishers.
Sandberg, U. (2008). Consumer Label for Tyres in Europe. Swedish National Road and Transport Research Institute (VTI).
European Federation for Transport and Environment (T&E).
Shoemaker, J. (2005). PIEK-Programme (The Netherlands). Noise. Netherlands, Best Urban Freight Solution (BESTUFS). Osmose.
Short, J., T. Trego and R. White (2010). Developing a Methodology for Deriving Cost Impacts to the Trucking Industry that Generate from Freight Bottlenecks. Transportation Research Board Annual Meeting. Washinton, DC.
Shoup, D. (2005). The High Cost of Free Parking, American Planning Association, Chicago.
Silas, M. A. and J. Holguín-Veras (2009). "Behavioral Microsimulation Formulation for Analysis and Design of Off-Hour Delivery Policies in Urban Areas." Transportation Research Record: Journal of the Transportation Research Board **2097**: 43-50. 10.3141/2097-06
Silas, M. A., J. Holguín-Veras and S. Jara-Díaz (2012). "Optimal distribution of financial incentives to foster off-hour deliveries in urban areas." Transportation Research Part A: Policy and Practice **46**(8): 1205-1215. 10.1016/j.tra.2012.05.015
Spiegelhalter, D., J., N. Best, G., B. Carlin, R. and A. van der Linde (2002). "Bayesian measures of model complexity and fit." Journal of the Royal Statistical Society Series B-Statistical Methodology: Vol.64,pp.583-616.
Sun, Z. and X. Ban (2013). "Vehicle trajectory reconstruction for signalized intersections using mobile traffic sensors." Transportation Research Part C **36**: 268-283.
Taylor, J. (1997). An introduction to error analysis: the statistical study of uncertainties in physical measurements., Sausalito, California: University Science Books.
Texas Transportation Institute (2012). "2012 Urban mobility report." Posted: from http://mobility.tamu.edu/ums/report/.
The City of New York (2005). Local Laws Of The City of New York For The Year 2005. The City of New York. **No. 113**.
The State of New York (2010). Article 10 - § 386 Motor Vehicle Sound Level Limits. Vehicle and Traffic.
TIME (2013). 10 Ideas That Make A Difference: Deliver a Fix for Traffic Jams. TIME. **181:** 40.

Transport for London (2013a). "Delivery Servicing Plans." Posted: Retrieved July 04, 2013, 2013, from http://www.tfl.gov.uk/microsites/freight/delivery_servicing_plans.aspx.
Transport for London (2013b). "A Pilot Delivery Servicing Plan for TfL's Palestra Offices in Southwark: A Case Study." Posted: Retrieved July 12, 2013, 2013, from http://www.tfl.gov.uk/microsites/freight/documents/20090921-DSP-Palestra-Case-Study.pdf.
U.S. Census Bureau (2011). "Zip Code Business Patterns." Posted: Retrieved July 25, 2011, from http://www.census.gov/epcd/www/zbp_base.html.
Vallamsundar, S. and J. Lin (2011). "MOVES Versus MOBILE: Comparison of Greenhouse Gas and Criterion Pollutant Emissions." Transportation Research Record **2233**: 27-35.
Vapnik, V. N. (1995). The nature of statistical learning theory. New York, NY, USA, Springer-Verlag New York, Inc.
Venugopal, M. (2010). Emission Inventories Development Using MOVES Model: A Dallas-Fort Worth, Texas Area Case Study. 19th International Emission Inventory Conference, San Antonio, Texas.
Vilain, P. and P. Wolfrom (2000). "Value Pricing and Freight Traffic: Issues and Industry Constraints in Shifting from Peak to Off-Peak Movements." Transportation Research Record **1707**: 64-72.
VTPI (2010). "Victoria Transport Policy Institute: Transportation Cost and Benefit Analysis: Techniques, Estimates and Implications." 2nd Edition. Posted: from http://www.vtpi.org/tca.
Wall Street Journal (2010). "Congestion Fight Runs Into Night." Posted: Retrieved July 2, 2010, from http://online.wsj.com/article/SB10001424052748704334604575339292960610492.html.
Walters, A. A. (1961). "The Theory and Measurement of Private and Social Cost of Highway Congestion." Econometrica **29**(4): 676-699.
Washington, S. P., M. G. Karlaftis and F. L. Mannering (2009). Statistical and econometric methods for transportation data analysis, Chapman & Hall/CRC.
Wieman, P. (2010). "PEAK 'Light" certificate for Iveco Stralis CNG." Posted: Retrieved 26 October 2011, from http://www.ttm.nl/nieuws/id27738-piek-light-certificaat-voor-iveco-stralis-cng.html.
Wood, R. T. (1970). Measuring Freight in the Tri-State Region. The Urban Movement of Goods. Paris, OECD**:** 61-82.
World Health Organization (2006). Night Noise Guidelines for Europe. WHO Regional Office for Europe. http://www.euro.who.int/__data/assets/pdf_file/0017/43316/E92845.pdf.
Yanmaz-Tuzel, O., K. Ozbay and J. Holguin-Veras (2011). "Value of Travel Time Estimation Using Hierarchical Bayesian Mixed Logit Approach: Toll Facilities in New York and New Jersey." Transportation Research Record **2187**: 85-96. http://dx.doi.org/10.3141/2187-12
Yuan, F. and R. Cheu (2003). "Incident detection using support vector machines." Transportation Research Part C **11**(3-4): 309-328.
Zhao, W. and A. Goodchild (2011). "Truck travel time reliability and prediction in a port drayage network." Maritime Economics & Logistics **13**(4): 387-418.

APPENDICES

LIST OF APPENDICES

APPENDIX 1

Low Noise Technologies for Off-hour Deliveries

Truck Technologies

Hybrid Trucks

The first 44-ton heavy duty truck that uses serial hybrid technology was created by The Colruyt Group. This truck was fully developed by their own engineers in collaboration with a few partners. The project which represents an investment of 650,000 Euros took eight years to efficiently employ the hybrid technology in a truck of that size. The prototype is complete and is set to begin off-peak deliveries to Colruyt stores in residential areas with heavy traffic in September. The engine is composed of a combination of serial diesel and electric motor (Colruyt Group, 2011).

The main difference between this parallel hybrid truck and most other vehicles with parallel hybrid systems is that the electric motor is able to operate independently of the diesel engine while the other parallel hybrid vehicle the engines are interdependent. The prototype is able to operate on a battery powered electric motor for around 10 kilometers (6.2 miles). The hybrid system operates in two ways:

1. The wheels are operated by an electric motor which is powered by a battery or directly by the diesel engine. The diesel engine is able to run at a constant speed and charge the battery since it not used immediately. This technique allows for silent deliveries (Colruyt Group, 2011).

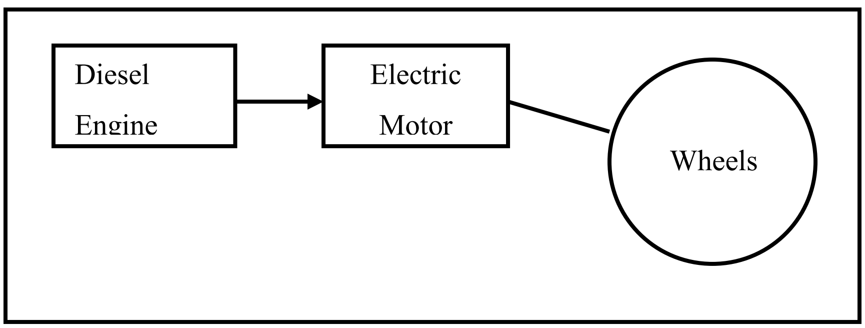


Figure A.141: Serial Hybrid Technology (Colruyt Group, 2010)

2. The electric motor and the diesel engine work in parallel to operate the truck.

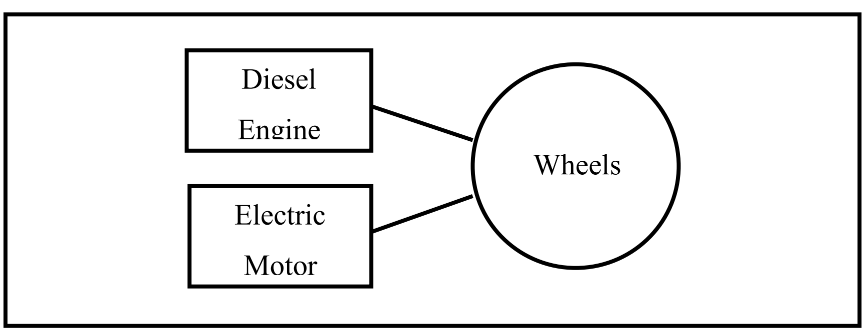


Figure A.142: The Parallel Hybrid System (Colruyt Group, 2010)

The truck is ideal for silent deliveries because regardless of what engine it is operating on it is remains under 65 dB (A). Another benefit is fuel cost savings, which results in decreased transport costs and CO_2 emissions. If the test drive goes well The Colruyt Group intends on using it to deliver to other stores owned by the group and to make the truck more environmentally friendly by reducing emissions and consumption by 20% (Colruyt Group, 2011).

Figure A.143: Hybrid Truck Developed by The Colruyt Group (Colruyt Group, 2011)

Natural Gas Trucks (NGTs)

The Mercedes-Benz Econic 1828 NGT is a 50 ton truck that runs on liquefied natural gas (LNG). The Econic is powered by an in-line six-cylinder 900-series engine in the form of a mono-fuel natural gas drive. The M906 LAG Engine displaces 6.9 liters of gas to produce 205 kilowatts (279 horsepower). Due to the use of the natural gas drive, the emissions produced do not contain any fine dust or particles. Another benefit of the LNG is it allows for low noise emission. This feature along with the use of an Allison transmission and optimized sound proofing, the truck is able to achieve a PIEK 'Light' compliant noise emission of 72 dB (A) allowing it to operate at any time of day and abide by the noise level requirements. This noise compliance capability has prompted the Simon Loos Logistic Company in the Netherlands to order 30 units. The truck's environmentally friendly characteristics has earned it a "Blue Angel" seal of approval (Daimler AG, 2011). The Blue Angel approval is issued by the German Government to products that are environmentally friendly (Ecolabel Index, 2011).

Using LNG in the Econic provides a long range comparative to that of diesel vehicles. Natural gas reserves are considerably greater than those of oil, and many countries are only able to transport natural gas in the form of liquefied natural gas. The Econic is also able to operate using renewable biogas without any adjustments to the vehicle. Biogas is a CO_2-neutral energy source and can be produced from fermented food waste. Simon Loos Logistic is able to compensate for the extra cost of the Econic NGT with increase in daily operations hours (Daimler AG, 2011).

The concept of the Econic was birthed in 1998, but back then was ahead of its time. As of today the Econic is a complete modular system with 2, 3 and 4 axle options. This model truck is widely being used in large cities such as: Berlin, Hamburg and Cologne in Germany: Paris, France; Stockholm, Sweden; Athens, Greece; and Valencia, Spain. Also due to its design it is in high demand in Singapore and Mexico (Daimler AG, 2011).

Figure A.144: Mercedes-Benz Econic 1828 NGT (Goevaers, 2011)

The Iveco an Italian truck manufacturer in collaboration with the Dutch PIEK program and is the first truck to meet the PIEK 'Light' standard, which focuses on the loading and unloading sounds. The Iveco Stralis has a compressed natural gas (CNG) engine and operates at a maximum of 72 dB(A) (Wieman, 2010). The current model of the truck has a capacity of 40 tons and has 330 horsepower but the engine has the capability of operating in larger models. The results of the noise test for the truck showed when accelerating the sound emitted measures 71 dB(A), brakes - 72 dB(A), idling - 68 dB(A) and reverse - 66 dB(A). The highest sound level of all the measurements is the one that is used to determine if the truck receives certification. The Iveco Stralis can be seen in Figure A.145.

Figure A.145: Iveco Stralis - Compressed Natural Gas (CNG) Engine (Goevaers, 2011)

The truck entered the market this year (2011) and at this moment is only sold in the Netherlands, but one hundred (100) of these trucks have already been sold because of its noise reducing advantage. The purchase of this Stralis, although more expensive than a standard truck, will result in savings. The business case for the Iveco Stralis in Table A.107, shows that using this truck instead of a standard diesel engine truck would offer an annual savings of 1563.43 Euros (Goevaers, 2011).

Table A.107: Business Case for the Iveco Stralis (Goevaers, 2011)

	Diesel Engine Truck	Iveco Stralis	Difference
Price	75000	120000	45000
Depreciation	7 years	7 years	
RST value	7500	7500	
Kilometer(km) per year	120000	120000	
Annual Depreciation	9642.86	16071.43	6428.57
Fuel cost			
Fuel Consumption	32	30	
Price	1.08	0.93	
Annual fuel cost	41472	33480	-7992
Maintenance Cost	0.055	0.055	0
Annual savings			**-1563.43**

Trucks with Low Noise Bodies

Although the engine, especially when idling, is commonly cited as the source of high noise levels, the body of the truck can also contribute to these sounds. This section focuses on technologies that lower the noise produced by truck bodies, in particular those which are refrigerated.

Low Noise Refrigeration System - Carrier Vector 1850 XLN

The Carrier Vector 1850 XLN (Xtra Low Noise) trailer refrigeration system is a low noise version of the original Carrier Vector created by Carrier Transicold, which made its introduction in 1999. This version has received the John Connell Award for technology in 2007 from the Noise Abatement Society (NAS) in the United Kingdom (UK). The XLN version of the vector embodies the vision of eco-responsibility that Carrier Transicold maintains, which entails respecting the Cold Chain as well as the environment and low cost of ownership. The Carrier Vector 1850 XLN was the result of a joint venture in the UK and the Netherlands, to develop technology to meet the Dutch noise regulations under the PIEK program. The model surpasses the minimum requirement of 60 dB (A) by operating at 59.5 dB (A). This impressive reduced level was not previously achieved by any transport refrigeration system manufacturers (MotorTrader.com, 2008).

The way the Carrier Vector 1850 XLN works is that the components of the traditional Vector 1850 refrigeration system was divided up from within the host unit. The engine is extracted from the original host unit and placed in an insulated undermount positioned under the trailer chassis. The undermount is made from special material and it is completely insulated, this is the vital part to the noise reduction being that the engine is the main cause of the noise created by the system. The other components such as the radiator of the system are left in the host unit for technical reasons such as heat output. The testing procedure for the system includes eight measuring points (three on each side of the trailer, one in front and one 1.5 meters from the top of the refrigeration unit); and the final result is the highest recorded level in decibels from the eight measuring points (MotorTrader.com, 2008).

The setup of the Carrier Vector XLN can be seen in Figure A.146 in the following the section. The host unit is on the front of the trailer and the engine of the refrigeration system is placed in a gray box underneath the trailer.

Low Noise Refrigerated Trailer

Gray & Adams Ltd which specializes in the manufacturing of trailers has built the first PIEK certified refrigerated trailer unit in the United Kingdom (UK) for Sainsbury one of the UK's oldest retailers. A Carrier Vector 1850 XLN (Extra Low Noise) unit is used to refrigerate the trailer. The unit is mounted in a encasing beneath the trailer and has a DH-SK(S) Ultra Low Noise retractable tail lift from manufacturer Dhollandia. Other low noise features of the trailer include a low noise floor from Gray & Adams which decrease the noise levels produced by the use of roll cages during loading and unloading. The sidewall kickstrips also manufactured by Gray & Adams was also adjusted to meet noise-reducing criteria(Gray & Adams, 2008).

Figure A.146: PIEK Certified Refrigerated Trailer Made for Sainsbury in the UK (Gray & Adams, 2008)

The Carrier Vector 1850 XLN was used by Gray & Adams Ltd, which specializes in the manufacturing of trailers, to build the first PIEK certified refrigerated trailer unit in the United Kingdom (UK) for Sainsbury one of the UK's oldest retailers. Other low noise components of the trailer are a DH-SK(S) Ultra Low Noise retractable tail lift from manufacturer Dhollandia; Gray & Adams low noise floors which decrease the noise levels produced from the use of roll cages during loading and unloading. The sidewall kickstrips, also their own make, was also adjusted to meet noise-reducing criteria(Gray & Adams, 2008).

The FT Silent Green is another model of refrigerated trailer produced by French refrigerated vehicle specialist Frappa, was recently awarded PIEK certification from Cemafroid, making Frappa the first French manufacturer to receive this award. Therefore, the model meets the sound pressure requirements of 60 dB(A). The features of the truck includes a 1000 liter cryogenic nitrogen tank under the vehicle, instead of in the front, which flows the nitrogen into the loading space, which maintains temperature. The truck also features a electrically operated rolling door at the rear. The interior of the truck was also developed to minimize noise, while additional noise reductions are gained from the noise absorbing aluminum floor that is also skid proof. An optional feature that can be added if requested is a PIEK certified tailgate (Haldex, 2010).

This three-axle semi-trailer is capable of doing the same job as ten 3.5 ton trucks. Investments in this model result in significant cost savings for drivers and vehicles. Savings in fuel costs for the refrigeration unit is also a benefit when compared to conventional refrigerated vehicles; as nitrogen-fueled operations are cheaper than those that are diesel operated (Haldex, 2010).

Figure A.147: Ft Silent Green (Frappa, 2011)

This three-axle semi-trailer is capable of doing the same job as ten 3.5 ton trucks. Investments in this model result in significant cost savings for drivers and vehicles. Savings in fuel costs for the refrigeration unit is also a benefit when compared to conventional refrigerated vehicles; as nitrogen-fueled operations are cheaper than those that are diesel operated (Haldex, 2010).

Truck Accessories

After addressing the physical structure of the truck and its engine, there are additional considerations of truck accessories that can reduce noise levels. This section considers tires and lifts already on the market which has been shown to meet required noise outputs.

Tires

As a part of the European Council Directive 2001/43/EC, van and truck tires must obtain an “s-marking” in line with the rolling sound regulations starting October 1, 2009. An example of the “s-marking” on a tire is shown in Figure A.148 (European Parliament and Council of the EU, 2001).

Figure A.148: Tire Showing "S-marking" (BANDVULC Group, 2009)

As stated in the Directive 2001/43/EC, the maximum allowable noise limits are given for the various commercial vehicle tire options; this can be seen in Table A.108.

There are organizations which grant labeling to products given that they meet certain environmental standards. Some of these organizations include noise emissions from tires as a product that can receive labeling. One such eco-labeling organization is the Nordic Swan, where tires that meet the noise limits stated in Table A.108 are awarded a Nordic Swan environmental label. This labeling system is organized by the Nordic Council and offers eco-labeling for a number of products to its five member countries (Sweden, Denmark, Norway, Finland and Iceland). The noise emission requirements to receive a Nordic Swan label, as shown in Table A.108, are more strict than those issued by the EU Directive (Sandberg, 2008).

Table A.108: Comparison of the Noise Limits for Commercial Vehicle Tires for Nordic Swan and the EU Directive (European Parliament and Council of the EU, 2001; Sandberg, 2008)

Vehicle Type	Class of Tire	Tire Section Width [mm]	Noise Limit [dB (A)]	
			Nordic Swan	EU Directive
Van	C2b	≤ 165	72	75/77/78
	C2c	> 165 ≤ 18	73	75/77/78
	C2d	>185 ≤ 215	74	75/77/78
	C2e	>215	75	75/77/78
Truck	C3 Normal	Normal	76	76
	C3 Snow	Snow	78	78
	C3 Special	Special	78	79

Tires that receive the labeling will be granted a unique six-digit license number that is required to be displayed along with the label, which is shown in Figure A.149 (Nordic Swan, 2009).

Figure A.149: Design of the Nordic Ecolabel (Nordic Swan, 2009)

Another such label is the German Blue Angel organization, which offers a system that labels tires on its environmental properties. The system is called "Low-Noise and Fuel-Saving Automobile Tires - RAL-UZ 89". In order to receive this label the tire has to meet the following requirements:

- Weight
- Noise emission
- Rolling resistance coefficient
- Mileage (service life in km, as specified by the National Highway Traffic Safety Administration(NHTSA) Uniform tire Quality grade (UTQG) standards)
- Braking distance
- Aquaplaning Speed

Noise level requirements are more stringent than those of Nordic Swan at 72 dB(A) for all categories (Sandberg, 2008). Tires that receive the Blue Angel Label will carry the symbol shown in Figure A.150.

Figure A.150: German Blue Angel Label (Ecolabel Index, 2011)

The Belgian company Dhollandia that specializes in vehicle lifts, especially those for trucks was awarded the first Noise Abatement Society (NAS)/PIEK certificate for silent deliveries in the category of lifts at a Commercial Vehicle Show in April 2008. The lift is able to operate below 60 dB(A) threshold (Dhollandia, 2011). The main features of the DH-SKS-Lift which enables it to function with little noise include:

- A silent power pack - this has a silent motor-pump combination and a casing with sound-dampening panels.
- Sound absorbing platform coating – a long lasting heavy-duty coating that has high anti-slip characteristics.

- Automation - allows the lift to perform loading functions that are normally done manually, decreasing the human factor of noise creation.
- Intelligent Interlocks - prevents the misuse and damage of automatic functions; this characteristics allows for safe operations and extends the life of the lift (Dhollandia, 2012).

Figure A.151: DH-SKS-Lift (Dhollandia, 2012)

Cargo Handling Equipment

Through the European studies, it was also shown that other factors can contribute to high sound levels, which include the cargo handling equipment. The tires on standard forklifts or pallet trucks create loud noises when contacting metal truck beds, so new alternatives are discussed here.

Low Noise Forklifts

The 8-Series Internal combustion cushion tire lift truck has low noise and vibration levels. The lift is equipped with the industry's first 4-way suspension seat as well as easy to use controls which increase user comfort. Information on the operating noise level forklift was not stated but due to the design of the cushioned tires, this model of forklift offers noise reduction capabilities (Toyota Industrial Equipment, 2011a).

Figure A.152: Toyota 8-Series Internal Combustion Cushion Tire Lift Trucks (Toyota Industrial Equipment, 2011a)

Hand Pallet Trucks

The BT Lifter Silent LHM230SI is an updated quiet model of a previous model of a hand pallet truck produced by Toyota. It has been certified by the PIEK program in the Netherlands because it operates below 60 dB (A). Its features are industry standard and it is able to carry up to 2300kg (2.54 tons). The features that enable the BT Lifter Silent to operate a low noise levels are the rubber steer wheels and Powerthane® bogie wheels which enables the pallet truck to drive smoothly and quietly. The frame has special shock-absorbing material which further reduces noise cause by vibrations. Further noise reductions are realized from the adjustable rubber studs at the push rod ends minimizes rattling when the forks are completely lowered (Toyota Industrial Equipment, 2011b).

Figure A.153: Hand pallet truck - BT Lifter Silent LHM230SI (Toyota Industrial Equipment, 2011b)

Roll Cages

The CC Euro Rollcontainer is a two-sided roll cage that possesses low noise wheels which enables it to be used in silent deliveries because its noise level is a maximum of 60 dB(A). Its design is focused on noise and weight reduction and meets the European legal requirements as well as the PIEK requirements. The two-sided roll cage allows for efficient picking, packing and transportation of goods to receivers. The lift up hinged base and swing-back sides at the back. The CC Euro Rollcontainer complies with PIEK regulations as well as European Union (EU) legislation(Container Centralen Ltd., 2010).

Specifications of the CC Euro Rollcontianer	
Length	811 mm
Width (external / internal)	640 / 620 mm
Height (external)	1900 mm
Handling height / width	173 / 565 mm (on long side)
Weight	33 kg
Materials	Deck: recycled black plastic with a steel frame Sides: steel Wheels: elastic-vulcanised rubber
Dynamic load capacity	400 kg UDL*
RFID** label	UHF Class 1 Gen 2
Temperature range	–30°C to +50°C
Certifications	NL PIEK certification pending

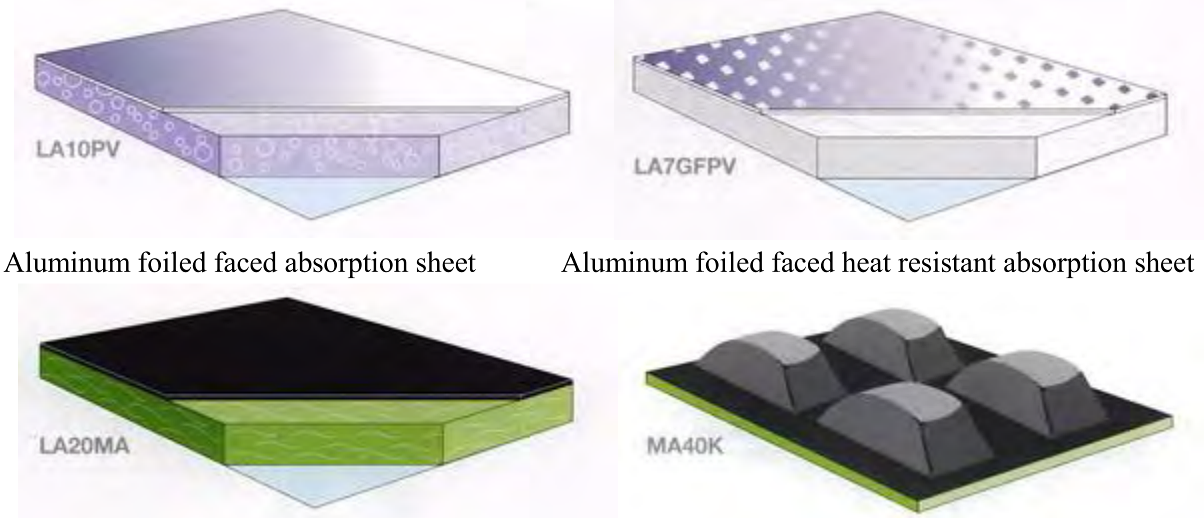
Figure A.154: CC Euro Rollcontainer and Specifications Table (Container Centralen Ltd., 2010)

Noise Absorbing Materials

Noise absorbing materials can be placed inside the truck as well as the receivers' location to reduce noise level made by deliveries. Some of these options are explained below. The information was taken from a noise control company in Finland but there was no indication if they are PIEK approved.

Airborne Sound Absorption Sheets

Absorption materials such as polyether or polyester foam, recycled foam, white glass wool, or recycled textile fiber are used to make sound absorption sheets that can be strategically placed to diminish noise levels. Applications of these sound absorption sheets related to off-peak deliveries are engine compartments as well as other parts of the vehicle and room acoustics. The type of material and the thickness is determined by the noise source and the noise level that needs to be achieved (Noisetek, 2011).



Aluminum foiled faced absorption sheet — Aluminum foiled faced heat resistant absorption sheet

Felt faced absorption sheet — Motor Absorption sheet

Figure A.155: Types of Absorption Sheets (Noisetek, 2011)

Barrier Mats

Barrier mats are used in vehicles, lifts, walls, enclosures, doors, ventilations systems and all vibrating sheet metal structures. Materials that are used to make barrier mats are bitumen board, EPDM, vinyl. The thicker mats are constructed from ethylene propylene diene monomer (EPDM) rubber or bitumen and the thinner mats from bitumen. The barrier mats are used to curb the generation of structure-borne noises (vibration) in solid materials and also to enhance airborne sound insulation properties. In the case of a thick structure a two-layer mat is suggested to reduce the airborne noises resulting from vibrations; the two layers are comprised from a heavy layer of barrier mat adhered to a foam layer (Noisetek, 2011).

Vibration damping mat

Barrier mat - made from bitumen

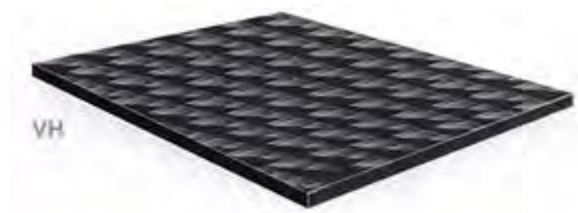
Barrier mat - made from EPDM

Barrier mat - vinyl with thin black upholstery trimming

Figure A.156: Types of Barrier Mats (Noisetek, 2011)

Floor Mats

These multilayer floor mats are suitable for applications wherever sound and heat insulation is required. Floor mats are available in rubber and vinyl in various surface textures such as a checkered, diamond or coin patterns (Noisetek, 2011).



Mat - oil resistant diamond pattern vinyl mat

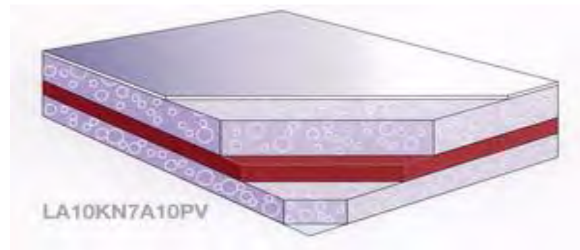
Floor mat - open cell polyether foam with barrier mat and rubber mat.

Figure A.157: Types of Floor Mats (Noisetek, 2011)

Composites

These composites are from varying layers using all the foam options, barrier mats, floor mats as required for the specific application. They are suitable for applications where both low and high frequency noise occurs. Examples of composites can be found in (Noisetek, 2011).

Aluminum faced multi-layer sheet



Faced multi-layer sheet

Figure A.158: Types of Composites (Noisetek, 2011)

APPENDIX 2

APPENDIX 2A

Off Hour Delivery Program

IAG Kickoff Meeting

November 30, 2011
NYCDOT 55 Water Street

Welcome and Introductions

Acknowledgements

United States Department of Transportation

ALK Technologies

Rutgers, The State University of New Jersey

Agenda

- Background of OHD Pilot Phase
- Launch Phase Concept and Discussion
- Branding Brainstorm
- Timeline and Next Steps

OHD Pilot

PARTICIPANTS

- Baldor Specialty Foods
- Sunburger / BRGR
- Chris's Cookies
- Foot Locker and Lady Foot Locker
- Gotham Bistro / Four Points by Sheraton
- Gourmet Guru
- Just Salad
- Kolache Mama
- McMahon's Farm
- Midtown Restaurant
- Mossé Beverage Industries
- New Deal Logistics
- Overlook
- Peet's Coffee
- Pipa Restaurant
- SYSCO
- Whole Foods Market
- 63 Bites

Goals

- Decreasing truck traffic during peak hours
- Reducing traffic congestion and improving environmental conditions
- Increasing cost savings
- Enhancing reliability of deliveries

Launch Phase

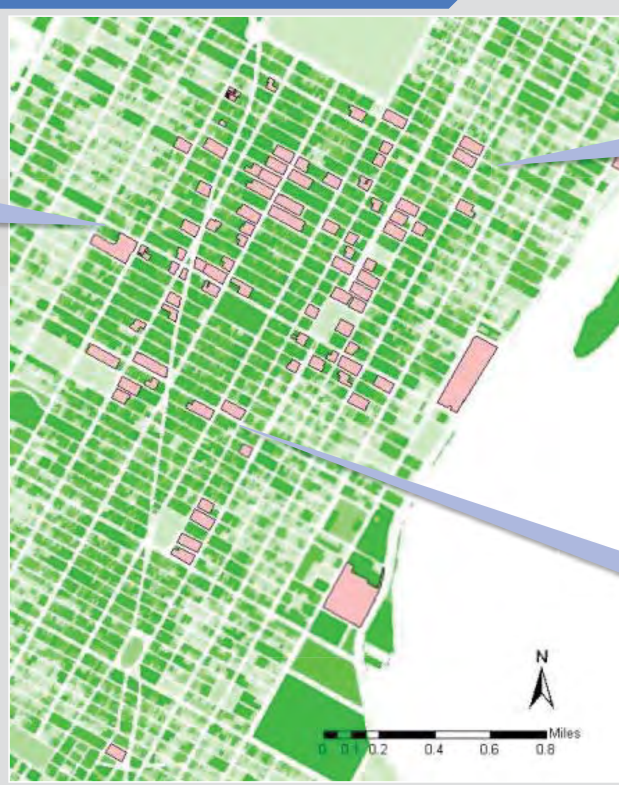
Goals

- Midtown/Lower Manhattan focus
- Increase density of participating locations
- Pursue large traffic generators
- Measure the public benefits
- Demonstrate that OHD can be replicated in other cities

Large Traffic Generators

59th Street

42nd Street



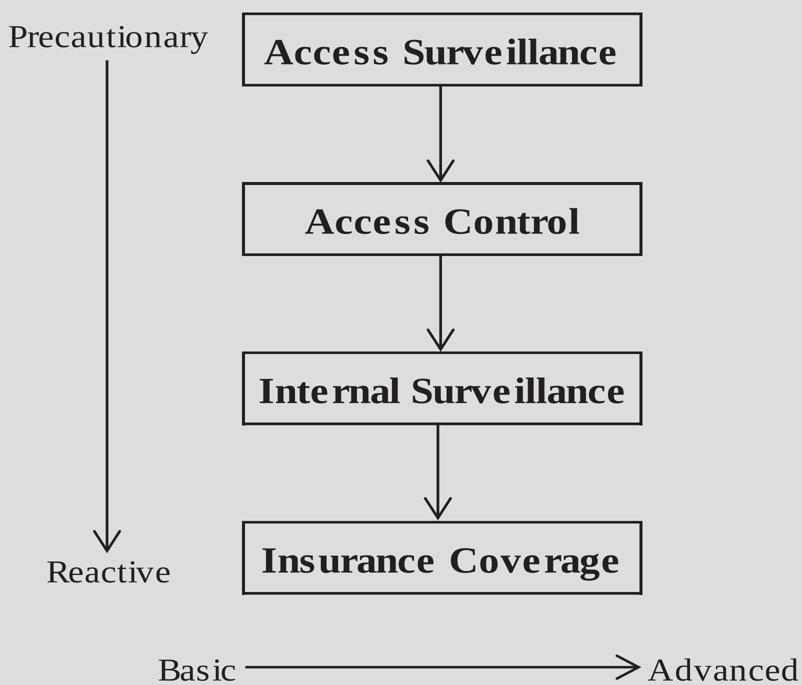
34th Street

Concepts Being Considered

The team is designing programs and incentives to foster participation

- Unassisted Off Hour Deliveries (UOHD)
- Noise Reduction

Design of UOHD Programs



UOHD Program Alternatives

Access surveillance	Access control	Internal Surveillance	Insurance Coverage
Security camera	Delivery lockers	Security camera	Carrier-supplied policy
Camera + DVR	Double doors	Camera + DVR	
Camera + RTM	Two-stage deliveries	Camera + RTM	
Camera + DVR + RTM	Key deliveries	Camera + DVR + RTM	
	Keyless entry		
	Electronic doorman		

KEY
DVR = digital video recording
RTM = real-time monitoring

Low Noise Solutions

Trucks
- Low noise engines, bodies, tires, lift gates

Cargo Handling Equipment
- Forklifts
- Hand pallet trucks
- Other cargo handling equipment

Sound Absorption Materials

Physical Changes to Delivery Locations

Training Drivers on Noise Abatement

Branding Brainstorm

Branding and Marketing

Other Recognition Schemes

OHD Recognition

Participation

Name/Logo

Recognition Schemes around the World

Comprehensive Programs

- Include assessing the overall operations of the members
  - Business operations
  - Fleet management
  - Environmental impact
  - Driver skills

Area Specific Programs

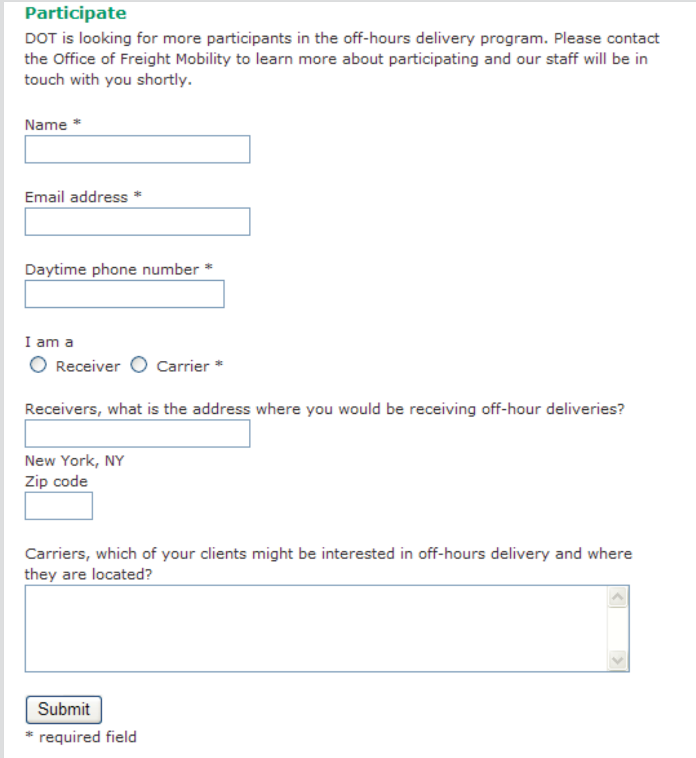
- Concentrate on one specific area of concern

Award Programs

- Issue awards for various categories related to freight operations

OHD Recognition Scheme

Participation Strategy



Participate

DOT is looking for more participants in the off-hours delivery program. Please contact the Office of Freight Mobility to learn more about participating and our staff will be in touch with you shortly.

Name *

Email address *

Daytime phone number *

I am a

Receiver Carrier *

Receivers, what is the address where you would be receiving off-hour deliveries?

New York, NY

Zip code

Carriers, which of your clients might be interested in off-hours delivery and where they are located?

Submit

* required field

Branding Focus Areas

Savings (time/money)

Green/Environmental/Sustainable

Quiet/Good Neighbor

Unlocking the Grid/Efficient

Safety

Timeline and Next Steps

Launch Phase Timeline

- **Nov. 2011 - Jan. 2012**
  - Branding
  - Organizing Participants
- **March 2012**
  - Group 1
  - 50 participants
- **May 2012**
  - Group 2
  - 50 participants
- **July 2012**
  - Group 3
  - 50 participants
- **Sept. 2012**
  - Group 4
  - 50 participants

Next Steps

Promotion

Press Release

OHD highlights on your website, in a newsletter

December 2011
- Promotion
- Participation Prep
- Survey

→

January – April 2012
- Participation Prep

→

March 2012
- Group 1 begins

Broaden Participation

Participation Prep:

Carrier: Customer Information

Receiver: Vendor Information

BID/Association: Constituent Information

December 2011
- Promotion
- Participation Prep
- Survey

→

January – April 2012
- Participation Prep

→

March 2012
- Group 1 begins

Motivating Factors for Participation

Participant Survey:

RPI

December 2011
- Promotion
- Participation Prep
- Survey

→

January – April 2012
- Group Launch Prep

→

March 2012
- Group 1 begins

Contact

For next steps and participation information, contact RPI:

Jeff Wojtowicz
Senior Research Engineer
518-276-2759
wojtoj@rpi.edu

For concerns regarding landlord and other regulation and policy issues, contact DOT:

Stacey Hodge
Director, Office of Freight Mobility
212-839-6666
shodge@dot.nyc.gov

References

[1]Goevaers, R. (2010a). PIEK: Low Noise Equipment, Off Peak Hours Transport. Transportation Research Board.

[2]Daimler AG (2011, 18 July 2011). "Making deliveries with the Econic NGT and the "environmental angel"." Retrieved 20 July 2011, from http://media.daimler.com/dcmedia/0-921-656149-1-1409409-1-0-1-0-0-1-12639-0-0-1-0-0-0-0-0.html?TS=1311168453056.

[3] Goevaers, R. (2011). Low Noise Trucks. R. P. I. Department of Civil Engineering.

[4] Colruyt Group. "The Colruyt Group develops a hybrid truck." Retrieved 20 July 2011, from http://www.colruytgroup.be/colruytgroup/static/energiebeleid-hybride_e.shtml.

[5] Gray & Adams. "Low Noise Trailer Design for Night Time Distribution Trials Sainsburys." Retrieved 20 September 2011, from http://www.gray-adams.com/7,224/case_studies/low_noise_trailer_design_for_night_time_distribution_trials/.

[6] European Parliament and Council of the EU (2001). Directive 2001/43/EC of the European Parliament and of the Council of 27June 2001, Amending Council Directive 92/23/EEC Relating to Tyres for Motor Vehicles and Their Trailers and to Their Fitting. 2001/43/EC. The European Parliament and The Council of the European Union, Official Journal of The European Communities. **L 211/25**.

[7] Nordic Swan (2009). "Nordic Ecolabelling of Vehicle Tyres." (Version 3.1).

[8] Sandberg, U. (2008). Consumer Label for Tyres in Europe. Swedish National Road and Transport Research Institute (VTI).

[9] Dhollandia (2011, 28 March 2011). "1ste NAS/PIEK-certificaat voor superstille DH-SKS-laadklep." Retrieved 20 July 2011, from http://www.dhollandia.be/nl/nieuwsbrief2.asp?id=69.

[10] Toyota Industrial Equipment (2011b). "Hand pallet truck: BT Lifter Silent LHM230SI ". Retrieved 21 September 2011, from http://www.toyota-forklifts.eu/en/Products/ProductRange/Products/Pages/BTLifterLHM230SI.aspx.

[11] Container Centralen Ltd. "CC Euro Rollcontainer." Retrieved 20 July 2011, from http://www.container-centralen.com/en/cc%20products/cc%20low%20noise/cc_euro_rollcontainer.aspx.

[12] Toyota Industrial Equipment (2011a). "8-Series Internal Combustion Cushion Tire." Retrieved 21 September, 2011, from http://www.toyotaforklift.com/products/lift_trucks/InternalCombustionCushion/ICCushionTire.aspx.

[13] http://www.tfl.gov.uk/microsites/fors/

[14] http://www.tyneandwearfreight.info/news/pdfs/freight-conference2011/presentations/Freight%20Operator%20Recognition%20Scheme.pdf

[15] http://www.epa.gov/smartway/transport/index.htm

[16] http://www.fta.co.uk/policy_and_compliance/environment/logistics_carbon_reduction_scheme.html

[17] http://www.fta.co.uk/services/well_driven_scheme.html

[18] http://www.cargonewsasia.com/afsca/mainpage.html

NEW YORK CITY DOT

Launch Phase

NEW YORK CITY DOT

Noise Reduction Literature

The standard diesel engine - 80 dB(A)

- Truck is not only source of noise irritations.
- Typical sounds that occur in the delivery process measured at a distance of 7.5 meters [1] without low noise technologies:

Action	Noise Measurement dB(A)
Slamming door	74
Driving up/away	67-83
Load hatch	65-92
Containers over load floor	74-85
Refrigeration kicking in	70-78
Removing onboard forklift	77-82
Shopping trolleys	53-77

Low Noise Truck Technologies

Natural Gas Trucks

- Liquefied Natural Gas (LNG)
- Compressed Natural Gas (CNG)
- Able to operate on renewable biogas without any adjustments to the engine.
- Emissions produced does not contain any fine dust particles.

Mercedes-Benz Econic 1828 NGT [2]

- LNG - 72 dB(A)

Iveco Stralis [3]

- CNG - 72dB(A)

Noise Reduction Literature

Hybrid Trucks: Parallel Hybrid truck created by the Colruyt Group [4]

- Operates under 65 dB(A)
- Operates in two ways:
  - Serial Hybrid Technology - Electric motor is powered by a battery or directly by the diesel engine. Battery is charged when the diesel engine is being used.
  - Electric motor and diesel engine work in parallel.

Low Noise Bodies

Refrigerated Trailer - Created by Gray & Adams [5]

- Combination of all features meet 60dB(A).
- Carrier Vector 1850 XLN (Extra Low Noise) - engine of the refrigerating unit mounted in an insulated encasing under the trailer.
- DH-SK(S) Ultra Low Noise retractable tail lift from manufacturer Dhollandia.
- Low noise floor – reduces sounds created from using roll cages.
- Side wall kick strips adjusted to meet noise-reducing criteria.

Low Noise Tires

- European Union (EU) directive tires labeled with S-marking offers 75-79 dB(A) depending on commercial vehicle tire category [6]

- Nordic Swan Ecolabel – 72 - 78dB(A) depending on category [7]

- German Blue Angel Label – 72 dB(A)[8]

Low Noise Tail Lifts

DH-SKS-Lift – Manufactured by Dhollandia (Belgian company)[9]

- A low sound platform coating
- Automated functions – perform loading functions typically done manually
- Smart links – prevent misuse and damage of the automated functions

Cargo Handling Equipment

- Hand pallet trucks – 60dB(A) [10]
- Shopping trollies
- CC Euro Rollcontainer – 60 dB(A)[11]
- Forklift [12]

Other Noise Solutions

Application of noise absorption materials

- Truck: engine, truck body
- Delivery location

Physical changes to delivery locations

- e.g. repaving driveways –smooth driveways reduce noise

Staff training on noise abatement [1]

- Mind the speed
- Mind the revolutions per minute (RPM) level
- Turn off the radio
- Do not slam the doors
- Do not drop the cargo storage bar

Recognition Schemes in the World

Comprehensive Programs

- Include assessing the overall operations of the members
  - Business operations
  - Fleet management
  - Environmental impact
  - Driver skills

Area Specific Programs

- Concentrates on one specific area of concern

Award Programs

- Issue awards for various categories related to freight operations

Comprehensive Programs

Freight Operator Recognition Scheme (FORS)[13]

- FORS is free, voluntary and open to any company operating vans or lorries in London, England.
- FORS benchmarking uses four performance indicators:
  - Fleet management
  - Driver management
  - Performance management
  - Transport operations

FORS continued…

Three levels[14] :

Bronze membership (base level)

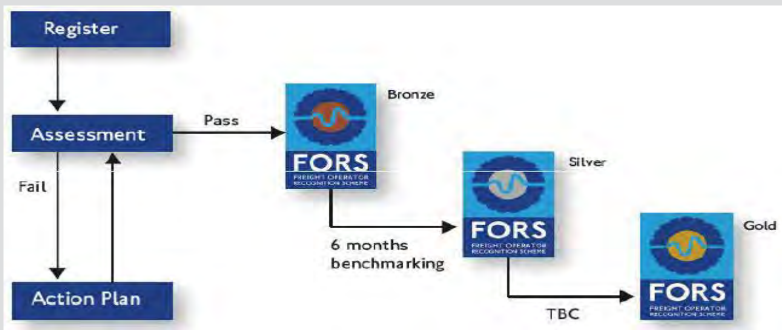
- Meet the standards set out in the FORS specification

Silver membership

- Contribute 6 months of continuous data into the FORS benchmarking system

Gold membership

- Meet performance thresholds by using FORS benchmarking



Area Specific & Award Programs

Area Specific Programs

- Environmental impacts – reducing emissions
  - U.S. Environmental Protection Agency (EPA) SmartWay Transport [15]
  - Logistics Carbon Reduction Scheme (LCRS) – UK[16]
- Driving performance
  - Well Driven Scheme – UK[17]

Award Programs

- Asian Freight & Supply Chain Awards (ASFCA)[18]

- designed to honor organizations that demonstrate leadership and consistency in quality of service, innovation, customer relationship management and reliability.

APPENDIX 2B

NEW YORK CITY DOT

Department of Transportation

JANETTE SADIK-KHAN, Commissioner

MEETING SIGN IN SHEET

DATE: 11/30/11

RE: Off Hour Delivery IAG Meeting

NAME	ORGANIZATION	PHONE	EMAIL
Joe Killeen	NDL/Dynamic Group	732-[illegible] 787-1203	Joe.Killeen@DYNAMICONLINE.com
Philip Verpic	[illegible]	[illegible]	[illegible]
Daniel Wald	Freshdirect	718-928-1566	dwald@freshdirect.com
Nimish Dixit	Freshdirect	718-928-1210	NDixit@freshdirect.com
Ari Kahn	Mayor's Office		akahn@cityhall
Nina Haiman	NYC DOT	212-839-6244	nhaiman@dot.nyc.gov
Suchi Sanagavarapu	NYCDOT	212.839.7143	ssanagavarapu@dot.nyc.gov
Tom Maguire	NYC DOT	212 839.6675	tmaguire@dot.nyc.gov
Stacey Hodge	NYCDOT	212 839 6666	shodge@dot.nyc.gov
DAN GIACOMAZZA	DOWNTOWN ALLIANCE	212 835-2758	DGIACOMAZZA@DOWNTOWNNY.COM
JAN LARSEN	MILLENIUM HILTON	212-312-2025	JAN.LARSEN@HILTON.COM
Robert Heim	SYSCO	201-433-2000 x2045	Heim.Robert@METRONY.SYSCO.COM
David Woloch	DOT	212 839 6410	dwoloch@dot.nyc.gov
Jessica Wurwarg	DOT	212.839.6423	jwurwarg@dot.nyc.gov
Jacob Bielecki	34th St. Partnership	212-719-3434	jbielecki@urbanmgt.com
Kendra Adams	NYSMTA	518-458-9696	Kadams@nytrucks.org
Patricia Brodhagen	Food Industry Alliance	203-977-2438	pat@fiany.com
Andrew Rigie	NYS Restaurant Assn	212-398-9160	AndrewR@NYSRA.net
NANCY PLOEGER	MANHATTAN CHAMBER	212-473-7875	NP@MANHATTANCC.ORG
Tom Connery	NEMF	908-965-0100	TCONNERY@NEMF.COM
Sandra Rothbard	NYC DOT	212-839-6668	srothbard@dot.nyc.gov
Jose Holguin-Veras	RPI	518-276-6221	jhv@rpi.edu
Jeff Wojtowicz	RPI	518-276-2759	wojtoj@rpi.edu
Ivana Campbell	RPI		Campbs4@rpi.edu

NYC Department of Transportation
55 Water Street, New York, NY 10041
T: 212.839.6400 F: 212-839-6453
www.nyc.gov/dot

APPENDIX 2C

Name:
Company:

Recognition Scheme Response Summary (8 responses)

Based on our pilot and the recognition schemes we've highlighted, what strategy will businesses honor and value? Please check the level of importance you think businesses will give to the following:

1) Recognized for…	1 not at all important	2 not very important	3 somewhat important	4 very important	5 most important
Being Green and Sustainable			4	4	
Being Efficient and Improving Traffic		2	2	3	1
Being a Good Neighbor		1	4	2	5

Other: **Safety, financial incentives, display of certificate of green compliance, need to show restaurants they can save $. Killeen: should require carbon assessment and footprint from "reduction", business should be able to show using off peak hours**

2) Recognized by…	1 not at all important	2 not very important	3 somewhat important	4 very important	5 most important
Physical Award or Certificate		3	4		1
Press Event		1	6	1	
Presence on DOT website	1	6			1
Sticker with program name/logo on business or truck		4	3	1	

Other:____

3) Please list any recognition or award your business has received and which have meant the most to you and why: **Heim: An energy reduction award from NJ for reducing our energy consumption by 25% post install of energy efficient lighting, motion sensors, throughout our facility. Bielecki: Neighborhood awards. Something that was publicized and included a plaque that we could hang on our wall.**

4) Some recognition schemes, like FORS which is summarized in your handout, provide different levels of recognition based on different levels of participation. Meeting performance thresholds would result in Bronze recognition, going above the threshold would result in Silver and the top level of participation would result in Gold recognition, etc. We are interested in your views on having different levels of participation and therefore different levels of recognition. The alternative is no variation with one type of award for all participants. Please tell us your thoughts:__

Heim: Recognition is nice but not necessary. SYSCO is looking to be part of improving the overall efficiencies in the NYC area. Bielecki: I think it might be better to not have a variation of awards. Killeen: need levels in recognition program. Dixit: This would be great and a good thing to be able to say and represent. There may be a flood of this in the marketplace – too many. It would be great if it was a city-wide effort. Wald: The level of the award will not matter if there is little added reward above a different color medal.

APPENDIX 2D

Name: Robert Heim
Company: SYSCO FOOD of METRO NY.

Recognition Scheme

Based on our pilot and the recognition schemes we've highlighted, what strategy will businesses honor and value? Please check the level of importance you think businesses will give to the following:

1) Recognized for...	1 not at all important	2 not very important	3 somewhat important	4 very important	5 most important
Being Green and Sustainable	☐	☐	☐	☑	☐
Being Efficient and Improving Traffic	☐	☐	☐	☐	☑
Being a Good Neighbor	☐	☐	☐	☑	☐

Other: Being SAFE

2) Recognized by...	1 not at all important	2 not very important	3 somewhat important	4 very important	5 most important
Physical Award or Certificate	☐	☐	☑	☐	☐
Press Event	☐	☐	☑	☐	☐
Presence on DOT website	☐	☐	☐	☐	☑
Sticker with program name/logo on business or truck	☐	☐	☑	☐	☐

Other:

Robert Hem

3) Please list any recognition or award your business has received and which have meant the most to you and why:

AN ENERGY REDUCTION AWARD FROM NJ FOR REDUCING OUR ENERGY CONSUMPTION by 25% POST INSTALL of ENERGY EFFICIENT LIGHTING, MOTION SENSORS, throughout OUR FACILITY.

4) Some recognition schemes, like FORS which is summarized in your handout, provide different levels of recognition based on different levels of participation. Meeting performance thresholds would result in Bronze recognition, going above the threshold would result in Silver and the top level of participation would result in Gold recognition, etc. We are interested in your views on having different levels of participation and therefore different levels of recognition. The alternative is no variation with one type of award for all participants. Please tell us your thoughts:

Recognition is Nice but NOT NECESSARY. SYSCO is Looking to be part of improving the overall efficiencies in the NYC AREA.

Name: Peter Verpir
Company: Grand Central Partnership

Recognition Scheme

Based on our pilot and the recognition schemes we've highlighted, what strategy will businesses honor and value? Please check the level of importance you think businesses will give to the following:

1) Recognized for...	1 not at all important	2 not very important	3 somewhat important	4 very important	5 most important
Being Green and Sustainable	☐	☐	☑	☐	☐
Being Efficient and Improving Traffic	☐	☐	☐	☑	☐
Being a Good Neighbor	☐	☐	☑	☐	☐

Other:____

2) Recognized by...	1 not at all important	2 not very important	3 somewhat important	4 very important	5 most important
Physical Award or Certificate	☐	☐	☑	☐	☐
Press Event	☐	☐	☑	☐	☐
Presence on DOT website	☐	☑	☐	☐	☐
Sticker with program name/logo on business or truck	☐	☑	☐	☐	☐

Other:____

Peter Lempik

3) Please list any recognition or award your business has received and which have meant the most to you and why:

4) Some recognition schemes, like FORS which is summarized in your handout, provide different levels of recognition based on different levels of participation. Meeting performance thresholds would result in Bronze recognition, going above the threshold would result in Silver and the top level of participation would result in Gold recognition, etc. We are interested in your views on having different levels of participation and therefore different levels of recognition. The alternative is no variation with one type of award for all participants. Please tell us your thoughts:

Name: Jacob Biebecki
Company: 34th Street Partnership

Recognition Scheme

Based on our pilot and the recognition schemes we've highlighted, what strategy will businesses honor and value? Please check the level of importance you think businesses will give to the following:

1) Recognized for...	1 not at all important	2 not very important	3 somewhat important	4 very important	5 most important
Being Green and Sustainable	☐	☐	☒	☒	☐
Being Efficient and Improving Traffic	☐	☐	☐	☒	☐
Being a Good Neighbor	☐	☐	☒	☐	☐

Other:____

2) Recognized by...	1 not at all important	2 not very important	3 somewhat important	4 very important	5 most important
Physical Award or Certificate	☐	☐	☒	☐	☐
Press Event	☐	☐	☐	☒	☐
Presence on DOT website	☐	☒	☐	☐	☐
Sticker with program name/logo on business or truck	☐	☐	☒	☐	☐

Other:____

Jacob Bielecki

3) Please list any recognition or award your business has received and which have meant the most to you and why: Neighborhood Award

Something that was publicized and included a plaque that we could hang on our wall

4) Some recognition schemes, like FORS which is summarized in your handout, provide different levels of recognition based on different levels of participation. Meeting performance thresholds would result in Bronze recognition, going above the threshold would result in Silver and the top level of participation would result in Gold recognition, etc. We are interested in your views on having different levels of participation and therefore different levels of recognition. The alternative is no variation with one type of award for all participants. Please tell us your thoughts:

I think it might be better to not have a variation of awards

Name: Joe Kellem ?
Company:

Recognition Scheme

Based on our pilot and the recognition schemes we've highlighted, what strategy will businesses honor and value? Please check the level of importance you think businesses will give to the following:

1) Recognized for...	1 not at all important	2 not very important	3 somewhat important	4 very important	5 most important
Being Green and Sustainable	☐	☐	☒	☐	☐
Being Efficient and Improving Traffic	☐	☐	☒	☐	☐
Being a Good Neighbor	☐	☐	☒	☐	☐

Other: FINANCIAL INCENTIVES
BOTH POSITIVE AND NEGATIVE
Should require CARBON ASSESMENT / FOOT PRINT FROM
BUSINESS
TO BE ABLE TO SHOW - "REDUCTION"
USING ~~[illegible]~~ OFF PEAK HRS.

2) Recognized by...	1 not at all important	2 not very important	3 somewhat important	4 very important	5 most important
Physical Award or Certificate	☐	☒	☐	☐	☐
Press Event	☐	☒	☐	☐	☐
Presence on DOT website	☐	☒	☐	☐	☐
Sticker with program name/logo on business or truck	☐	☒	☐	☐	☐

Other:

Joe Killeen

3) Please list any recognition or award your business has received and which have meant the most to you and why:

4) Some recognition schemes, like FORS which is summarized in your handout, provide different levels of recognition based on different levels of participation. Meeting performance thresholds would result in Bronze recognition, going above the threshold would result in Silver and the top level of participation would result in Gold recognition, etc. We are interested in your views on having different levels of participation and therefore different levels of recognition. The alternative is no variation with one type of award for all participants. Please tell us your thoughts:

NEED LEVELS IN RECOGNITION PROGRAM —

Name: N Dixit
Company: FreshDirect.

Recognition Scheme

Based on our pilot and the recognition schemes we've highlighted, what strategy will businesses honor and value? Please check the level of importance you think businesses will give to the following:

1) Recognized for…	1 not at all important	2 not very important	3 somewhat important	4 very important	5 most important
Being Green and Sustainable	☐	☐	☐	☒	☐
Being Efficient and Improving Traffic	☐	☐	☐	☒	☐
Being a Good Neighbor	☐	☐	☐	☒	☐

Other:____

2) Recognized by…	1 not at all important	2 not very important	3 somewhat important	4 very important	5 most important
Physical Award or Certificate	☐	☐	☒	☐	☐
Press Event	☐	☐	☒	☐	☐
Presence on DOT website	☐	☒	☐	☐	☐
Sticker with program name/logo on business or truck	☐	☐	☐	☒	☐

Other:____

N. Dixit

3) Please list any recognition or award your business has received and which have meant the most to you and why:

4) Some recognition schemes, like FORS which is summarized in your handout, provide different levels of recognition based on different levels of participation. Meeting performance thresholds would result in Bronze recognition, going above the threshold would result in Silver and the top level of participation would result in Gold recognition, etc. We are interested in your views on having different levels of participation and therefore different levels of recognition. The alternative is no variation with one type of award for all participants. Please tell us your thoughts:

This would be great and a good thing to be able to say and represent. There may be a flood of this in the marketplace. - too many.

It would be great if it was a city-wide effort.

Name: Daniel wald
Company: Fresh Direct

Recognition Scheme

Based on our pilot and the recognition schemes we've highlighted, what strategy will businesses honor and value? Please check the level of importance you think businesses will give to the following:

1) Recognized for...	1 not at all important	2 not very important	3 somewhat important	4 very important	5 most important
Being Green and Sustainable	☐	☐	☐	☒	☐
Being Efficient and Improving Traffic	☐	☒	☐	☐	☐
Being a Good Neighbor	☐	☒	☐	☐	☐

Other: Many businesses prominently display certificates of "green" compliance.

2) Recognized by...	1 not at all important	2 not very important	3 somewhat important	4 very important	5 most important
Physical Award or Certificate	☐	☐	☐	☐	☒
Press Event	☐	☐	☒	☐	☐
Presence on DOT website	☒	☐	☐	☐	☐
Sticker with program name/logo on business or truck	☐	☒	☐	☐	☐

Other:

Daniel Wald

3) Please list any recognition or award your business has received and which have meant the most to you and why:

4) Some recognition schemes, like FORS which is summarized in your handout, provide different levels of recognition based on different levels of participation. Meeting performance thresholds would result in Bronze recognition, going above the threshold would result in Silver and the top level of participation would result in Gold recognition, etc. We are interested in your views on having different levels of participation and therefore different levels of recognition. The alternative is no variation with one type of award for all participants. Please tell us your thoughts: The level of the award will not matter if there is little added rewards above a different color ~~medal~~ medal.

Name: Andrew Rigie
Company: NYS Restaurant Association

Recognition Scheme

Based on our pilot and the recognition schemes we've highlighted, what strategy will businesses honor and value? Please check the level of importance you think businesses will give to the following:

1) Recognized for…	1 not at all important	2 not very important	3 somewhat important	4 very important	5 most important
Being Green and Sustainable	☐	☐	X	☐	☐
Being Efficient and Improving Traffic	☐	X	☐	☐	☐
Being a Good Neighbor	☐	☐	X	☐	☐

Other: Showing restaurants that they can save money is the most important.

2) Recognized by…	1 not at all important	2 not very important	3 somewhat important	4 very important	5 most important
Physical Award or Certificate	☐	X	☐	☐	☐
Press Event	☐	X	X	☐	☐
Presence on DOT website	☐	X	☐	☐	☐
Sticker with program name/logo on business or truck	☐	X	☐	☐	☐

Other:

Andrew Rigie

3) Please list any recognition or award your business has received and which have meant the most to you and why: ______

4) Some recognition schemes, like FORS which is summarized in your handout, provide different levels of recognition based on different levels of participation. Meeting performance thresholds would result in Bronze recognition, going above the threshold would result in Silver and the top level of participation would result in Gold recognition, etc. We are interested in your views on having different levels of participation and therefore different levels of recognition. The alternative is no variation with one type of award for all participants. Please tell us your thoughts: ______

Name: Pat Brodhagen
Company: Food Industry Alliance

Recognition Scheme

Based on our pilot and the recognition schemes we've highlighted, what strategy will businesses honor and value? Please check the level of importance you think businesses will give to the following:

1) Recognized for…	1 not at all important	2 not very important	3 somewhat important	4 very important	5 most important
Being Green and Sustainable	☐	☐	☑	☐	☐
Being Efficient and Improving Traffic	☐	☐	☑	☐	☐
Being a Good Neighbor	☐	☐	☐	☐	☑

Other:____

2) Recognized by…	1 not at all important	2 not very important	3 somewhat important	4 very important	5 most important
Physical Award or Certificate	☐	☑	☐	☐	☐
Press Event	☐	☐	☑	☐	☐
Presence on DOT website	☐	☑	☐	☐	☐
Sticker with program name/logo on business or truck	☐	☐	☑	☐	☐

Other:____

Pat Brodhagen

3) Please list any recognition or award your business has received and which have meant the most to you and why: ______

4) Some recognition schemes, like FORS which is summarized in your handout, provide different levels of recognition based on different levels of participation. Meeting performance thresholds would result in Bronze recognition, going above the threshold would result in Silver and the top level of participation would result in Gold recognition, etc. We are interested in your views on having different levels of participation and therefore different levels of recognition. The alternative is no variation with one type of award for all participants. Please tell us your thoughts: ______

APPENDIX 2E

NYC deliverEASE

Off-Hour Delivery Meeting
September 7th, 2012

Participant Accomplishments

New Interest

- Café Metro
- Chef Driven Group/5 Napkin Burger
- Dallas BBQ
- The Waldorf Astoria
- New York City Hospitality Group
- Culintro
- The Beverage Works NY, Inc.
- Sysco outreach

Data

Signed NDAs:

- Waldorf Astoria
- National DCP (Dunkin Donuts)
- Fresh Direct
- Duane Reade
- Anonymous receiver

Team Accomplishments

Off-Hour Delivery Meeting September 7th, 2012

Outreach

NYC deliverEASE
Off-Hour. On Time.

Newsletter 1, Fall 2012

Rensselaer Polytechnic Institute Issues Request for Information for Noise Reducing Technologies

Rensselaer Polytechnic Institute has issued a Request for Information (RFI) to identify new noise reducing technologies that could potentially be used during off-hour deliveries. In order to spread the word on the RFI and the program in general, representatives from RPI and NYC DOT attended the annual Internoise conference, where we spread the word about the program, enjoyed new ideas and met with counterparts from other countries. To learn more and view the entire RFI visit: http://cite.rpi.edu/off-hour-deliveries/rfi/

Whole Food Names Numerous Off-Hour Delivery Benefits

Transitioning to Off-Hour Delivery allowed Whole Foods to serve their customers through better in-stock position, enhanced their commitment to the Green Mission through more efficient trucking operations and improved their collaboration with vendors, according to Rob Twyman, Regional Vice President for Whole Foods Market in the Northeast Region.

Clean Cities Coalition Is Developing a Green Vehicle Rating

NYC deliverEASE participants – receivers and carriers - will be eligible to participate in the green vehicle rating program developed by our local Clean Cities coalition (NYCLHVCC.) The rating, the first of its kind, is designed to showcase fleets that have been making a real effort in greening their vehicles and businesses that work with them. We are partnering with NYCLHVCC to make sure modifications to trucks and fleets which relate to NYC deliverEASE are integrated into this rating system. Clean Cities also awards the annual Green Vanguard award, which DHL received last year. To learn more about Clean Cities visit www.NYCLHVCC.org

GoPost Delivery Lockers

NYCDOT, together with the United States Postal Service is implementing GoPost, a delivery locker system, here in NYC. Customers can ask for goods to be delivered to a GoPost locker instead of to their home, eliminating the need for repeat deliveries. Leasing space to a GoPost location is a great way for businesses to increase foot traffic to their stores and show commitment to the environment. Want a GoPost locker in your business? Contact Nan McKenzie from the United States Postal Service at 202-268-3089 or nan.k.mckenzie@usps.gov.

cite.rpi.edu/off-hour-deliveries/

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CITE | Center for Infrastructure, Transportation, and the Environment

New York City Off-Hour Deliveries

in PROJECTS

Integrative Freight Demand Management in the New York City Metropolitan Area – Launch Phase

This current US DOT Research and Innovative Technology Administration (RITA) funded project is a joint effort between Rensselaer Polytechnic Institute, the New York City Department of Transportation (NYC DOT), Rutgers University, and ALK Technologies. This project seeks to identify the ideal combination of incentives, policies, and technologies to convince Manhattan businesses, including retail, restaurants, and hotels, to accept overnight deliveries (typically between 10PM and 6AM). The highly successful first phase of the project demonstrated how shifting deliveries to off-hours could benefit local businesses while reducing daytime truck traffic. This phase, a culmination of more than eight years of research, will refine many key processes, focus on unstaffed (referred to as "unassisted") overnight deliveries, and increase the number of participating businesses from 33 to more than 200.

Principal Investigator (PI): José Holguín-Veras
Co-PIs: Jeff Ban, Cara Wang, Stacey Hodge, Kaan Ozbay

Media coverage

- NYC DOT Pilot Article
- Journal of Commerce
- Transport Topics Online
- Wall Street Journal

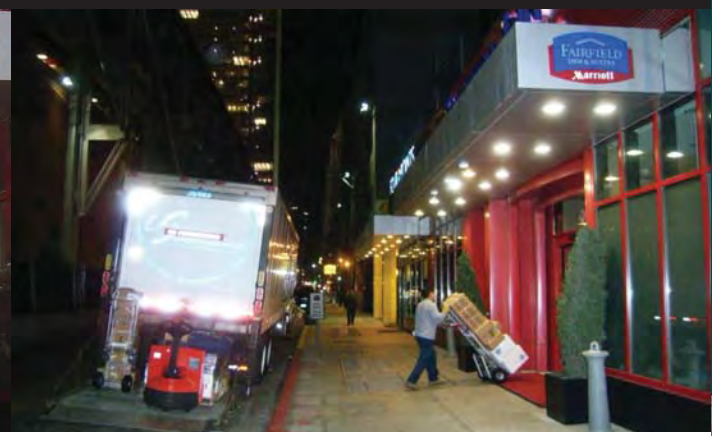
Benefits of Off-Hour Deliveries

business hours

- Traffic congestion
- Busy sidewalks
- Unreliable delivery
- Parking tickets

off-hours

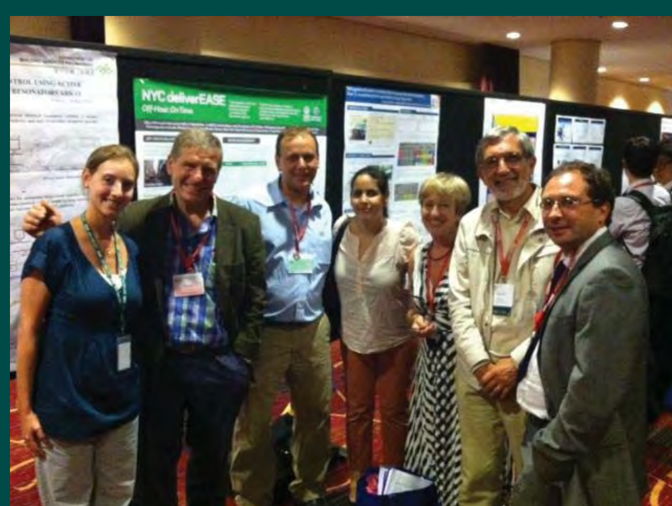
+ Increased travel speeds
+ Free sidewalks
+ On-time delivery
+ No parking tickets
+ Faster unloading time



Noise

Cemafroid
L'expertise de la chaîne du froid

noise abatement society



Finished NDA, Next Steps

- Meet with team one-on-one
- Provide data
- Work with RPI and stakeholders
- Begin to transition

Other, Next Steps

- Improve outreach
- Team presentations at events and meetings
- Other ideas?

USPS

To learn more contact:

Nan McKenzie
Manager, Special Services
(202)-268-3089
nan.k.mckenzie@usps.gov

APPENDIX 2F

NEW YORK CITY DOT

Department of Transportation

JANETTE SADIK-KHAN, Commissioner

MEETING SIGN IN SHEET

DATE: September 7th, 2012

RE: Off-Hour Delivery Meeting

NAME	ORGANIZATION	PHONE	EMAIL
James W Versocki	NYS Restaurant Assoc	631-249-6565	jversocki@abgllaw.com
Mary Snow Thurber	WholeFoodsMarket	201 710 0368	mary.thurber@wholefoods.com
Sudi Sanagavarapu	NYCDOT	212 839 7143	ssanagavarapu@dot.nyc.gov
Zeph Parmenter	BBCO	718 222 7	zparmenter@dot.nyc.gov
Jesse Goldman	Downtown Alliance	212-835-2776	jgoldman@downtownny.com
Dan Graltd	Duane Reade	917 623 6739	dgraltond@duanereade.com
Jay Peltz	Food Industry Alliance of NYS	914-715-1750	jay@fianys.com
On the phone			
Andrew Moesel	NYSRA	347-852-3140	Andrew@sheinkopf.com
Nina Haiman	MBCO	212-839-6244	nhaiman@dot.nyc.gov
Nancy Ploeger	Manhattan CC	212-473-7875	np@manhattancc.org
Brett Gipe	Smith Electric	816-243-1656	brett.gipe@smithelectric.com
Raschelle Parker	U.S. Postal Service	2123303070	Raschelle.A.Parker@usps.gov
Jeff Wojtowicz	RPI	518-276-2759	wojtoj@rpi.edu
Victoria Stephen	US Postal Service	703-280-7304	victoria.k.stephen@usps.gov
Jose Holguin-Veras	RPI	518-276-6221	jhv@rpi.edu

NYC Department of Transportation
55 Water Street, New York, NY 10041
T: 212.839.6400 F: 212-839-6453
www.nyc.gov/dot

NEW YORK CITY DOT Department of Transportation

JANETTE SADIK-KHAN, Commissioner

MEETING SIGN IN SHEET

DATE: September 7th, 2012

RE: Off-Hour Delivery Meeting

NAME	ORGANIZATION	PHONE	EMAIL
Len Rooke	U.S.P.S	860 463-9533	leonard.P.Rooke@usps.gov
FRANK CALABRESE	USPS	(718) 348-3991	FRANK.CALABRESE@USPS.GOV
Bill Schnaars	USPS	2123303600	WILLIAM.J.SCHNAARS@USPS.gov
Cara Wang	RPI	518-276-2088	wangx18@rpi.edu

NYC Department of Transportation
55 Water Street, New York, NY 10041
T: 212.839.6400 F: 212-839-6453
www.nyc.gov/dot

NEW YORK CITY DOT

Department of Transportation

JANETTE SADIK-KHAN, Commissioner

MEETING SIGN IN SHEET

DATE: September 7th, 2012

RE: Off-Hour Delivery Meeting

NAME	ORGANIZATION	PHONE	EMAIL
Desiree Mercado	Ferry	718-876-8442	Dmercado@dot.nyc.gov
Jeffrey C Brown	The Beverage Works	732-522-0437	JBrown@TheBeverageWorks.com
Stacey D. Hodge	NYCDOT Freight	212 839 6523	shodge@dot.nyc.gov.
Roxanne Hosein	USPS-	718-348-3771	roxanne.hosein@usps.gov.
Nan McKenzie	USPS	202-268-3089	nan.k.mckenzie@usps.gov
Joe Killeen	5th PL	732-757-1203	Joe.Killeen@5thpl.com

NYC Department of Transportation
55 Water Street, New York, NY 10041
T: 212.839.6400 F: 212-839-6453
www.nyc.gov/dot

APPENDIX 2G

NYC deliverEASE
Off-Hour. On Time.

Participant Packet

U.S. Department of Transportation

NEW YORK CITY DOT

Rensselaer Polytechnic Institute 1824

In 2010, 33 companies took part in a successful pilot program to shift their Manhattan deliveries to the off-hours (during the nighttime). The project was piloted by the New York City Department of Transportation (NYC DOT) together with Rensselaer Polytechnic Institute and funded by the US Department of Transportation. The participants ranged in size, and were divided into carriers (businesses that deliver goods) and receivers (businesses and organizations that accept deliveries from carriers). Sysco, Whole Foods Market, New Deal Logistics and Foot Locker received Commissioner awards for their leadership roles from NYC DOT.

The pilot was a SUCCESS!

Receivers gained:

- More time for customer interaction during business hours
- Higher staff productivity
- On-time deliveries
- Increased reliability of shipments

Carriers saved time and money:

- Shorter delivery times, saving as much as 3 hours per route
- Lower fuel costs
- Faster traveling speeds – as much as a 75% improvement
- Fewer parking tickets, with an average monthly savings of $500-1,000 per truck

Truck drivers reported:

- Much lower stress
- Increased feeling of safety
- Less congestion

Neighbors of receiving businesses enjoyed side-benefits:

- Reduction in congestion
- Reduction in air pollution
- More space on sidewalks

After the 2010 pilot we are now embarking on a launch phase.

“Whole Foods Market Union Square has enjoyed the ability to take deliveries in overnight, serve our customers better and enhance our commitment to the environment through more efficient trucking operations.”

Mary Snow Thurber, Director of Receiving
Whole Foods Market Northeast Region

“The expansion of off-hour deliveries is a smart business decision.”

Joe Killeen, COO
New Deal Logistics

“The Off-Hours Delivery Program… [is] a win-win as business owners and citizens will both realize real immediate benefits.”

Nick Kenner, Managing Partner
Just Salad LLC

BENEFITS OF PARTICIPATION

What are the benefits of joining the program?

Governmental and Community Relations Support:
The NYC deliverEASE project team will help participants with navigating government and community relations including but not limited to: investigating curb regulations that support off hour deliveries, coordinating with building owners, truck noise monitoring and outreach to community groups.

Leverage State of the Art Best Practices:
The NYC deliverEASE program will connect participants with experts and other companies locally, regionally and internationally to share cutting edge best practices about logistics, retrofitting, liability and safety and security, placing them ahead of the curve in terms of preparing for future trends.

Gain Access to Funding:
The NYC deliverEASE program will keep participants current on potential business support opportunities. Currently, the team is offering a $2,000 per location incentive for receivers that switch some of their operations to night deliveries.

Recognition for Responsible Business Operations:
The NYC deliverEASE program participants will receive public recognition for being early adopters of sustainable delivery options. Participating companies will be recognized through press events, social media and awards.

INCENTIVES FOR PARTICIPATION

The goal of this program is to improve travel speeds, reduce congestion, and reduce costs for receivers and carriers through off-hour deliveries. The Launch Phase will focus on Midtown and Lower Manhattan.

INCENTIVES FOR RECEIVERS

A $2,000 financial incentive will be provided for receivers. 60% of the incentive will be provided for one successful quarter of participation and the remaining 40% for the second quarter. In addition, some vendors might provide shipping discounts when more customers sign up for off-hour deliveries.

Recognition for Participants:

Baseline requirements:

- Participate for a minimum of one quarter
- Sign Code of Conduct.
- Participate in noise webinar.
- Provide performance measures data before and after the shift to off-hours. Both carriers and receivers must participate in a pre- and post-implementation survey.

Award program with Commissioner and recognition on the DOT and other websites, as well as a quarterly newsletter to participants where key businesses will be highlighted based on the work they are doing.

Additional recognition and incentives will be awarded to businesses that exceed the baseline criteria. For carriers examples can include consolidation of orders/deliveries and promotion of the project on a storefront. For receivers examples can include consolidation of deliveries, shipping discounts to receivers and using quiet technologies.

LAUNCH PHASE ELEMENTS

UNASSISTED OFF-HOUR DELIVERIES (UOHD)

These provide opportunities for the driver to deliver goods without requiring an employee to be an off-hour receiver. Approximately half of the receivers in the pilot phase used unassisted off-hour deliveries (UOHD). The driver was given a key to the establishment or may have used a keypad code if the business had one installed. Perishable food and beverage commodities were left in the walk-in refrigeration units, which made it easy for the restaurant staff to put the food away once they arrived. This increased the amount of face time that staff was able to spend with customers by decreasing the time spent receiving goods during regular business hours. Safety and security concerns associated with UOHD are addressed at the access points as well as inside the business.

How does it work?

- ***Double doors:*** The driver is provided with a key/keypad code to an outside door that leads to a small storage area separated from the rest of the business by a second door.
- ***Virtual cage:*** The driver is provided with a key/keypad code to the establishment and must deposit the goods within the confines of a laser-bounded area.
- ***Key deliveries with key box:*** The driver is provided with a key/security code to open the key box and get a key to the establishment. Such deliveries can also be monitored by security cameras.

NOISE REDUCTION

Improved technologies, electric vehicles, and change in behavior will help ensure that deliveries are quieter.

A major concern for the off-hours is the issue of noise emissions. Noise emissions may cause sleep or other disturbances. The observable effects on sleep include awaking, raised blood pressure, and body movements. The intensity of the effect depends on the nature of the source and the magnitude of the noise. Above 55 dB(A) adverse effects frequently occur to the general public and increasingly so on vulnerable groups.

Noise emissions associated with the delivery of goods have an effect on surrounding residential areas. These noises are even more pronounced for deliveries during off-hours when there is less ambient noise. Apart from annoyance or disturbance that noise creates, it can also negatively impact one's health; therefore, efforts are being made by the freight community to decrease these effects.

How does it work?

- ***Training staff about noise abatement:*** There are simple behavior modifications that can significantly reduce noise, such as turning off the radio and avoiding slamming doors.
- ***Improvements to existing trucks:*** Noise absorbing sheets made of materials such as polyester foam or recycled textile fiber can diminish noise levels. In addition, low noise engines, bodies, tires, and tail-lifts can be used.

- ***Quieter cargo handling equipment:*** Quieter hand pallet trucks and cargo rollers are available.
- ***Quieter trucks and trailers:*** Alternative fuel (i.e., CNG and electric) engines typically produce less noise than standard diesel engines. There are also quieter models of refrigerated trailers available.
- ***Absorption materials at delivery locations:*** Applying noise-absorbing materials on sidewalks, store floors, walls, and ceilings can reduce noise levels.
- ***Noise absorbing mats:*** Placing mats on sidewalks reduces noise of goods placed on concrete.

Companies that join the program will participate in a webinar on noise reduction.

MAINTAINING FOOD SAFETY

Any business that deals with food is familiar with NYC's food safety requirements. In the pilot, drivers successfully left goods in the appropriate environments, such as walk-in refrigerators. No additional health and safety certification is necessary for UOHD, but it is the restaurant's or grocery store's responsibility to ensure that both are addressed in a manner that is compliant with the Health Code and other applicable regulations.

PARTICIPANT BASICS

ELIGIBILITY

NYC deliverEASE is a US Department of Transportation (US DOT), New York City Department of Transportation (NYC DOT), and Rensselaer Polytechnic Institute (RPI) program dedicated to working with carriers (businesses that deliver goods) and receivers (businesses and organizations that accept deliveries from carriers) to transition to off-hour deliveries (OHD). Off-hour deliveries are deliveries made between 10:00 pm and 6:00 am, thus avoiding congestion and its negative impacts. The program focuses on deliveries to Midtown and Lower Manhattan. If your company delivers to or receives in these areas, you are a potential participant.

What happens before the project is launched?

- Pre-launch, participants cooperate with NYC DOT and RPI to collect data in order to document the anticipated benefits for the individual location or company and tailor the transition to OHD to the needs of specific companies. The process will include visits to delivery sites.
- Information on current practices of carriers, truck drivers, and receivers will be collected through surveys and GPS data when available.
- Noise levels will measured during several daytime and nighttime deliveries.

How do I transition to off-hour deliveries?

- Review curb regulations in order to provide curb access during certain times of the day.
- Depending on the specific needs of each company, we may:
  - Assist you in identifying financing for capital expenses such as truck retrofits.
  - Work with building managers to allow access to loading docks and elevators, as well as unassisted delivery.

What happens post-launch?

- Post-launch, data gathering will continue in order to document the benefits of the program and help new companies join the program. The process will again include visits to delivery sites.
- Suggest optimal delivery routes based on the route data previously gathered.
- Information on off-hour delivery practices of carriers, truck drivers, and receivers will be collected through surveys and GPS data when available.
- Noise levels will measured during several off-hour deliveries.
- Participating companies will receive recognition.

I AM INTERESTED IN PARTICIPATING. WHAT'S NEXT?

1) Let us know! Contact the team to discuss pre-launch preparations.

2) Take our noise reduction webinar, where you will learn about the latest technologies in noise reduction and resources available.

3) Sign the NYC deliverEASE Code of Conduct.

CODE OF CONDUCT AND STANDARDS FOR PARTICIPANTS IN THE NYC DELIVEREASE PROGRAM

Every driver, fleet manager, receiver, and employee who is part of the NYC deliverEASE program must read, sign, and promise to adhere to the following Code of Conduct in order to participate:

COMMITMENT TO MAINTAIN A GOOD RELATIONSHIP WITH FELLOW CARRIERS AND RECEIVERS

Receivers:

A receiving business shall ensure that anyone delivering to the location will have a safe and healthy work environment. The driver shall have no obstacles when making unassisted deliveries in the off-hours. Receivers will provide innovative ideas for unassisted deliveries and work with the team to develop entry, storage, and security strategies.

Carriers:

A carrier business shall maintain a logistics plan that is efficient, timely, and optimizes deliveries for receivers. The client's interest shall always be the top priority. Carriers must have in place an effective system of vehicle maintenance and safety checks, as well as a system to check driver performance. An honest business relationship between carriers and receivers where communication is key is needed for the success of this program. Adhering to the rules set forth in this Code of Conduct will ensure improvements in the NYC freight industry.

COMMITMENT TO THE COMMUNITY

Quiet Neighbor

In order to remain a quiet neighbor and respect the local community, receivers and carriers must ensure that the building and commercial vehicle infrastructure is designed to be as quiet as possible. All participants in NYC deliverEASE must attend a noise webinar to learn how to improve both infrastructure and driver behavior in order to make quiet deliveries in the off hours and abide by the NYC Noise Code.

PARTICIPANTS SHALL MAKE BEHAVIORAL AND PHYSICAL MODIFICATIONS TO REDUCE NOISE

Behavioral changes for the driver:

- Do not slam truck doors or gates
- Do not slam of lift gates into sidewalk
- Turn off the radio
- Do not idle the truck
- Use equipment quietly and gently as to reduce noise

(See Page 10 for Code of Conduct Acknowledgement Form)

Physical changes for both carrier and receiver:

- Retrofit vehicle, store, and equipment to reduce noise

The OHD team shall provide information on how to make behavioral shifts and what technologies can be used for retrofits. Health and Safety Participants shall ensure that food is handled safely and that food deliveries and storage adhere to the NYC health code.

The NYC Department of Transportation and the Rensselaer Polytechnic Institute are committed to the highest standards of business conduct and require all participants to treat employees fairly and all employees to perform their job with the utmost level of professionalism.

For more information contact Jeff Wojtowicz of RPI at 518-276-2759 or wojtoj@rpi.edu or Stacey Hodge of NYCDOT at 212-839-6523 or shodge@dot.nyc.gov.

Code of Conduct and Standards for Participants in the NYC deliverEASE Program

By initialing this memo and returning it to the project team, you acknowledge that your company plans to abide by the NYC deliverEASE Code of Conduct and Standards for Participants.

Company Name: ____

Date: _____________

Initials: ___________

Code of Conduct and Standards for Participants in the NYC deliverEASE Program

The success of this program depends on an honest business relationship between carriers and receivers. Drivers, fleet managers and receiving companies participating in the NYC deliverEASE program must adhere to the following code of conduct:

COMMITMENT TO MAINTAIN A GOOD RELATIONSHIP WITH FELLOW CARRIERS AND RECEIVERS

Receivers: A receiving business shall ensure that anyone delivering to the location will have a safe and healthy work environment. The driver shall have no obstacles when delivering in the off-hours. Receivers will help identify strategies to accommodate unassisted deliveries if staff is not available.

Carriers: If needed a carrier will identify technologies and suggest changes to driver behavior for drivers to reduce any noise resulting from deliveries. If unassisted deliveries are taking place, the driver will ensure that the receiver's property is not damaged in any way and that the products being delivered are handled appropriately.

COMMITMENT TO THE COMMUNITY

Health and Safety: Participants shall ensure that food is handled safely and that food deliveries and storage adhere to the NYC Health Code.

Quiet Neighbor: In order to remain a quiet neighbor and respect the local community, receivers and carriers must ensure that the building and commercial vehicle infrastructure is designed to be as quiet as possible. All participants in NYC deliverEASE are encouraged to attend a free noise webinar to learn how to improve both infrastructure and behavior in order to make quiet deliveries in the off-hours and abide by the NYC Noise Code.

PARTICIPANTS SHALL MAKE EFFORTS TO MINIMIZE NOISE THEY PRODUCE WHILE MAKING DELIVERIES

Changes to driver behavior:

- Do not slam truck doors or lift gates (into truck or sidewalk)
- Do not shout
- Turn off the radio
- Reduce engine idling (3 minutes or less unless vehicle is used to operate equipment)
- Use equipment quietly and gently as to reduce noise

Physical changes for both carrier and receiver:

- As needed, provide retrofits for vehicles, store and equipment to reduce noise

The OHD team will provide information on how to make changes to driver behavior and what technologies can be used for retrofits to both reduce noise and support unassisted deliveries.

NYC DOT and Rensselaer Polytechnic Institute are committed to the highest standards of business conduct and require all participants to treat employees fairly and all employees to perform their job with the utmost level of professionalism.

APPENDIX 2H

PLEASE JOIN US!

#

We invite you to participate in an upcoming "think tank" session that will **help contribute to the successful expansion of NYC DOT's Off Hour Delivery program**, a program that seeks to **increase the economic competitiveness of the Manhattan Central Business District**, and to **improve livability for all New Yorkers, by reducing congestion on the streets**.

You'll be joined by other area business leaders and community leaders for an interactive and engaging workshop to **develop innovative ideas that will expand the success of the Off Hour Delivery pilot program**.

When: Tuesday, July 9th, 2013
Time: 8:30 am – 11:00 am (breakfast will be provided at 8:00 am)
Where: 16 W 22nd St. (between 5th and 6th Avenues), 12th floor
New York, NY 10010

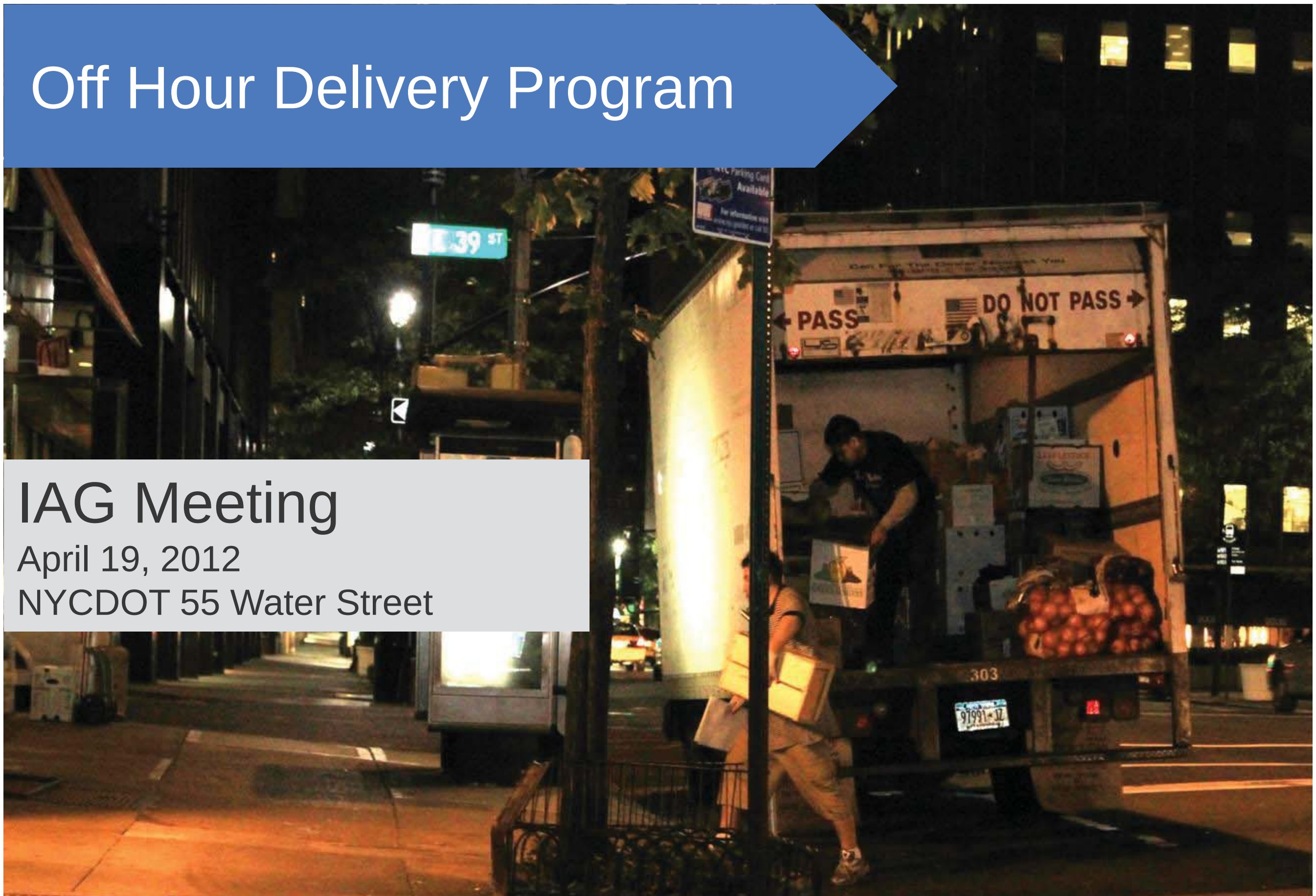
To RSVP, ***please respond by Monday, July 8th to***
Ben_zumsteg@nakedcomms.com.

For more information about the Off Hour Delivery Program, please **click here.**

#

APPENDIX 2I

Off Hour Delivery Program



IAG Meeting

April 19, 2012
NYCDOT 55 Water Street

Commissioner Janette Sadik-Khan
New York City Department of Transportation

United States Department of Transportation

NEW YORK CITY DOT

Project Progress

United States Department of Transportation

NEW YORK CITY DOT

Outreach Accomplishments

- Dunkin Donuts National DCP
- Duane Reade
- Smith Electric
- Food Industry Alliance of NYS
- Union Square Partnership
- Grand Central Partnership
- Downtown Alliance
- Millenium Hotel Vendors
- Whole Foods
- Dicks Hardware
- McDonald's
- Utz Snacks area distributor
- Phoenix Beverages
- NJ Motor Truck Association

Outreach by Project Team

Federal Agency:

- NYSERDA
- EPA
- FHWA
- HUD
- US Dept of Energy
- SBA

Local Technical Advisory Group:

- Regional Planning Association
- NYCEDC
- PANYNJ
- Dept of Buildings
- Dept of City Planning

Local Agency:

- Dept of Environmental Protection
- Dept of Health
- Environmental Compliance team for the Lower Manhattan Construction Command Center (LMCCC)

United States Department of Transportation
NEW YORK CITY DOT

EPA/FHWA
Request for Proposals

The Federal Highway Administration (FHWA) Office of Freight Management and Operations in partnership with the Environmental Protection Agency (EPA) FHWA has issued a competition for small to medium size cities, MPOs, or multijurisdictional organizations to compete for part of $450,000 in grant funding to implement off-hours goods movement/delivery programs

Implementation Planning

Lessons learned

- UOHD examples
- Receivers request discounts for OHD
- Liability issues with UOHD
- Cross Harbor Rail usage
- Consolidation Centers
- Noise Mitigation Methods – nautical rope mats
- Public Recognition is highly valued

Case Study: Lessons learned

Each pallet is brought to the storefront and left outside while the additional pallets are retrieved from the freight elevator.

United States Department of Transportation
NEW YORK CITY DOT

Case Study: Lessons learned

Left: The security gate outside the store is brought up and down electronically by the turn of a key. This is the first level of access control.

Right: Once inside, the driver is restricted by a virtual cage that is marked off by four sensors. The area is almost the full width and roughly half the depth of the store.

Case Study: Lessons learned

Left: The goods are brought inside the store past the security tag detectors, which will sound if the boxes are brought back outside. Right: Goods are automatically entered into the inventory system.

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NEW YORK CITY DOT

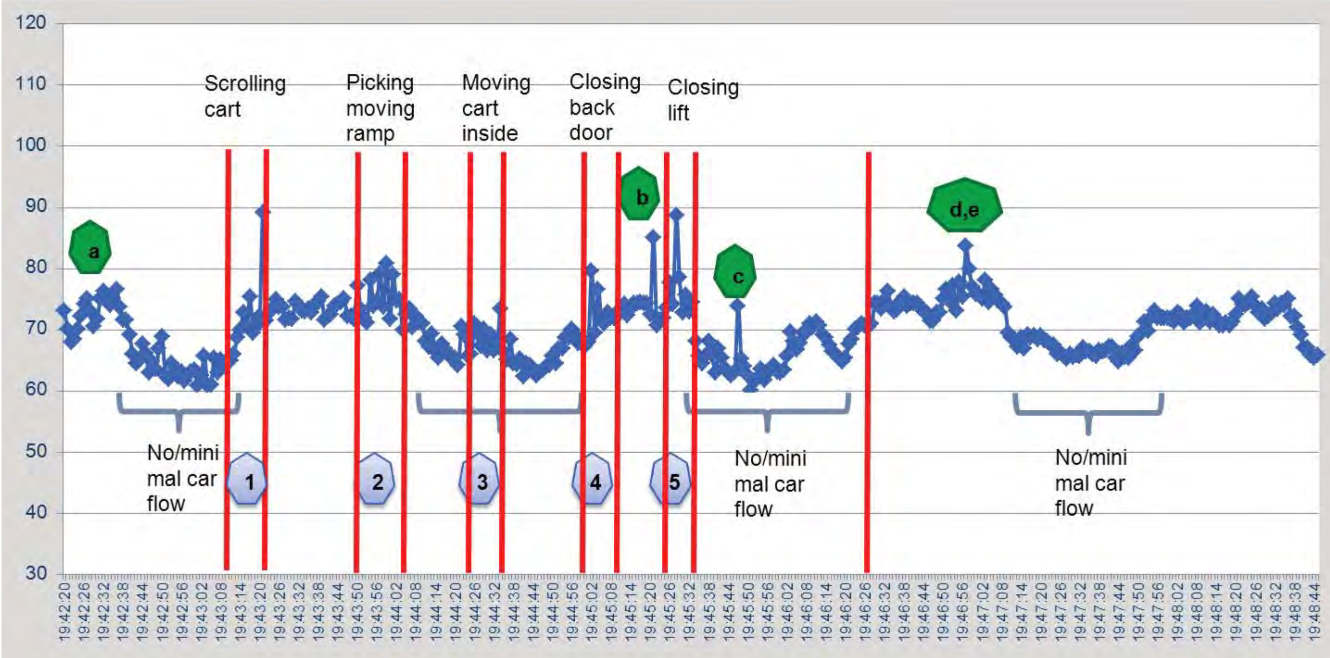
Case Study: Lessons learned

- Delivery started at 3:30 am with driver at the dock.
- Daytime drivers can wait 30-60 minutes for an opening.
- Retailer received 1.5 pallets (47 boxes) of goods, which was noted to be smaller than typical.
- Driver can unload to UOHD retailer and then bring goods up to other stores while waiting for store personnel.
- Driver saves roughly 1.5-2 hours per day this way.
- Delivery took roughly 30 minutes with research team asking questions and observing.

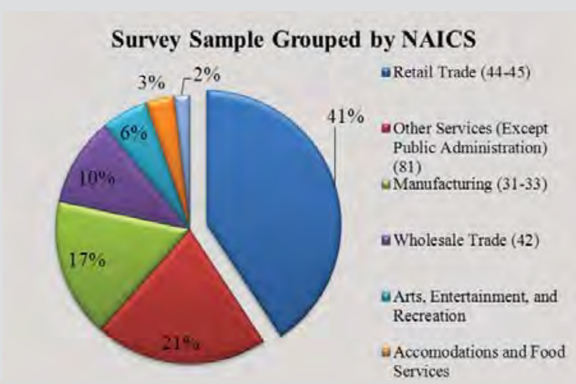
Mobile Noise Monitoring

United States Department of Transportation
NEW YORK CITY DOT

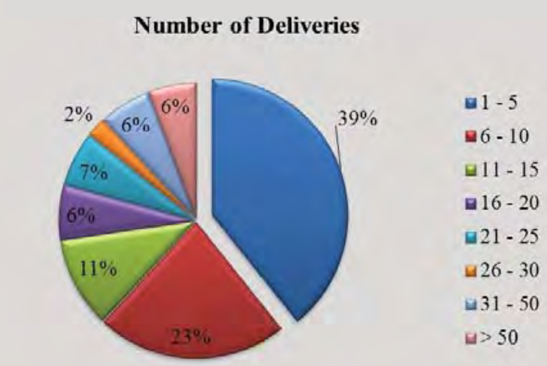
Mobile Noise Monitoring



RPI Market Survey



Over 40 % of the sample belong to Retail Trade Industry (n = 263)



39 % of the sample had between 1 and 5 deliveries (n= 260)

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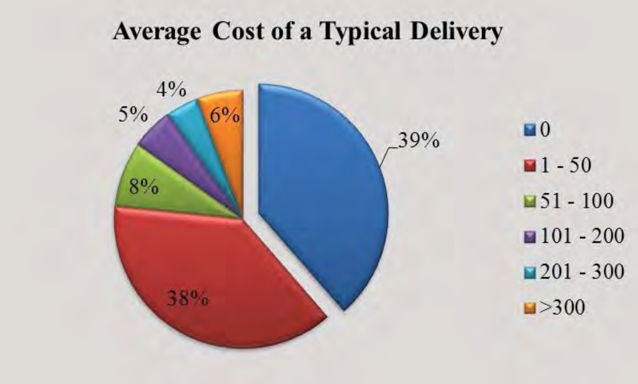
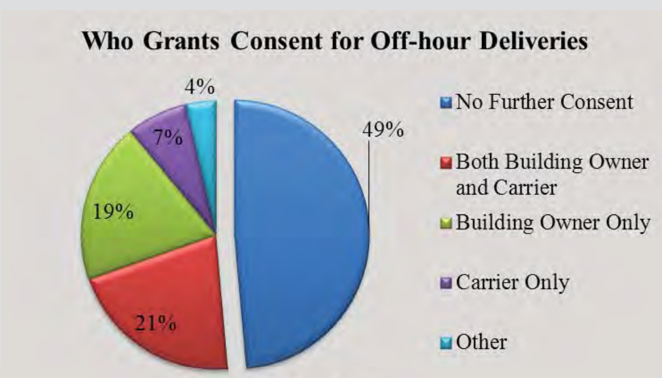
RPI Market Survey



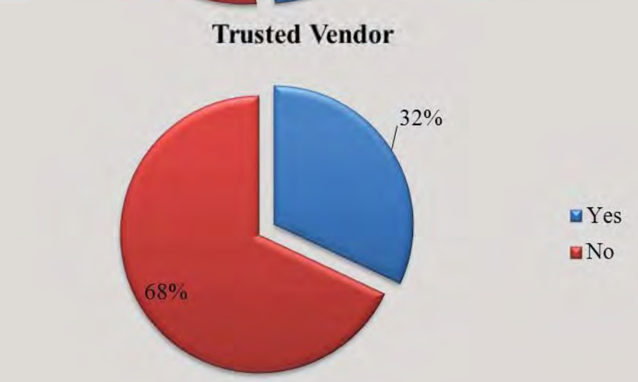
Almost 40% do not pay for deliveries (n=171)

Majority of companies (47%) have 1 to 5 vendors (n=247)

RPI Market Survey



Almost half of the sample do not need any consent for off-hour deliveries (n = 247)



32% have trusted vendors to do off-hour deliveries (n = 253)

RPI Market Survey

4% already do off-hour deliveries and 16% have considered it (n = 259)

Majority stated that City Agency can help with parking regulations for trucks (n = 39)

Incentive Structure

The amount of the one-time financial incentive will be determined by:

(1) the number of truck trips shifted to off-hours; and
(2) operational improvements (to truck or buildings) implemented by the company to foster unassisted off-hour deliveries.

Based on the extent of (1) and (2), the incentive will be determined.

Code of Conduct

- Commitment to maintain a good relationship with fellow carriers and receivers and those you do business with

- Commitment to the community
  - Ensure health and safety of products
  - Quiet neighbor through physical and behavioral modifications

Participant Package

Baseline Requirements:

- Sign Code of Conduct
- Participate in noise webinar
- Participate in program for a minimum of 1 month
- Provide performance measures
- Display program name on vehicle or storefront

Additional Requirements for Recognition (based on size of business):

- % of deliveries that switch to the off-hour
- Consolidation Centers
- Noise reduction tech and behavior
- Innovative unassisted solutions

Data Sharing and NDAs

Data Collection

Stop 3: McDonald's at 34 W. 22nd St. (example of Stop No/Store Name/ Address)

1. It took me __________ minutes to find parking
2. I arrived at ____:_____ AM / PM
3. I departed at _____:______AM / PM
4. Vehicle mileage at this stop was ___________
5. I left the delivery at: (1) Sidewalk
   (2) Inside the store
   (3) Cellar
   (4) Shelf

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NEW YORK CITY DOT

Next Steps

- Marketing
- Press Release/Event
- Community Stakeholder Group
- Quarterly newsletter

APPENDIX 3

APPENDIX 3A

MTM Model Structure and Network Reconfiguration

Existing MTM Modeling Structure

The New York City Department of Transportation (NYCDOT) developed a general modeling platform in the New York/New Jersey Metropolitan region. The platform started with the MTM, for the area of Manhattan (south of 179th Street). Figure A.159 graphically depicts the concept of linking/integrating travel demand (macroscopic), mesoscopic and microscopic models. The impetus for developing this integrated modeling platform was twofold to assess the operational changes to the roadway network in the Manhattan Central Business District (CBD). The initial MTM incorporates:

- NYMTC's BPM;
- A mesoscopic traffic model covering Manhattan (south of 179th Street) and regional facilities to and from Queens, Brooklyn, Staten Island, Bronx and New Jersey; and
- A microscopic traffic model covering a corridor bound by 37th Street, the East River, the Hudson River and 32nd Street.

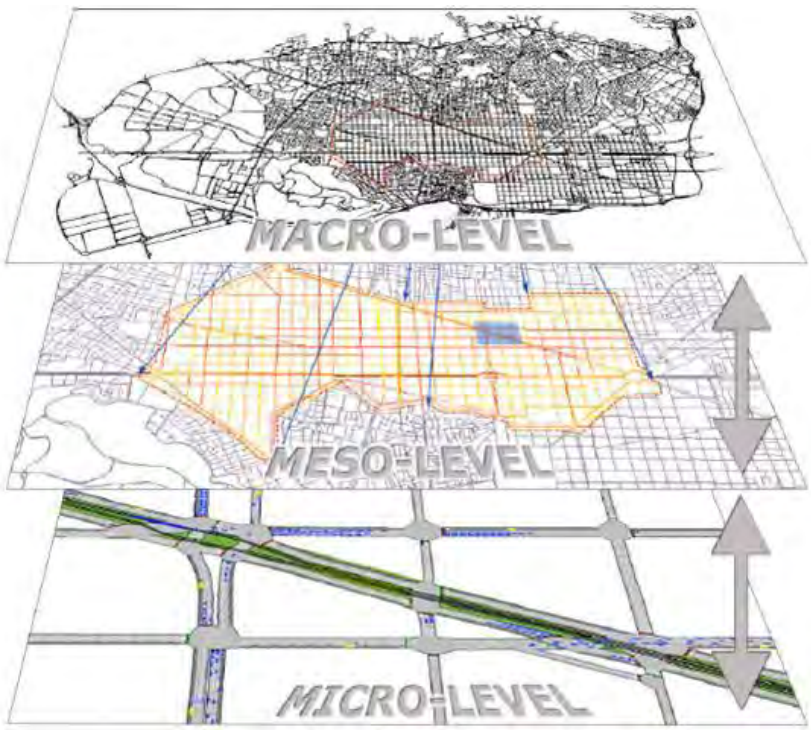


Figure A.159: Integration of Travel Demand and Traffic Operations Models

The macro-level component of MTM is represented by NYMTC's BPM model, while the mesoscopic and microscopic elements will be developed utilizing the Aimsun software. The Aimsun software was previously utilized for the development of the Green-Light Broadway model, which will provide the basis for the MTM development. The modeling structure of the existing MTM model was illustrated in Figure A.160 as follows.

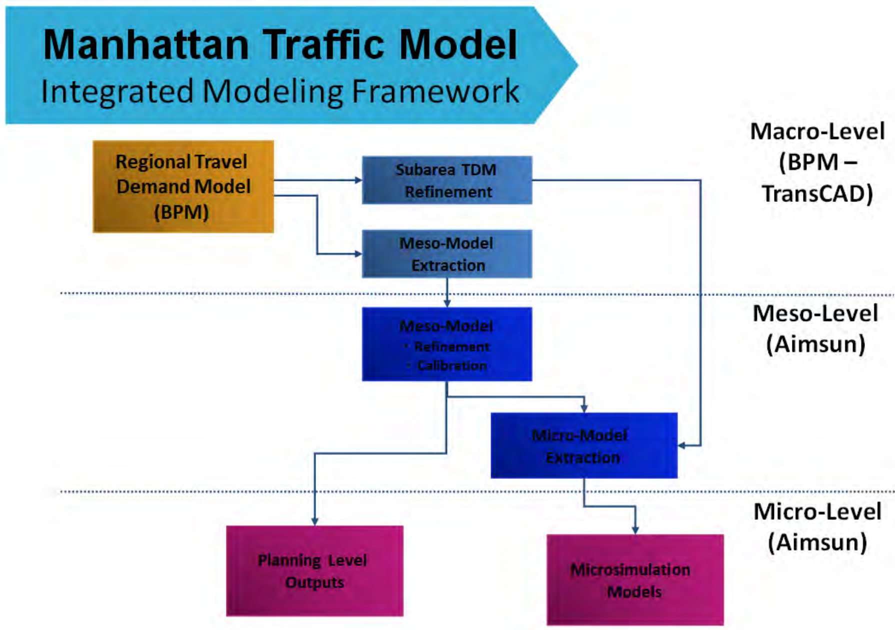


Figure A.160: Integration of Travel Demand and Traffic Operations Models

Existing MTM Network

Given the size of the BPM, the timeframe to complete the study and the budgetary resources, a focused approach covering the BPM study area is not feasible for the MTM model. Nevertheless, given that the 34th Street corridor traverses Manhattan and connects two regional facilities (Lincoln Tunnel and Queens Midtown Tunnel) a simple Window-based approach, where the river crossings define the boundaries of the subarea, may neither capture all the potential diversions nor accommodate future uses of MTM.

As such, the MTM study area reflects a hybrid approach where the network and zone density progressively increases towards 34th Street (focused), while the boundaries of the study area are defined by regional significant corridors in Brooklyn, Queen, Bronx, Manhattan (north of 179th Street) and New Jersey.

The MTM study area was composed of a primary study area – where the effects of proposed 34th Street corridor scenarios could be traced – and a secondary study area, in which the regional travel patterns are captured. Furthermore, the zone and network density increases towards 34th Street to better capture the local patterns. As shown in

Figure A.161, the MTM framework included a screenline validated macro-network, an overall meso network, and a sub-area meso network in the micro-simulation area (31st Street – 37th Street).

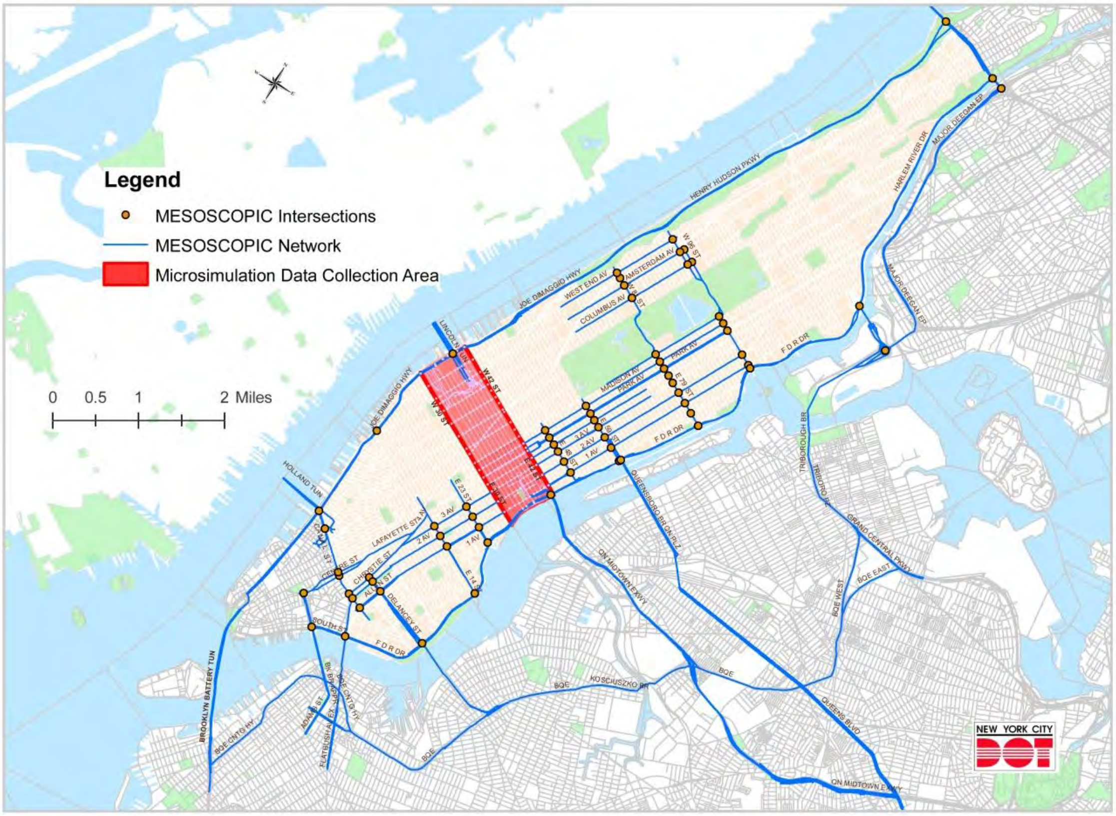


Figure A.161: Integration of Travel Demand and Traffic Operations Models

Core Study Area

The core study area extends from 44th Street to the North, to 28th Street to the South, and from the Hudson River to the West to the East River to the East. The Aimsun model developed for the Broadway project ("Green Light for Midtown") will be leveraged to fast track the development of the microscopic element of the MTM. Portions of the Broadway model will be expanded to maintain the same level of detail in terms of geometrics, signal timings and other network characteristics as necessary. Maintaining the same level of detail with the Broadway model will provide NYCDOT with a consistent network for the 34th Street corridor to analyze operational changes that require the use of a micro-simulation model. The existing and proposed Aimsun network within the core study area will have all signal timings, geometry and curbside activity (e.g., bus stops, double parking, on-street parking, etc.) verified based on field observations. Since the mesoscopic and microscopic models are based on Aimsun, the network detail and the operating characteristics of the core study area also will be reflected in both the mesoscopic and microscopic models.

The micro-simulation area is a subset of the core area and will extend from 37th Street to the N, to 32nd Street to the South, from the Hudson River to the West, and to the East River to the East.

Primary Study Area

The primary study area will extend from 66th Street to the North, to 14th Street to the South, from river to river. The purpose of the primary study area is two-fold:

1. To capture the local travel patterns/paths to and from the core study area and ensure proper allocation of traffic; and
2. To capture traffic operation changes due to proposed no-build projects (e.g., Fifth and Madison Avenue bus lanes).

It is envisioned that the primary study area network will be an extension of the current Broadway model and will include all streets within its boundaries with a coarser level of operational detail. Since the Western part of the primary study area is consistent with the Broadway model, available information such as geometric information, signal timings, etc. will be migrated to MTM where applicable. For the Eastern part of the primary study area, aerial photos and NYCDOT data will be utilized, validated by information collected from selected streets that were field inventoried. For intersections not included in the inventory, signal timings will be assigned based on the templates or on available information from other simulation models provided by NYCDOT.

Secondary Study Area

The secondary study area in Manhattan will extend from 179th Street in the North, to Battery Park in the South, from river to river. In addition the secondary study area will cover selected facilities in the other boroughs as well as New Jersey. The purpose is as follows:

- To capture the regional travel patterns to, from, and through the secondary study area;
- To capture traffic operational changes due to proposed no-build projects (e.g., First and Second Avenue BRT).

The secondary study area was only modeled to the extent of reflecting the zoning and network details of NYMTC's BPM network (e.g., avenues and major cross-town streets). The structure of the secondary area was illustrated on Figure A.162 as follows.

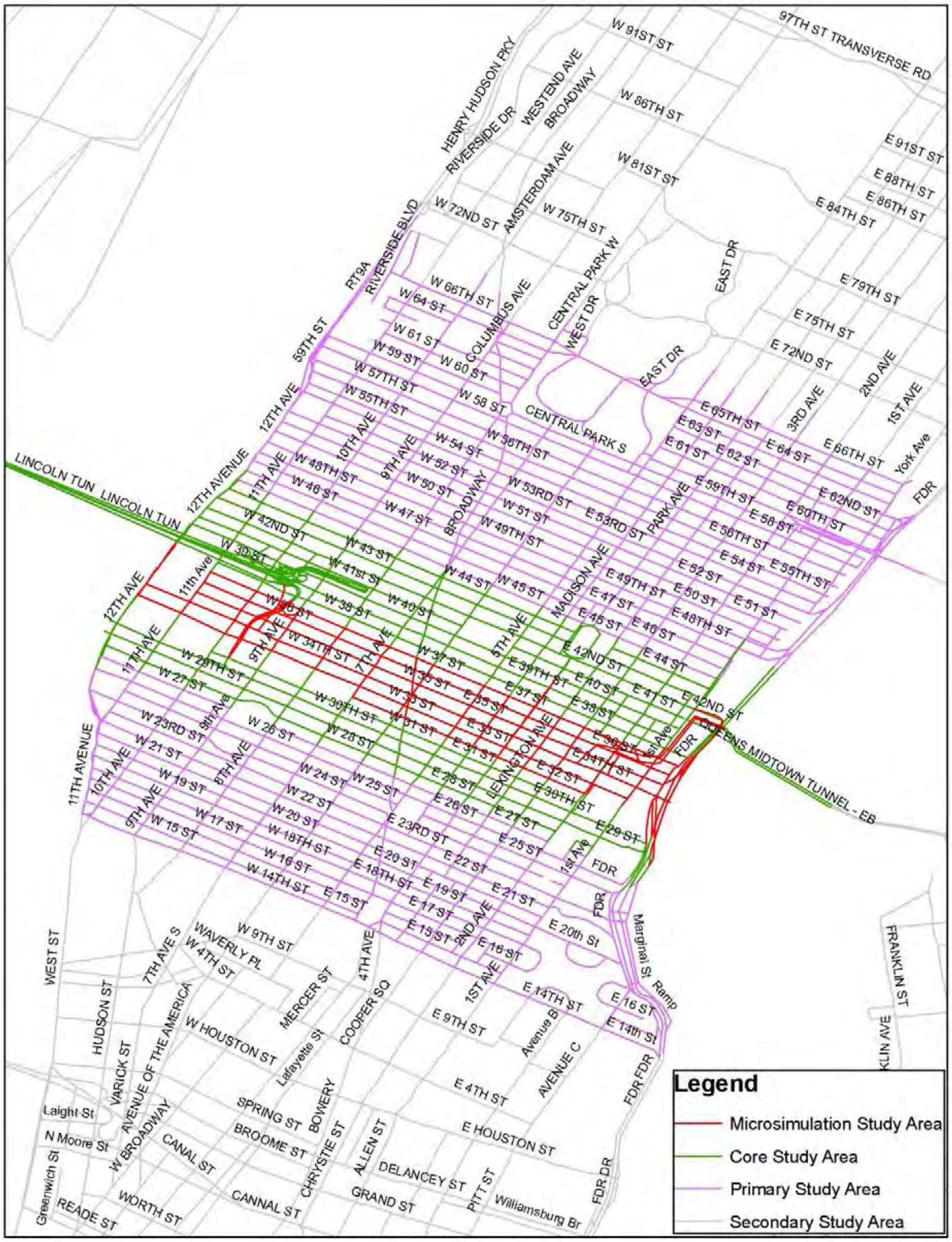


Figure A.162: Integration of Travel Demand and Traffic Operations Models

Expansion of Micro-Simulation Area

It is recognized that the detail provided by the micro-model will be of value not only in assessing reduced truck demand in the peak periods, but also in estimating traffic impacts of reduced double-parking behavior at street level. To that end, the micro-model needs to be extended, particularly for the primary study area with detail network links. While the first focus will logically be in the vicinity of large generators, a study area from 14th to 66th Streets and from the FDR to 12th Avenue has being created since then.

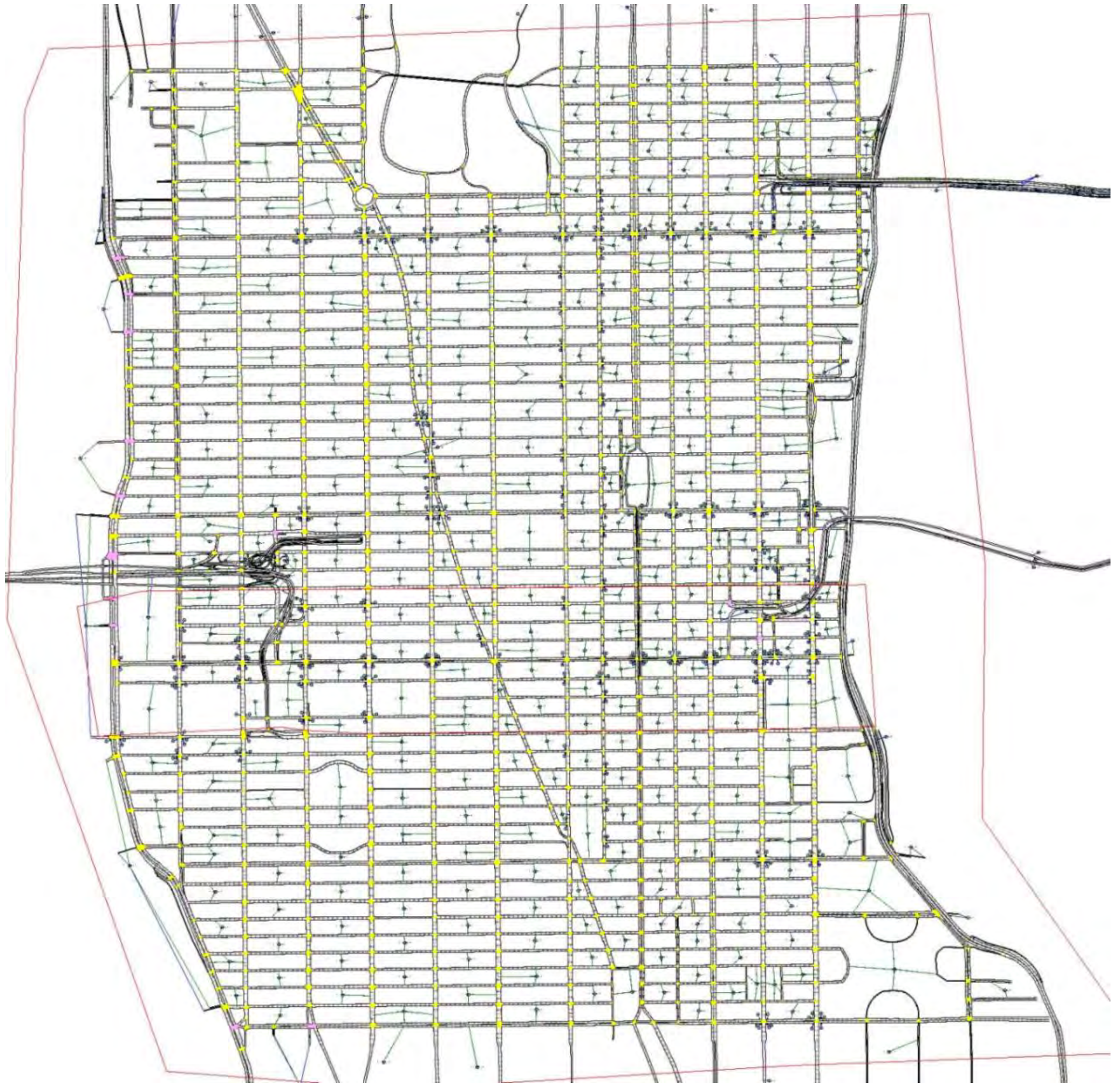


Figure A.163: Expanded Micro-Simulation Area

Network Reconfiguration for Large Area Micro-Simulation Network

The current MTM modeling framework started from the modification of BPM network to estimate the mode shifts. The resulted BPM Origin-Destination (OD) matrices were compared and scaled to zoning level to obtain traffic growth for various zoning pairs. The BPM zoning pairs were disaggregated to MTM centroids as the basis of demand estimation in the build year. Generally, the modeling structure comprised of five steps:

i. Create BPM build scenario and obtain results from subarea extraction
ii. MTM macro-simulation model validated by BPM screenline
iii. MTM meso-simulation layer validated by Screenline counts
iv. MTM meso-simulation layer in micro-simulation subarea validated by Screenline counts
v. Screenline validated MTM micro-simulation layer in micro-simulation subarea with link validation of selected 40 links

Different percentages of path assignments are permitted to combine macro-, meso-, and microscopic simulation.

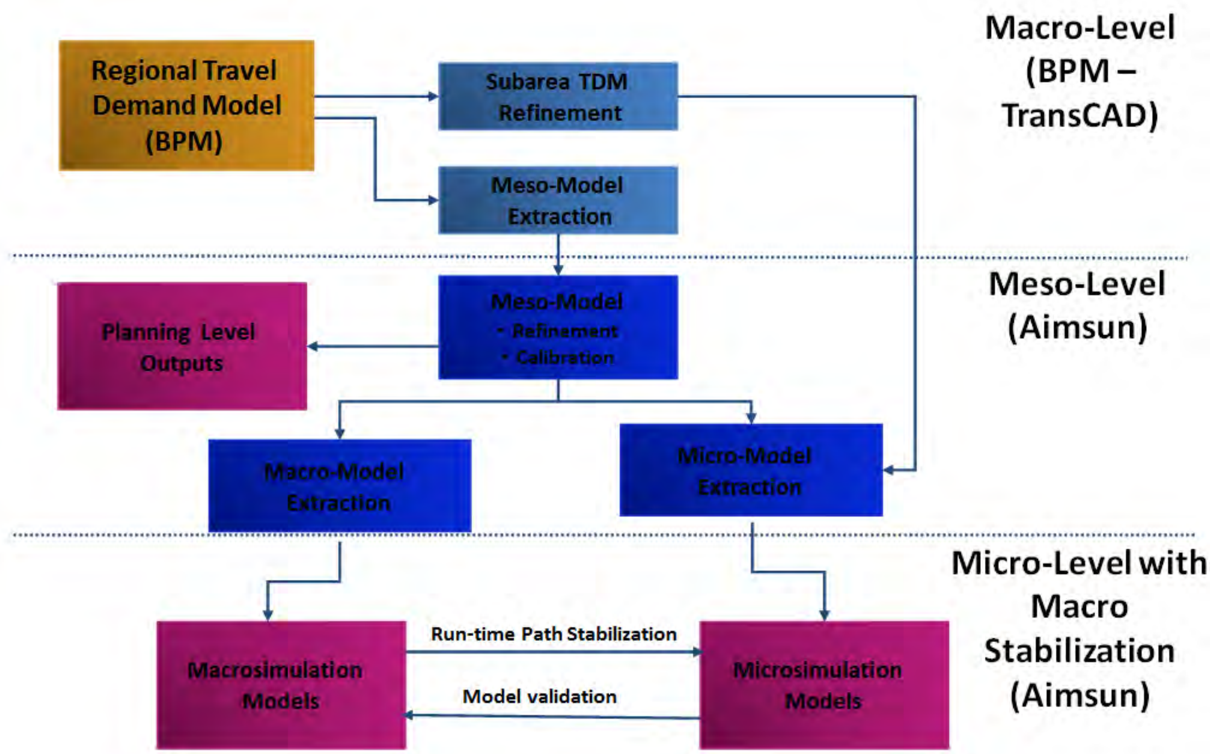


Figure A.164: Integration of Travel Demand and Traffic Operations Models For Large Area Micro-Simulation Network

Demand Estimation and Update

Network Demand Estimation Procedures

The MTM OD estimation was conducted by an Origin-Destination Matrix Estimation (ODME) procedure on the basis of BPM Seed OD Table, link counts and turning movement counts. The approach was to achieve a balance between the need to closely match observed values and the desire to maintain the structure of the BPM extracted BPM trip table. The ODME process had some unique features:

- A large coverage of traffic count data was summarized or collected to provide a more realistic representation of the operational characteristics of the transportation network;
- Taxi trips were estimated directly from TLC's Taxi-GPS data to provide a more realistic representation of the taxis flow in the network;
- New York City Planning Land Use Data (PLUTO) is to provide a more accurate estimation of activity within the primary study area as well as a reference for allocating demand from the BPM zones to the finer MTM zones**;**
- Origin-destination survey data collected by the PANYNJ and MTA to provide additional information on travel patterns at their respective facilities; and
- Time-of-day information from the activity based BPM sub-models.

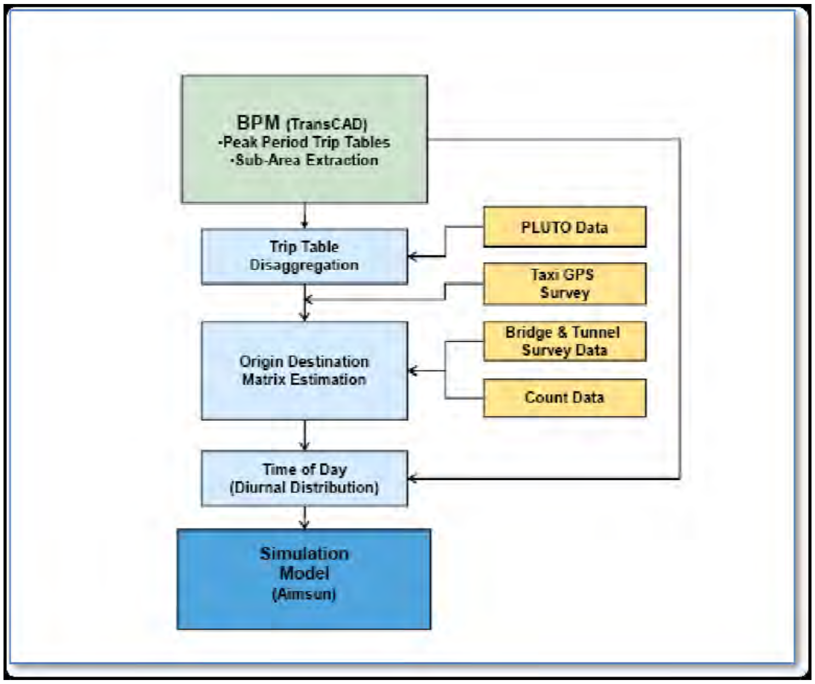


Figure A.165: Illustrated the Framework of the Origin-Destination Matrix Estimation (ODME) Process

BPM Subarea Analysis

The primary source for the mesoscopic OD trip table is NYMTC's BPM regional trip table. The 2012 conformity run was conducted on the basis of the 2005 base year OD trips table, social economic data (SED), trips generated by major projects and transportation system improvements from 2005 to 2012.

The extracted BPM trip tables are based on the BPM zone system and therefore they need to be disaggregated to the finer MTM zone system within the primary and core study areas. The BPM zone system within the core and primary study areas generally reflects block groups or census tracts, while the MTM zone system reflects individual blocks. There are ninety-one (91) BPM zones, compared to seven hundred thirty six (736) MTM zones, in the core and primary study areas. The secondary area zone system is the same zone system as the BPM.

Due to the nature of the BPM model, the extracted trip tables may include intrazonal trips; i.e.; trips that originate and destined within the same zone. The larger the BPM zone, the higher the propensity for these trips. When the BPM auto trip tables are disaggregated to the MTM zone system, these intrazonal trips become short interzonal trips. In order to avoid adjusting these trips through the ODME process, and potentially overloading intersections, with very short auto trips, the BPM Auto intrazonal trips were removed within the core and primary study areas before the trip tables were disaggregated to the MTM zone system. In addition, since the taxi trips for the MTM model are being created from the taxi GPS data, the BPM Taxi OD table was not utilized. Auto and truck BPM trip tables were disaggregated to the MTM zone system using estimates of vehicle trip ends calculated from land use data and vehicle trip generation rates.

Pluto Database

Land use data was assembled from the PLUTO database. Amongst other data, the PLUTO data contains an estimate of the gross floor area in each tax parcel that is used for commercial, residential, industrial and/or other uses, as well as the number of dwelling units.

The PLUTO database provided the basis to disaggregate BPM demand zones. The estimated BPM subarea OD pairs were divided to multiple production or attraction zones of Aimsun centroids in proportion to the generated trips from PLUTO data.

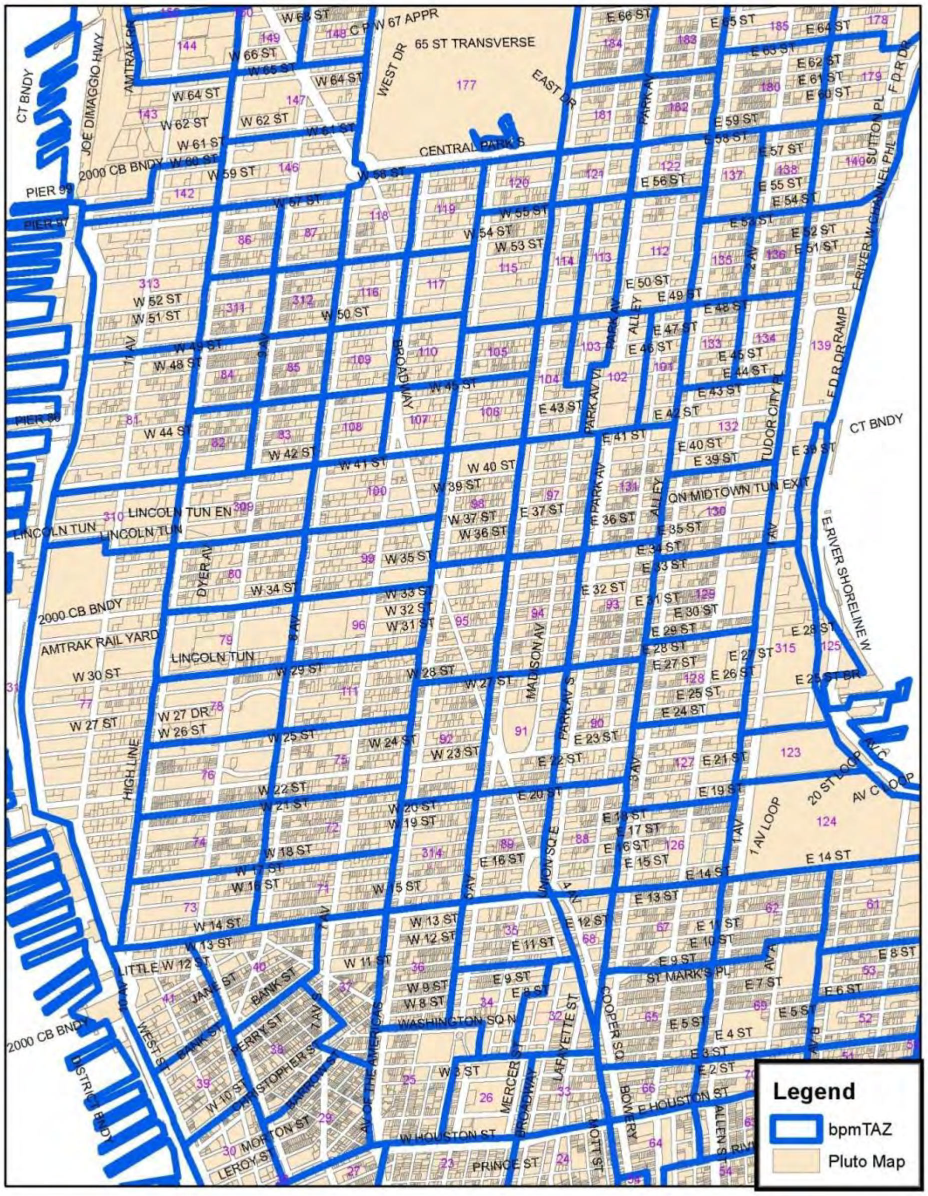


Figure A.166: Illustration of Pluto Map in the study area

Demand Estimation in the Mesoscopic Network

The initial trip table for the mesoscopic model was extracted from the BPM subarea, and the resulting flows at the boundaries of the MTM study area that were reviewed against currently available and newly collected traffic counts. As with previous mesoscopic model, development efforts, there was a need to undertake a trip table adjustment utilizing ODME techniques using the BPM extracted subarea trip table as an input ("seed"). This type of adjustment encompasses techniques that range from proportional fitting to maximum entropy and linear optimization and generally pays close attention to those observations that the analyst thinks has greatest value (e.g. high link volumes or links of special interest such as the boundary of the core study area or 34th Street itself). The overall objective of the ODME was to provide the mesoscopic model with OD matrices by vehicle type (auto, taxi, and truck) for each time slice during the entire simulation period that is consistent with ground counts and available regional facility surveys.

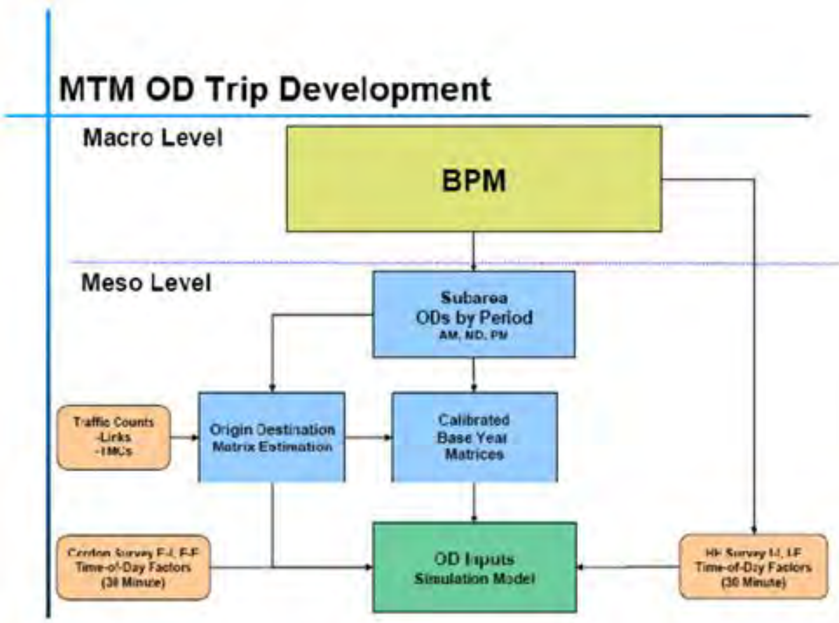


Figure A.167: Manhattan Traffic Model (MTM) OD Trip Development

Micro-Simulation Demand Interpolation

The previous MTM microscopic model only extended from 32nd Street to 37th Street. For the expanded micro-simulation area from 14th Street to 66th Street, new OD demand matrices need to be estimated. In addition, the MTM model did not have a nighttime scenario. The night network had to be created from scratch. To keep the regional trip patterns, the OD demand of micro-simulation model should be estimated from the link counts and NYBPM OD demand as seed matrices. The base model of NYBPM has been extracted for the micro-simulation subarea from 14th Street to 66th Street. The importance of regional pattern was proven from the summary of the Origin Destination Matrices estimation (ODME) procedure. The following map illustrated the process of OD matching from macroscopic TAZ zones to microscopic Aimsun centroids.

Figure A.168: Illustration of Aimsun Microscopic OD Zones and Centroids

The OD Trips were loaded into Aimsun network via centroids and centroid links. The MTM centroid structure was originally build to directly use taxi-GPS record at each link. It was found that too many Internal-Internal trips (40%) were assigned during both AM and PM periods which caused unrealistic behavior. Therefore, new trip tables were created for primary area. Various alternatives were considered and NYBPM trip tables were still selected for use as seed in micro-simulation. The BPM sub-area trip tables were then manually adjusted and modified as part of the calibration effort. The microscopic and macroscopic network properties were also revised in order to achieve a good fit with traffic count data and speed data. Additional validation procedures were conducted to adjust the OD trips matrices.

Table A.109: OD Trip Distribution by Trip Type

Trip Type	OD Trips	Percentage
Trip Type (4 PM -5 PM)		
Internal- Internal	12643	15.40%
Internal - External	28776	35.00%
External - Internal	21393	26.00%
External - External	19519	23.70%
Total	82331	100.00%
Trip Type (5 PM - 6 PM		
Internal- Internal	9488	12.00%
Internal - External	28356	36.00%
External - Internal	22282	28.30%
External - External	18629	23.70%
Total	78755	100.00%

Network Validation/Recalibration Process

Before the mesoscopic and microscopic models were used to evaluate the future traffic operations, they needed to be adjusted to ensure that they represent traffic conditions in the study area. The process was collectively referred to as calibration and validation. The procedure entailed the adjustment of network attributes and co-efficients of embedded relationships in order to replicate a certain set of observed conditions.

The calibration/validation process generally entails the adjustment of network attributes, trip tables, and co-efficients of embedded relationships in order to replicate a certain set of observed conditions. The calibration process accounts for the impact of "un-modeled" site-specific factors through the adjustment of the parameters included in Aimsun. Therefore, model calibration/validation involves the selection of a few parameters and the repeated operation of the model to identify the best values for those parameters that replicate a certain set of observed conditions.

The key steps in the process include:

- Identification of necessary model validation targets;
- Selection of the appropriate calibration parameter values to best match locally measured street, highway, freeway, and intersection capacities;
- Selection of the calibration parameter values that best reproduce current route choice patterns;
- Validation of the mesoscopic model at the boundaries and within the microscopic model study area;
- Validation of the microscopic model utilizing inputs from the mesoscopic model; and
- Validation of the models against system performance measures, such as travel time, delay, and queues.

A three-step strategy was used for calibrating traffic operational models:

1). **Capacity Calibration –** An initial calibration performed to identify the values for the capacity adjustment parameters that cause the model to best predict and reproduce observed traffic capacities in the field. A global calibration was performed first, followed by link specific, fine tuning.

2). **Route Choice Calibration –** Alternative paths make route choice calibration important. A second calibration process was performed with the route choice parameters, where a sample of OD pairs was selected and the validity of the paths were reviewed based on local knowledge.

3). **Operational Calibration** – The overall mesoscopic and microscopic model estimates of system performance (e.g., travel times and queues) were compared to the field measurements. Finely tuned adjustments were made to selected variables to enable the model to better match the field measurements.

Table A.110: Summary of Microscopic Model Validation Criteria and Targets

Validation Criteria and Measures	Validation Acceptance Targets
Selected approach volumes (maximum 40) – peak period	> 85 percent of links with less than 700 vph, within 30 percent of observed counts
Selected approach volumes (maximum 40) – peak period	> 85 percent of links with flows between 700 vph and 2,700 vph, within 15 percent, of observed counts
Roadway segment travel times	> 85 percent of cases (for peak periods) should be within the observed minimum and maximum sample run values
Microscopic/core boundary volumes	Within 15 percent (for peak and analysis periods)
Visual audits bottlenecks: visually acceptable queuing	To analyst's and client's satisfaction (for peak periods)

Major Improvement for the Expansion of Micro-Simulation Network

For a huge micro-simulation network with more than 800 intersections, the simulation runs would be not going through with more than two million OD pairs with thousands of pedestrians at each intersection in the study area. More efforts were placed on the micro-simulation model to reach the validation criteria.

Removal of Redundant Centroids within the Primary Area

The MTM model provided included centroids placed in each block representing sources and sinks. While this approach provides coverage in each block, it took an enormous amount of time to run simulations. In most of the cases, the simulation replications cannot run through due to the complexity of the OD demand matrices and centroid link connections. The MTM centroid structure was shown on Figure A.169 as follows.

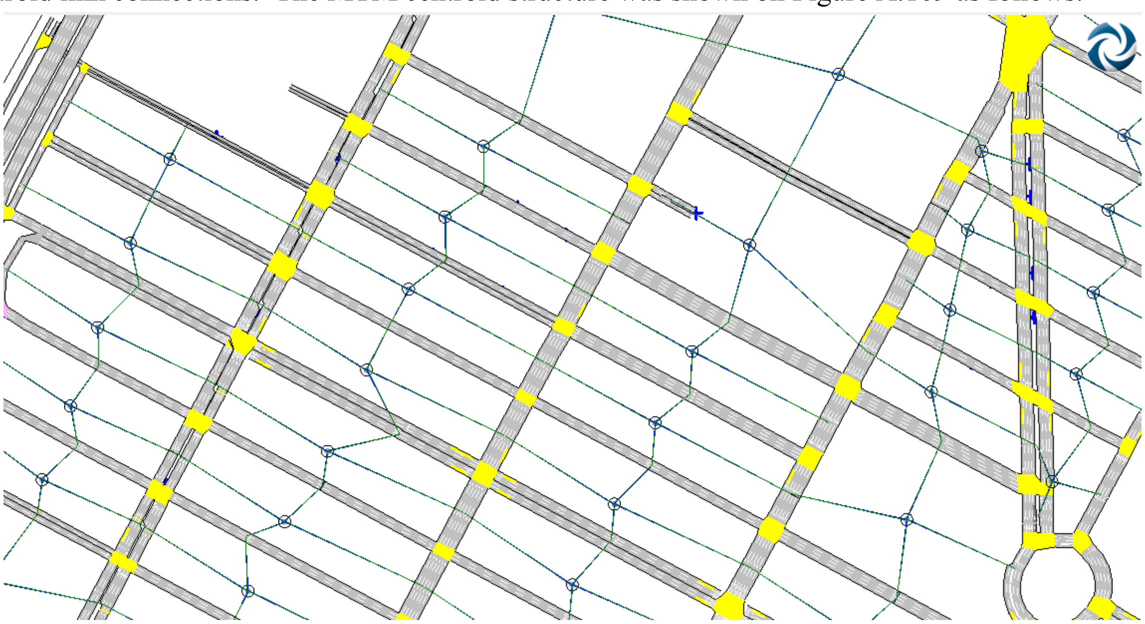


Figure A.169: Centroid Structure of Previous MTM Model

Centroids within the primary area are placed in each block. This creates a redundancy since one street is usually connected by two centroids. Removing one centroid and transferring the data to nearby centroids (North, East, West and South) allows the same coverage.

Procedure:

- List the centroids to be removed and the centroids to be assigned.
- Write a Python script to process all the matrices in MTM.
- Remove the centroids

Result:

- The process reduced the size of matrices since existing short trips between the surrounding centroids were removed as part of the redundant OD pairs.
- The trips were assigned to nearby centroids to avoid fractional trips.
- Avenue centroid connectors created problems and unexpected behavior. They were removed according to the parking garages distributions. After avenue connector removal, the accuracy and run speeds of models were improved.

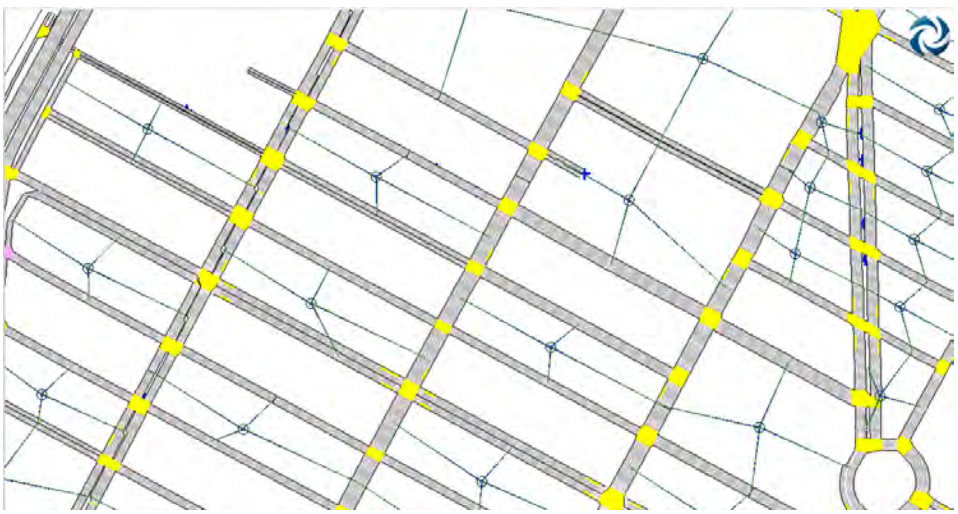


Figure A.170: Micro-Simulation Network Structure after Removal of Redundant Centroids

This step improved the model accuracy and allowed more control over flows in and out from each centroid within the primary area. Upon completed, the micro-simulation model was able to run though the whole peak periods in current available hardware configurations.

Placement of Parking and Bus Lane Reservations on the Links

The parking and bus lane reservations were not specified in MTM, resulting in overestimation of the link capacities. Parking and bus lane reservations were placed on the links based on the aerial photographs and field survey of Midtown Manhattan.

Correction of Bus Routes and Behavior Simulation

Bus routes were reviewed and corrections to the routes were made, particularly to ensure that a realistic number of buses are leaving Manhattan via Lincoln Tunnel. Buses coming from the Port Authority bus terminal via the bus ramp reduce the tunnel capacity available for vehicles which queue along 9th and 11th Avenues. Approximately 500 to 700 buses per hour enter the tunnel during PM peak period.

Data Consolidation and Reduction

Real data used in MTM development was reviewed and inconsistencies were identified. These inconsistencies are either due to data collected at different time periods or errors in collection/reduction. In order to correct these problems and aid with data reduction, an excel spreadsheet utility was developed. The corrections and the selection of the source to represent the data for a link were done using this spreadsheet. After combining eight different sources, the database included 1362 links. Balancing this large data set was not possible given the time frame and budget, but instead, composite flow maps were prepared after eliminating the inconsistencies.

Micro-Simulation Network Development and Update

For the purpose of comparing the peak hour travel conditions and off-hour travel conditions, NYCDOT developed a new nighttime scenario as the base of the typical off-hour network. The development of the nighttime model followed the above procedures of network expansion, BPM disaggregation, OD estimation, network calibration and validation. The night model showed light traffic in most of the area except Lincoln Tunnel and 59th Street bridge area. Various updates were made to reflect network changes from the 2009 MTM development year to the 2012 off-hour base year.

Network Geometry Update

Network geometry was updated in 2012 for all of the curbside activities such as revised parking regulations, roadway closures due to long-term constructions, or specific projects. For example, Broadway was fully/partially closed around Herald Square and Times Square. For the purpose of safety and traffic calming in midtown, other roadway closures were also implemented near 42nd Street and other locations. The plaza program has kept the closing of redundant street links to provide public spaces. The Bike Share program has also occupied many shoulder lanes, in addition to bike lane alignment on many surface streets. The geometry update process involved the spot check of nearly 1,000 intersections and selected update of over 200 intersections.

Traffic Signal Update

All of the traffic signals within the 14th to 66th Street micro-simulation boundary were updated in 2013. About 300 traffic signals were revised due to the implementation of the new signal phases or offsets in the recent two years.

Implementation of Pedestrian Simulation in the Key Intersections

In order to reflect more realistic turning behavior, over 100 key intersections were updated with pedestrian data during peak hours, including intersections with significantly high pedestrian volume such as 7th Avenue and 42nd Street. As a result of pedestrian activities, more detail behaviors are modeled on the micro-simulation level, such as vehicular behavior waiting for a gap of pedestrian flow on crosswalks, double left-turn/ right-turn behaviors, temporary blockage due to length of bus/trucks, complicated intersection channelization, and effect of pedestrian walking/flashing “Don’t Walk” periods.

Modeling of Double Parking Events

In Manhattan, on-street parking capacity is limited while the demand is very intense during the daytime periods. Most of the curb parking spaces are already fully occupied during the peak periods. In order to find one or two nearby available spots, many drivers keep circling street blocks. The trucks usually have to stick to the destination stores for loading and unloading. The unavailability of curb parking spaces leaves no options for delivery trucks but to double park in front of the delivery destination. A double parked truck usually occupies one travel lane and has a tremendous impact on the intersection or link capacities. Various double parking events were coded in the micro-simulation network to reflect the double parking behavior. The basis of double parking frequency is generally based on the survey results displayed in Table A.111.

Table A.111: Parking Demand and Capacity (2-Hour AM Peak Period)

ZIP	Area	Employment	Establishment	AM Freight Truck	PM Freight Truck	Estimated AM Parking Slots Needed	Estimated PM Parking Slots Needed	Total Parking Slots Needed	Estimated Parking Slots Available	Occupancy Rate	Double Parking All (vehs)
10001	0.36	166,510	8,418	16,716	14,557	635	1,660	2,295	1,670	137.40%	56
10010	0.32	72,110	3,008	5,143	4,455	195	508	703	927	75.80%	17
10011	0.67	66,075	3,820	7,064	5,989	268	683	951	2,380	40.00%	23
10016	0.35	119,843	6,648	10,910	9,635	415	1,098	1,513	1,646	91.90%	37
10017	0.12	191,724	6,984	10,747	9,307	408	1,061	1,469	943	155.80%	36
10018	0.39	124,665	6,672	14,607	14,494	555	1,652	2,207	958	230.50%	54
10019	0.45	171,407	5,572	9,854	8,667	374	988	1,363	1,746	78.10%	33
10022	0.3	170,992	7,242	11,543	10,157	439	1,158	1,597	1,579	101.10%	39
10036	0.36	153,119	6,271	15,146	8,287	576	945	1,520	1,471	103.40%	37
Sub-total				101,730	85,548	3,866	9,753	13,618	13,319		332

The related study by RPI demonstrated the distribution of the following parking violations (Jaller et al., 2013b)

Table A.112: Parking Violation Survey by RPI

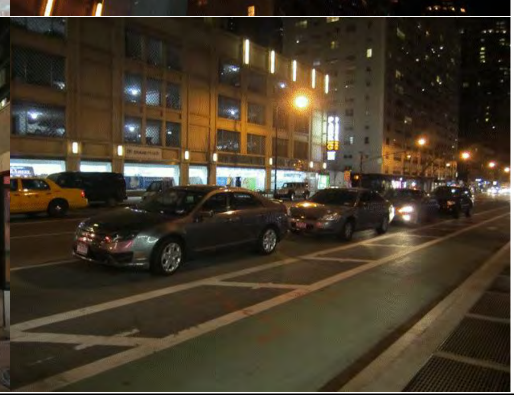
Description		Number of Commercial Vehicles	Percentage of Lawful and Unlawful Parking
Legally Parked		284	75.94%
Parking Violations		90	24.06%
Further Breakdown			
	Parking Meter Expired or Not Paid	41	45.56%
	Parking Sign Violation	18	20.00%
	Fire Hydrant	16	17.78%
	Double Parking	9	10.00%
	Bus Stop	3	3.33%
	Driveway	2	2.22%
	Near Crosswalk	1	1.11%
	Handicap	0	0.00%
	Parked Against Traffic Direction	0	0.00%
Total		374	100%

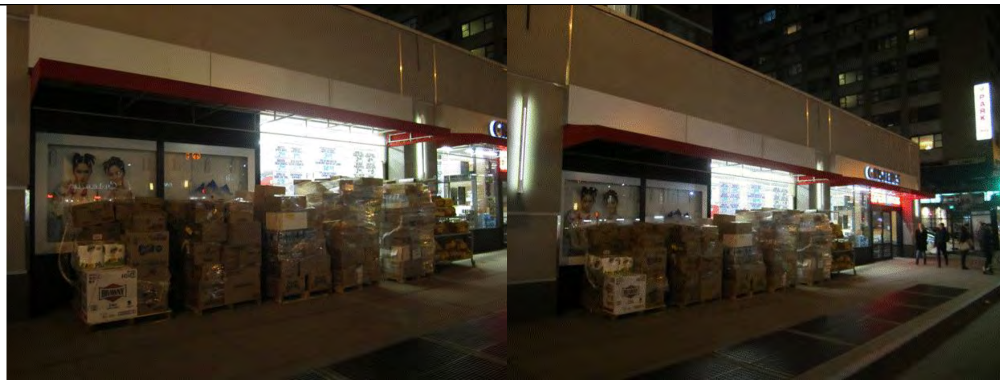
It would provide a major benefit to relieve congestion in Manhattan by diverting double parked trucks from peak hours to off-peak hours. With no detailed data indicating the location and frequency of double parked trucks, the micro-simulation model generally assumed that the double parked trucks would effectively block travel lanes up to 100 truck hours in the network in the peak hour. Among these 100 truck hours, about five truck hours would be relocated to off-hour under the incentives of $10,000 per receiver. As indicated by various studies, the double parked trucks would generally be ticketed heavily when loading and unloading in the peak hours. The actual percentage of double parked trucks among the diverted trucks should be generally higher than the average level. The assumed values were only intended to provide a conservative estimation without detailed data before actual implementations.

APPENDIX 3B

Noise Readings

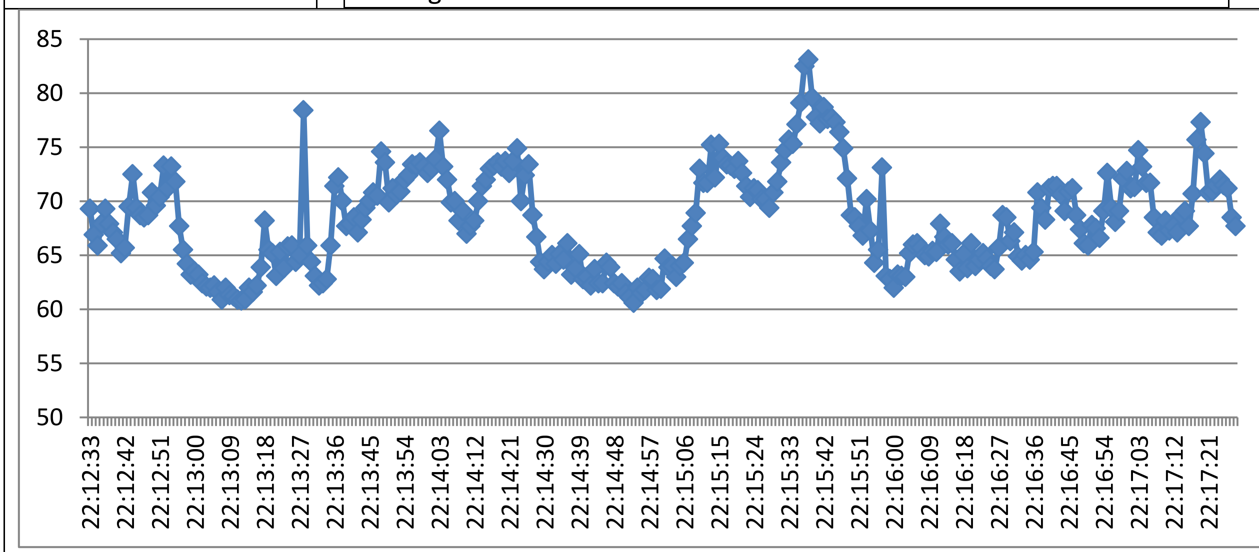
OHD Program – Implementation Phase: OHD Location Analysis			
Establishment Information			
Location ID:	GRI-1403	Type of establishment:	Supermarket
Establishment name:	Gristedes Supermarket #34		
Address:	907 8th Avenue, NY, 10019 (54th Street)		
Pictures:			





Data Profile	Noise data collection at intersection

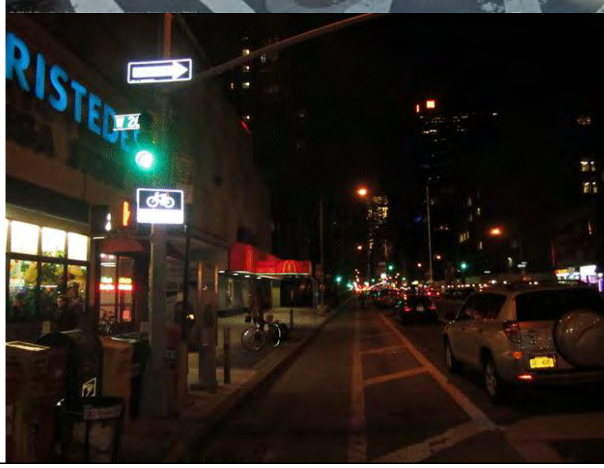
Start Time	22:12:33
End Time	22:17:28
Max	83.10 @ 22:15:38 dBA
Min	60.60 @ 22:14:53 dBA
Average	68.32



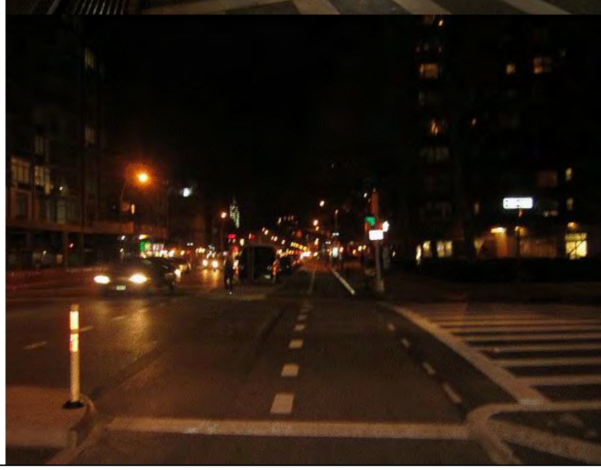
Comments:	This store is located at the intersection of Broadway and 103rd St., with entrance at Broadway. Various instances of the delivery process were recorded from the pick-up of pallets using an electric handcart inside the truck, while using the lift, and then moving from the back of the truck to the store's entrance. In addition, the process of breaking up the pallets and transporting them to the inside of the store using manual carts was recorded.

OHD Program – Implementation Phase: OHD Location Analysis			
Establishment Information			
Location ID:	GRI-1441	Type of establishment:	Supermarket
Establishment name:	Gristedes Supermarket #562		
Address:	307 West 26th Street, NY, 10001 & 8th Avenue		

Pictures:




RISTEDES ENTRANCE




GRISTEDES
ENTRANCE
WELCOME
SERVICE
UPRIGHT CITIZENS BRIGADE THEATRE

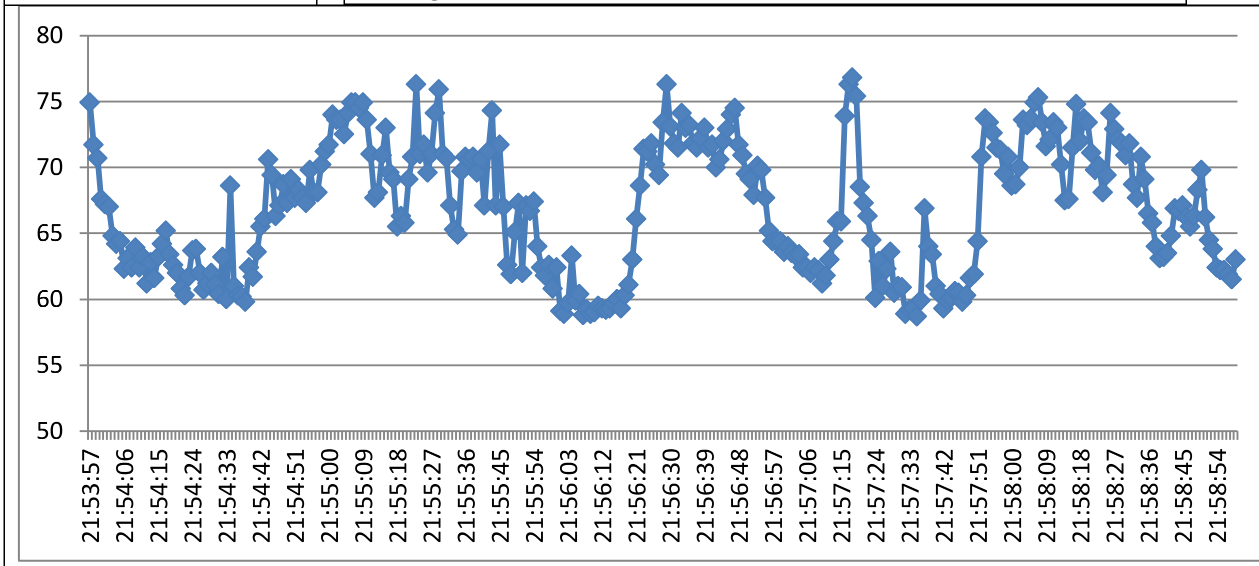

NO PARKING
8AM-6PM
MON FRI
DON'T LITTER
11AM TO
12:30PM
MON
& THURS


DELIVERIES
ONLY!
VIOLATORS
WILL BE
TOWED

Data Collected:	Pictures and ambient noise data 2 minutes of ambient noise at entrance of off-street loading dock on 26th St 5 minutes of ambient noise at corner of 26th St and 8th Avenue

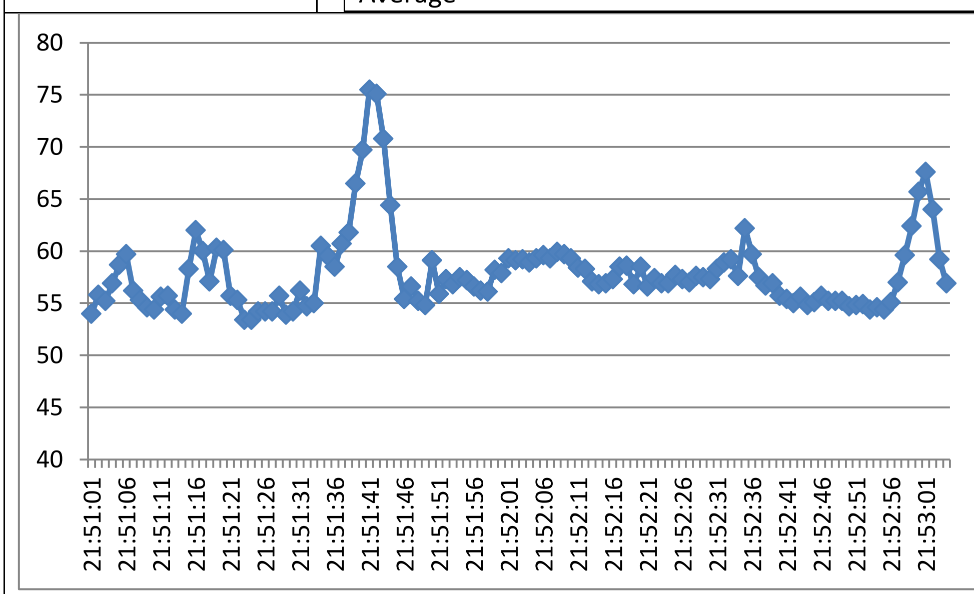
Data Profile	Noise data collection at intersection

Start Time	21:53:57
End Time	21:58:59
Max	76.80 @ 21:57:18 dBA
Min	58.70 @ 21:57:35 dBA
Average	66.84

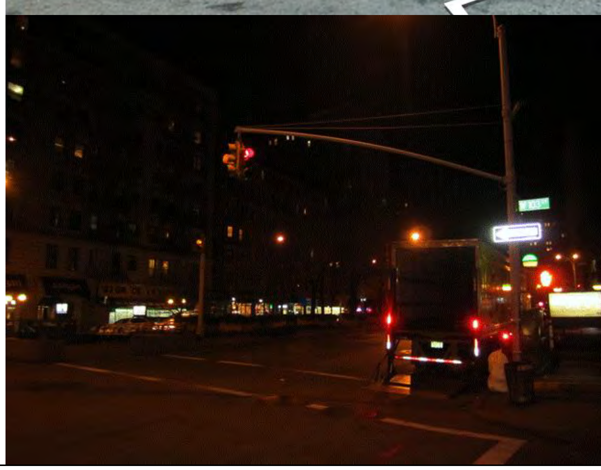


Data Profile	Noise data collection at loading dock location

Start Time	21:51:01
End Time	21:53:04
Max	75.50 @ 21:51:41 dBA
Min	53.40 @ 21:51:23 dBA
Average	57.89

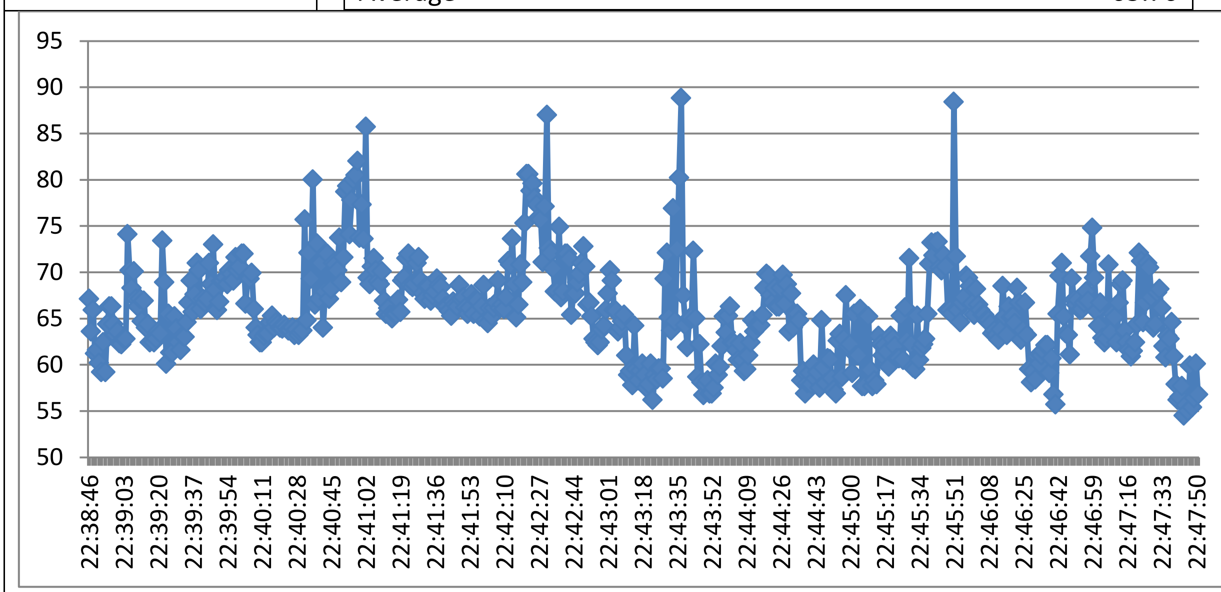


Comments:	At the time of the visit, there was a noticeable difference between the vehicle traffic flows between those traversing 26th St. and 8th Ave		
Establishment Information			
Location ID:	GRI-1445	Type of establishment:	Supermarket
Establishment name:	Gristedes Supermarket #601		
Address:	2700 Broadway, NY, 10025 (103rd Street.)		
Pictures:			



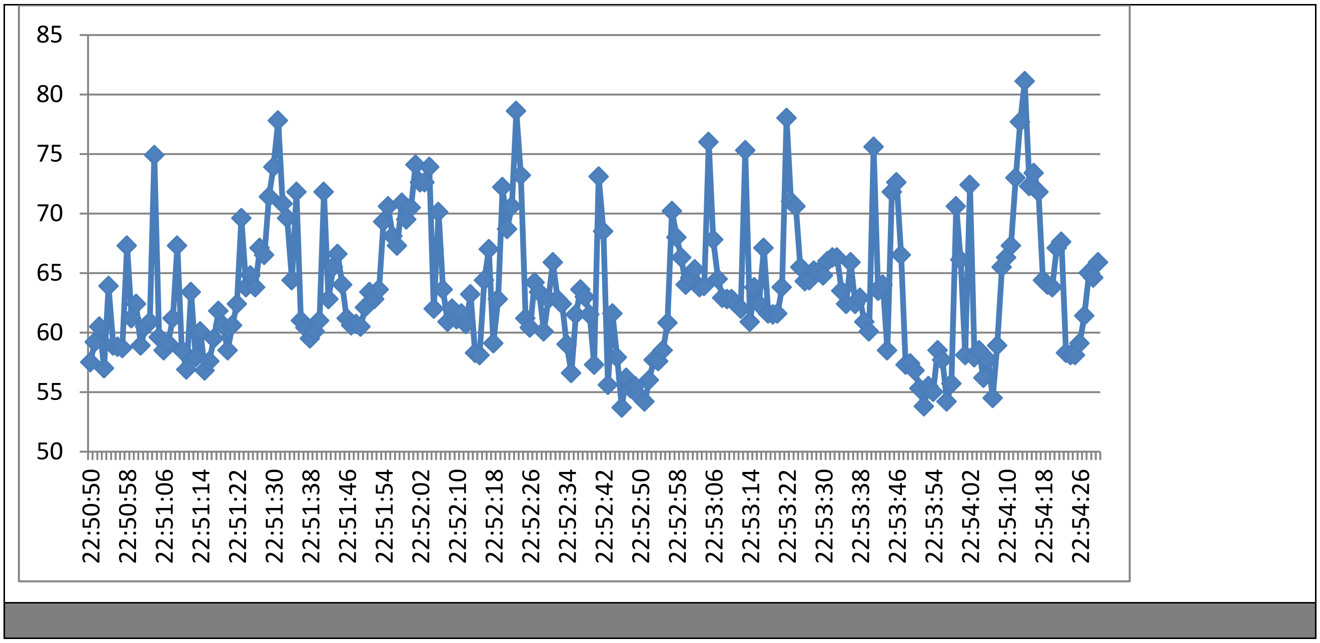
Data Collected:	Pictures and delivery truck/operations noise data before switch to OHD
Data Profile:	Noise data collection at intersection

Start Time	22:38:46
End Time	22:47:51
Max	88.80 @ 22:43:37 dBA
Min	54.50 @ 22:47:44 dBA
Average	65.76



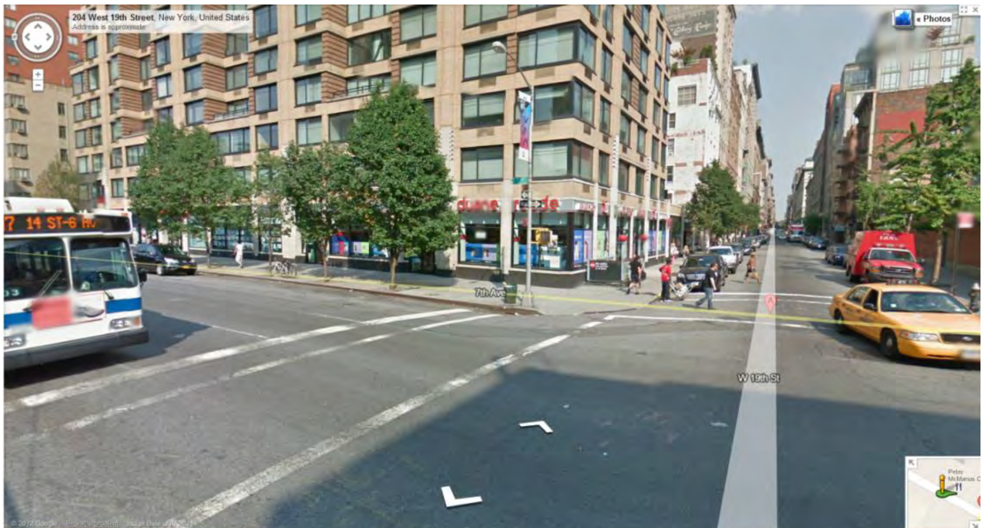
Data Profile:	Noise data collection while moving pallets on the sidewalk

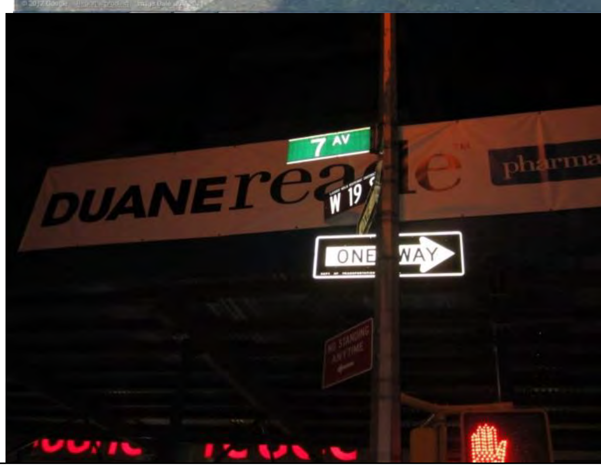
Start Time	22:50:50
End Time	22:54:30
Max	81.10 @ 22:54:14 dBA
Min	53.70 @ 22:52:46 dBA
Average	63.63

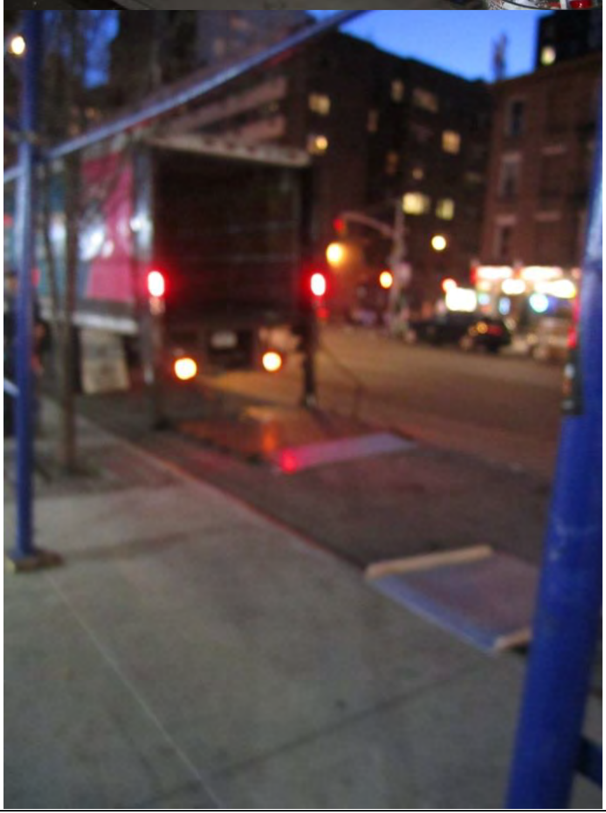

85
80
75
70
65
60
55
50
22:50:50
22:50:58
22:51:06
22:51:14
22:51:22
22:51:30
22:51:38
22:51:46
22:51:54
22:52:02
22:52:10
22:52:18
22:52:26
22:52:34
22:52:42
22:52:50
22:52:58
22:53:06
22:53:14
22:53:22
22:53:30
22:53:38
22:53:46
22:53:54
22:54:02
22:54:10
22:54:18
22:54:26

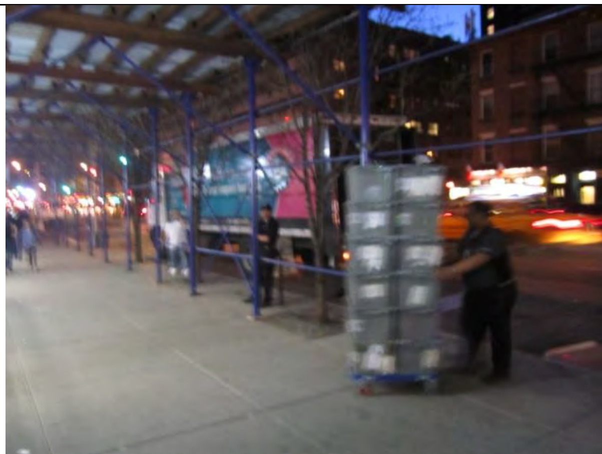
OHD Program – Implementation Phase: OHD Location Analysis			
Establishment Information			
Location ID:	DR-1907	Type of establishment:	Pharmacy
Establishment name:	Duane Reade		
Address:	19th St and 7Ave		

Pictures:



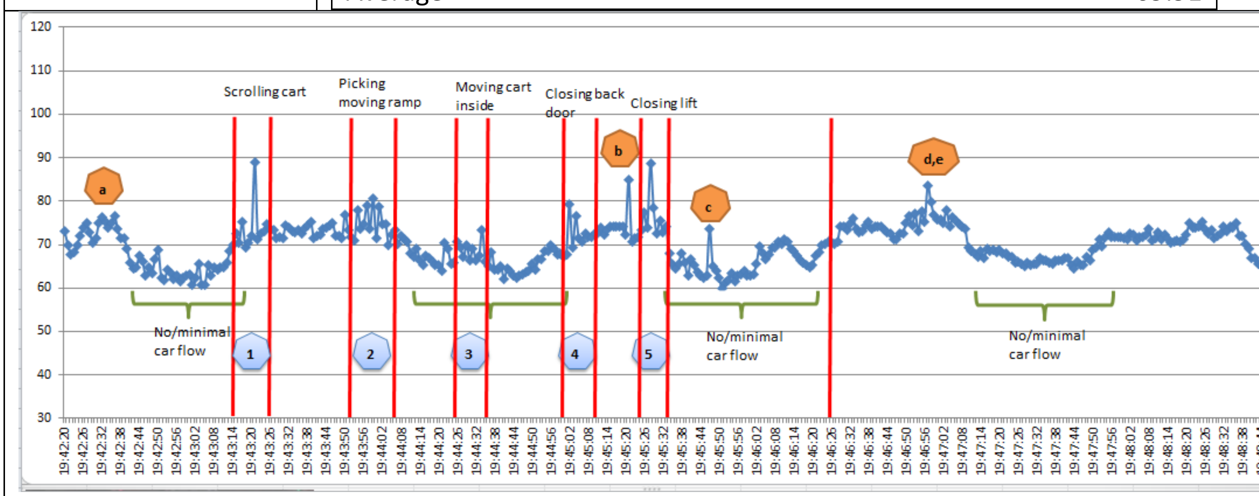






Pictures:	
Data Profile:	Noise data collection at intersection

Start Time	19:42:20
Max	89.00 @ 19:43:21 dBA
Min	59.90 @ 19:45:51 dBA
Average	69.91



OHD Program – Implementation Phase: OHD Location Analysis			
Establishment Information			
Location ID:	FD-T01	Type of establishment:	On-Street
Establishment name:	Fresh Direct Truck Intercept		
Address:	State St, between Bond and Hoyt, Brooklyn, NY		
Data Collected:	Pictures and Noise data collection from truck delivering at night at a residential area		
Data Profile:	Noise data collection at intersection		

Start Time	10-04-2012,21:29:10	
Max	71.00 @ 10-04-2012,21:31:51 dBA	
Min	46.60 @ 10-04-2012,21:30:45 dBA	
Average		54.09