OVERALL IMPACTS OF OFF-HOUR DELIVERY PROGRAMS IN THE NEW YORK CITY METROPOLITAN AREA

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ABSTRACT

This paper discusses the chief findings of the research conducted on policies to foster off-hour deliveries (OHD) in the New York City metropolitan area that estimated the overall impacts of an eventual full implementation of an OHD program. As part of the research, the team designed a system of incentives to the receivers of deliveries, combined with remote sensing monitoring based on Global Positioning System (GPS) enabled smartphones, to induce a shift of deliveries to the off-hours (7PM-6AM). The concept was pilot tested in Manhattan by 33 companies that switched delivery operations to the off-hours for a period of a month. At the in-depth interviews conducted after the test, the participants reported being very satisfied with the experience. This is the first real life trial of the use of financial incentives to receivers, as an alternative to road pricing schemes that target freight carriers. The analyses indicated that the economic benefits of a full implementation of an OHD program are in the range of $147-$193 million per year corresponding to travel time and environmental pollution savings for the regular hour traffic, and productivity increases to the freight industry. The pilot test also highlighted the great potential of unassisted OHD, i.e., OHD made without personnel from the receiving establishment present, as almost all the participants that used this modality decided to continue receiving OHD even after the financial incentive ended.

KEY WORDS: Off-hour deliveries, Freight transportation modeling, Transportation Economics

INTRODUCTION

The research conducted on the urban delivery industry's response to freight road pricing (Holguín-Veras et al., 2006) produced findings that challenged long-held assumptions. It showed that: (1) the ability of carriers to unilaterally change delivery times is limited as it necessitates the concurrence of the receivers (which tend to prefer regular hour deliveries as they could take advantage of the staff at hand); and, (2) cordon tolls are not likely to be effective in inducing a switch to the off-hours, as most segments of the urban freight industry cannot pass toll costs to their customers depriving them of the price signal needed to effect a change. The data from the Port Authority of New York and New Jersey indicate that: (1) only about 9% of carriers could pass the toll costs to their customers; and (2) when carriers were asked about why they did not change behavior in response to time of day tolls, about 70% of them cited "customer requirements" as the reason (Holguín-Veras et al., 2006). In essence, the receiver is the key decision maker.

Further analyses (Holguín-Veras, 2008) concluded that the difficulties that carriers have in passing cordon time-of-day tolls to their customers reflect a highly competitive market with delivery rates equal to marginal costs. Since the cordon toll is a fixed cost—as it does not depend on the unit of output—it does not enter in the rates. The empirical data confirmed that only the market segments with market power (i.e., carriers of stone/concrete, wood/lumber, food, electronics, and beverages) could pass toll costs in a meaningful way (Holguín-Veras, 2008). The key insight is that, since the price signal only reaches the receivers in those cases where the carrier has market power (though in a diluted fashion because the toll costs are allocated among the multiple receivers in the tour), carrier centered pricing policies are not as effective as they need to be because receivers have no incentive to change behavior. It follows that new policy paradigms—that specifically target the receivers to induce them to switch to the off-hours—are needed. The effectiveness of these policies has been established by the behavioral research conducted (Holguín-Veras et al., 2007; 2008).

The fundamental tenet of this paper is that the key to inducing a shift of truck traffic to the off-hours is to convince receivers to accept off-hour deliveries (OHD) by either providing incentives in exchange for their commitment to OHD; or by fostering the use of concepts such as unassisted OHD that do not require receivers to provide staff to handle deliveries during the off-hours. Since the carriers stand to benefit from doing off-hours work (because OHD are 20-30% cheaper than regular hour deliveries, and lead to much reduced parking fines that, in New York City, average $500-$1000 per truck/month for regular hour work), they would be glad to do OHD as long as a sufficient number of receivers are willing to accept OHD (Holguín-Veras, 2006). Inducing receivers to accept OHD would: (1) remove the barrier that prevents many carriers from doing OHD; (2) lead to significant shift of truck traffic to the off-hours; (3) reduce congestion and improve environmental conditions; and (4) enhance the competitiveness of the urban area as business activities will be more productive and efficient.

This paper discusses the chief findings of a research project funded by the United States Department of Transportation's Remote Sensing Program that estimated the overall impacts of an eventual full implementation of an OHD program, and the results of the first real life trial of the use of financial incentives to receivers as an alternative to road pricing schemes that target carriers. The paper provides a succinct account of the results from the OHD pilot test conducted (Chapter 2), and the anticipated economic impacts of a full implementation (Chapter 3). Other publications discuss the technical details of the modeling and economic research conducted (Holguín-Veras et al., 2007; Holguín-Veras, 2008; Holguín-Veras et al., 2008; Holguín-Veras, 2009; Silas and Holguín-Veras, 2009b). A conclusion section summarizes key findings.

PILOT TEST RESULTS

The OHD pilot test was organized around three industrial partners: (1) Foot Locker and New Deal Logistics; (2) Sysco and a sample of its customers; and (3) Whole Foods Market and a sample of its vendors. In all cases, these partners switched their distribution chains to the off-hours for at least a month. In total, about 25 receivers (30 receivers if partial participation is counted) and eight carriers/vendors participated in the test. About half of the receivers conducted staffed OHD (with staff present to accept the deliveries), while the other half did unassisted OHD (the receivers gave a store key to drivers). Since there were no interactions among the industrial partners, the pilot tests were run independently of each other. These partners committed a significant amount of effort as high level executives and, in some cases, their entire logistic teams participated in dozens of conference calls discussing the preparations for the pilot test. Although the team gave the partner carriers a token payment of $3,000—as a show of appreciation—this amount did not cover even a fraction of their staff time. Their investment in this effort provides clear evidence of the industry support for the concept.

The participating receivers were provided with a financial incentive of $2,000 for successful participation in the pilot test. This incentive was larger than the ones considered during the research work—which are associated with a long term commitment to off-hours—to compensate for the setup costs associated with switching from the regular to the off-hours at the beginning of the pilot, and then back to the regular hours upon completion. The rest of the carriers were given an incentive of $300 per truck participating in the pilot test to compensate for the corresponding setup costs. Obviously, since they stand to benefit from OHD, the amount of the incentive could be smaller than the one for receivers.

Data Collection Scheme

The remote sensing component was undertaken with Global Positioning System (GPS) enabled smartphones and the Copilot|Live turn-by-turn navigation software. The smartphones were configured in such a way that the only action required by the driver was to turn the phone on at the beginning of the route; no further interaction between the driver and the smartphone was required while driving. Safety was of the upmost concern and the team ensured that the smartphone would not be a distraction to the driver. Usage and safety information was provided when the phone was delivered by a representative of ALK Technologies. In cases where the companies already had GPS equipment, they were given the option of sharing the data with the team instead of using the phones. A noticeable number of participants elected to do that, and some even provided data for the entire metropolitan area, not just those involved in the pilot test. This enabled the team to obtain background performance data for a much larger fleet of trucks. In some cases, passive GPS data loggers were used as backup. The team analyzed the data to obtain estimates of travel speeds, delays, standard deviations, and other performance measures.

Productivity Impacts

This section discusses the results obtained during the pilot test, which are contrasted with the base case conditions in terms of productivity. The productivity analyses focus on the travel speeds from depot to the first customer in Manhattan, from customer to customer; and the service times (time spent at a given location making deliveries). The team separated the travel to the first customer from the customer-to-customer trips, because they have different characteristics (the former is a relatively long trip with few stops in between, while the latter are typically short trips with many stops due to signals, pedestrians, etc.). The team also estimated the service times, i.e., the amount of time the truck stay at a customer location, because they provide key insight into the delays associated with making deliveries. Since the data from the different groups in the pilot test were not enough to produce statistically representative results for the entire range of times of travel, the different data sets were pooled together to produce a more robust set of estimates. The speeds represent space mean estimates, i.e., the distance travel from a point of origin to a point of destination divided by the time it takes to make that trip. Instantaneous speeds are not used because they exhibit a great deal of variability and cannot capture the traffic obstructions mentioned above. A companion paper discusses customer satisfaction (Brom et al., 2011).

The data show that there are significant increases in travel speeds from the depot to the first customer in Manhattan. For example, the data for Group 1 (Foot Lockers/New Deal Logistics)—probably the most complete for this analysis—indicate that the average travel speed in the AM peak is 11.8 miles/hour. In contrast, in the off-hours (7PM-6AM) it increases to 20.2 miles/hour, for a travel speed increase of 71%.

In terms of customer-to-customer travel speeds in Manhattan, the results are equally significant. It should be mentioned, however, that there are almost no data for the time between 10PM and 5AM (the 4-5AM time period only contains a handful of observations). Similarly, although the entire data include about 4,000 individual trips no one can tell if they are representative of the overall truck traffic in the study area. In spite of these caveats, the data do provide a coherent picture of the potential impacts of OHD. The results are displayed in the form of a Box and Whisker plot that presents the 2nd, 25th, 50th (median), 75th, and 98th percentiles, and the outliers. In the plot, the 2nd percentile is the tip of lower whisker, the 25th percentile is the lower tip of the box, the 50th percentile (median) is the line in between the boxes, the 75th percentile is the top of the box, and the 98th percentile is the tip of the upper whisker. Values outside these percentiles are shown as crosshatches. The customer-to-customer speeds and their percentiles are shown in Figure 1.

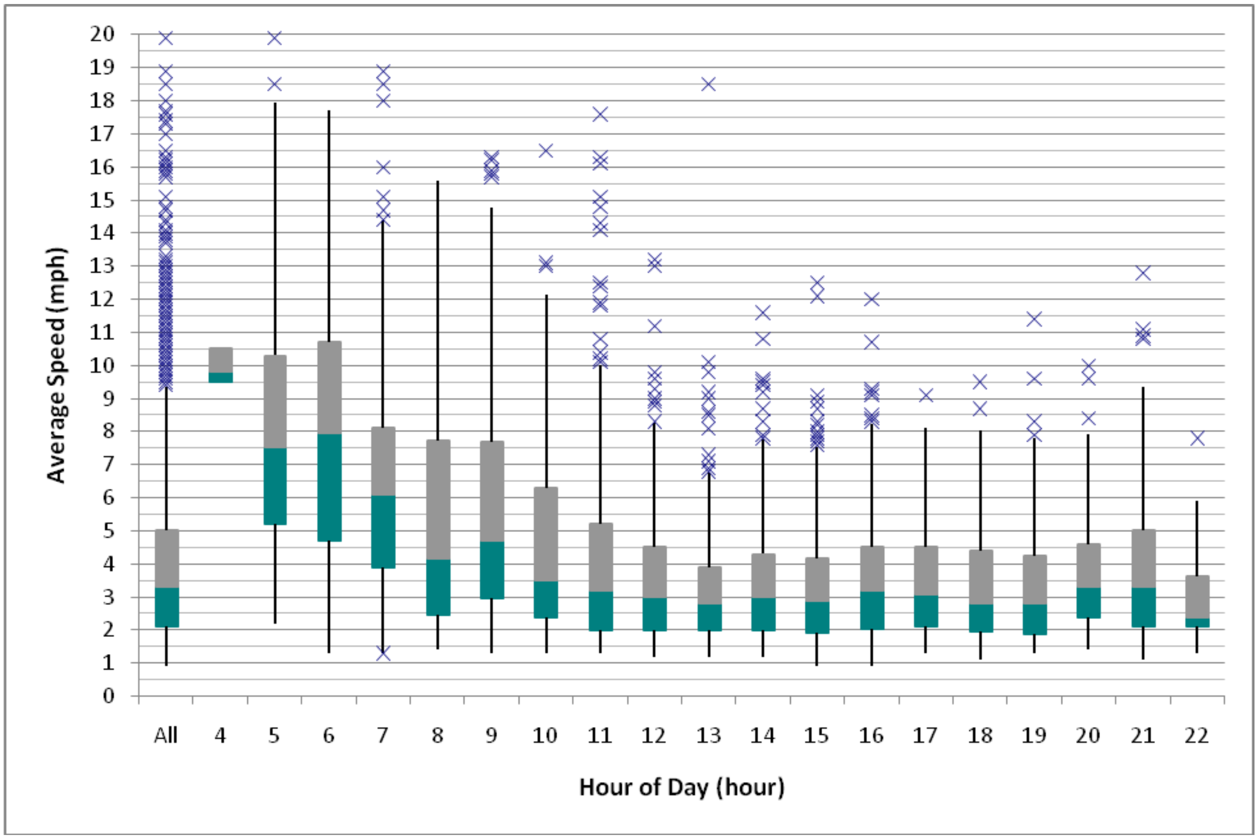

Figure 1 – Customer-to-customer space mean speeds by time of day

The results indicate a clear pattern in which the speeds decrease in the day hours and increase in the off-period. As illustrated in the figure, while the speeds in the 5-7AM almost reach 8 miles/hour (mph); they drop to below 3 mph in the day hours. The sparse data in the 4-5AM (only four observations) suggest that in the early hours of the day, travel speeds could be much higher. It is worthy of mention that different parts of New York City exhibit different speed distributions. The results indicate that a truck that travel for ten miles making deliveries, could save 1.25 hours of travel time if the average speeds are assumed to be 8 mph (off-hours) and 4 mph (regular hours) respectively. Obviously, the longer their tours are, the larger the economic savings associate with a switch to the off-hours.

The second performance measure used is the service time, i.e., the time spent by the driver at the customer location. This includes the amount of time that the driver spends: loading/unloading the cart used to transport the cargo, walking from/to the truck to/from the customer location, finding the person that would accept the delivery, waiting for the authorized individual to review the shipment made, waiting for proper signatures and/or payment, sorting out any problems that arise, and other related activities. Figure 2 shows the estimates produced by the team.

The figure shows that service times increase in the day hours, and decrease during the off-hours. While in the morning hours—which is when the bulk of the deliveries are made—the service times consistently exceeds an hour, reaching a maximum of 1.8 hours in the 10-noon period, they drop to about half an hour in the night hours. Although no one knows how representative these numbers are of industry wide conditions, they do indicate that carriers could save significant amounts of time when they switch from the morning to the night hours.

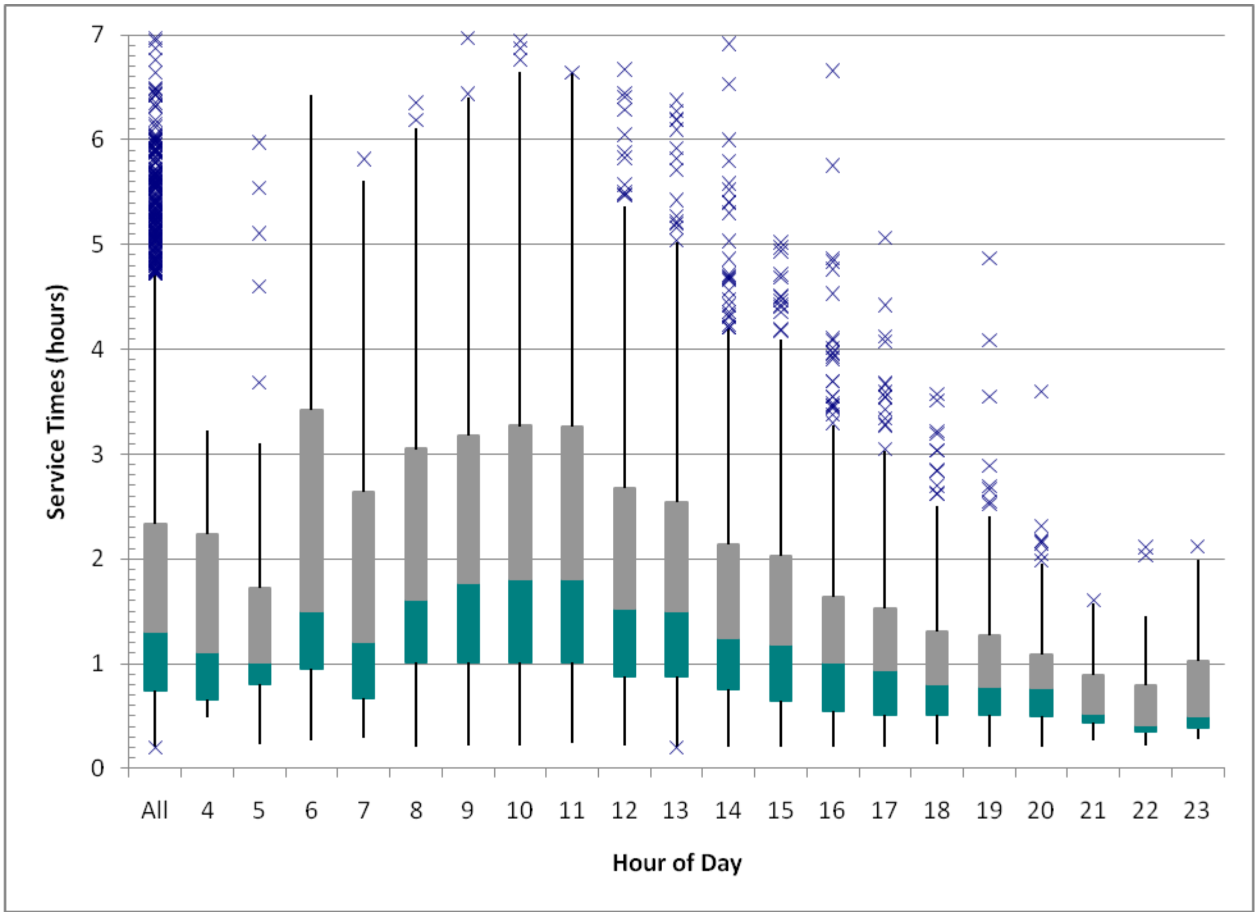

Figure 2 – Service times by time of day

It is important to mention that the authors discussed the results in Figure 2 with the industrial partners to assess their validity. The partners indicated that these results do represent the realities observed on the ground, which they deem part of the "…cost of doing business in New

York City…" They explained that in the day hours, drivers: typically are forced to park 2-3 blocks away from the customer location, have to wait for loading docks, experience delays in getting access to elevators (either because of other deliveries, or building visitors), have to move their trucks to other locations to avoid fines, and have to serve multiple customers from the same location (which necessitates long walks in some cases) to reduce the hassle of moving the truck and finding parking. In contrast, in the off-hours, they park closer to the customers and all the other issues diminish, or disappear altogether. The authors also asked about delivery sizes in both regular and off-hours. They indicated that during the off-hours shipment sizes tend to be larger than in the regular hours (because they take advantage of the larger productivity to transport more cargo). The implication is that, once the larger shipment sizes in the off-hours are factored in, the productivity savings associated with reductions in service times are likely to be larger than suggested by Figure 2.

These findings have major economic implications. The most obvious one is that reducing service times will increase the profitability of delivery operations and, ultimately, lower the cost of the products consumed in New York City. For instance, a delivery truck that saves 15 minutes at each of the six deliveries (about the average in New York City), will save a total of 1.5 hours. Regardless of the assumption made, the economic savings are substantial and potentially larger than the travel time savings attributed to faster speeds in the off-hours.

At the end of the pilot test, the team conducted in-depth-interviews with the participants, which reported to be very satisfied with the experience. Receivers indicated that what they liked the most was the reliability in OHD which completely removed any uncertainty about when the delivery was going to actually arrive. Carriers considered the increased productivity and less stress on the driver to be the most positive feature of OHD. The results of these interviews, and the satisfaction surveys conducted, are reported in a companion paper (Brom et al., 2011).

Upon termination of the incentive at the end of the pilot, all the receivers that did staffed OHD reverted back to regular hour deliveries. However, 90% of the receivers that tried unassisted OHD have continued with the practice to the great delight of the carriers. This provides an indication of the potential of unassisted OHD, as with minimal public sector intervention to induce receivers to try it may be possible to convince them to use them on a permanent basis.

IMPACTS OF A FULL IMPLEMENTATION

The quantification of the impacts of a full implementation of a off-hour delivery program required: (1) the quantification of the total number of truck-trips that would switch to the off-hours in response to a given financial incentive; and (2) the use of network models to quantify the impact of several scenarios of shifts to the off-hours on the entire network. This chapter succinctly describes the process followed and the chief results obtained.

The estimation of the potential participation in OHD required a two step process involving estimating the market response to financial incentives and quantifying the number of deliveries generated by the various industry segments (Holguín-Veras et al., 2010). The estimation of the market response to the financial incentive to receivers was done using a Behavioral Micro-Simulation (Silas and Holguín-Veras, 2009a), and an analytical model (Holguín-Veras, 2010) specifically designed for that purpose, that produced similar results. Based on the behavioral research conducted, these models estimate how many receivers in the simulated delivery tours would switch to the off-hours; simulate the response of the corresponding carriers; and aggregate the results for the various industry segments. The next step was to quantify the total number of deliveries made by the various industry segments, to compute the impacts of OHD on the transportation network. As part of this the team:

- Post processed the survey data collected to estimate freight trip generation models.
- Used the models to estimate the total number of deliveries by industry segment and ZIP code for the Manhattan area.
- Computed the number and percentage of deliveries that would switch to the off-hours for each ZIP code.
- Used these estimates to modify the inputs to the regional travel demand model (Best Practice Model, BPM), and a mesoscopic traffic simulation model developed by the team.

  The analyses revealed that:
- <u>A large number of freight deliveries are made to Manhattan.</u> The estimates—based on the freight generation data collected—show that about 113,000 freight deliveries are made to Manhattan for an average trip rate of 0.163 freight deliveries/employee, or 2.798 freight deliveries/establishment. Reflecting the consumer nature of the area, the industry segments with the largest share are: Consumer Goods with 54.48% (wholesale and retail), and the Food sector with another 24.28% (Eating / Drinking Places, and Food Stores).
- <u>The best candidates for participation in OHD are the Food and Consumer Goods sectors.</u> On the basis of the total number of deliveries generated and the inclination of each industry segment to participate in OHD, the team concluded that the best targets are the Food and Consumer Goods sectors. The team estimates that financial incentives of $5,000-$10,000/year would switch about 7-15% of the truck trips to the off-hours, which represents 7,000-16,000 truck trips/day.
- <u>Large Traffic Generators (LTGs) generate about 4-8% of the total number of freight deliveries in Manhattan.</u> The team estimated that the 88 buildings with their own ZIP code, e.g., Empire State building, generate about 4% of the total freight traffic in Manhattan. If the buildings that do not have their own ZIP code, e.g., Grand Central Terminal, and the large establishments with more than 250 employees are added, they would generate 4-8% of the total truck traffic. More importantly, since the LTGs tend to

have their own centralized delivery stations, they could receive OHD, and then deliver the cargo to the consignees during the regular hours without inconvenience to the actual receivers.

- Unassisted OHD are a very cost-effective alternative. "Unassisted OHD" refers to a range of systems that eliminate the need for human intervention at the receiving end. Examples include: (1) "key deliveries" in which the receiver gives a key to the carriers, enabling them to deposit the goods in the store; (2) the use of double doors that enable the driver to deposit the deliveries in the secured area with a key provided by the customer; (3) the use of delivery lockers in which a delivery is made to an electronically controlled cabinet at which the consignee retrieve the goods during the regular hours; and (4) the implementation of two-stage delivery systems in which supplies are transported during the off-hours and stored at a container, or storage pod, at a convenient location, e.g., a secured parking lot, from where the staff could retrieve needed goods using small and/or environmentally friendly, vehicles; among others. Regrettably, there were no behavioral data that could be used to assess how willing the various industry segments would be to participate in unassisted OHD.

Next, the team estimated the traffic impacts of alternative OHD scenarios with the assistance of both a regional travel demand model, i.e., New York Metropolitan Transportation Council's Best Practice Model (BPM), and a mesoscopic traffic simulation model of an extracted network focusing on Manhattan. In doing this, the team:

- Obtained the BPM and up-to-date hourly volume data from New York-area transportation agencies to calibrate the models.
- Extracted a Manhattan sub-network for more detailed mesoscopic simulation and analysis.
- Simulated of several scenarios of potential traffic shifts in both traffic models.
- Compiled and analyzed the impacts to the traffic network predicted by both models. The team used a post-processor developed by Ozbay et al. (2008) to compute environmental impacts.

The extensive traffic simulation effort produced solid estimates of the impacts to the Manhattan and the rest of the metropolitan network. The most prominent results indicate that:

- The proposed program has a net positive impact on the traffic networks of Manhattan and the entire New York City region over the entire day. Negative impacts to off-hour traffic conditions caused by increased commercial vehicle traffic are eclipsed by the benefits accrued during regular hours due to a reduced amount of commercial vehicles.
- Impacts are observed at both the local level in Manhattan and the entire metropolitan area. While most delivery trips in Manhattan originate within Manhattan (as part of a delivery tour), a significant number of freight trips originate outside of Manhattan (from ports and warehouses). Therefore the benefits from reduced truck traffic during the regular hours are observed throughout the entire metropolitan region.

- A 10% carrier participation in OHD in Manhattan would produce a reduction of more than 6% in travel times on Manhattan links during regular hours. When averaged with the increase in travel times during the off-hours, this translates into an overall reduction of 4% in Manhattan link travel times. Estimates for other scenarios were produced.

The next section discusses the economic impacts of the various alternatives considered.

ECONOMIC ANALYSES

The team used the results from both the regional network model (BPM), and the mesoscopic traffic simulation (MTS) to estimate the economic impacts in terms of travel time savings and air pollution reductions. The estimates are based on a composite value of time and valuations of the criteria pollutants. However, due to the uncertainty associated with the exact composition of the traffic in the entire network, the results are presented for different scenarios of composite value of time (VOT). Assuming a traffic composition of 83% passenger cars, 13% small trucks, 3% large trucks, and 1% buses; and values of time of $24 (which assumes an average occupancy of 1.2 passengers/vehicle), $35, $55, and $750 (VOT of passengers plus driver and vehicle) per vehicle class, respectively, leads to a composite value of $33.62/vehicle-hour. Different assumptions lead to values as low as $25/vehicle-hour, and as high as $40/vehicle-hour. The analysis considers three different cases:

- Financial incentives to Food and Retail Sectors. This is the policy previously identified by the team as the most effective one, i.e., a financial incentive to receivers for accepting OHD.
- Targeted programs aimed at LTGs. These policies focus on the major generators of truck traffic: large buildings that house scores of individual establishments, and large individual establishments in freight generation sectors with more than 250 employees.
- Unassisted OHD. These policies encourage OHD without the intervention of the staff from the receiving establishment. They have great potential as they could lead to economic benefits comparable to those produced by the financial incentives, at a fraction of the cost.

The total benefits and costs for the various stakeholders are shown in Table 1. Since there are no data about the incentive costs or the benefits in some of the alternatives, question marks have been added to the corresponding cells. For reference purposes, the values considered by the team as the most likely ones have been shaded. These values correspond to $30/hour for the composite VOT of roadway users, and $40/hour for the VOT for delivery trucks (large and small).

Table 1 – Summary of Economic Impacts

A) Road Users

	Trips Shifted	Annual Benefits (millions) [1] — Composite Value of Time (passenger cars, buses, and trucks) [2]: $20/hr BPM [3]	$20/hr MTS [4]	$25/hr BPM [3]	$25/hr MTS [4]	$30/hr BPM [3]	$30/hr MTS [4]	$35/hr BPM [3]	$35/hr MTS [4]	Public Sector Incentives (millions)
Financial incentives to Food and Retail Sectors and % of total truck traffic shifted										
$5,000 (6.49%)	7,262	$38.61	$20.68	$47.89	$23.95	$57.10	$27.23	$66.34	$30.51	$0.00
$10, 000 (14.10%)	15,982	$57.58	$51.23	$70.96	$58.74	$84.42	$66.25	$97.84	$73.76	$0.00
$15,000 (20.90%)	23,617	$68.24	$65.50	$84.24	$76.11	$100.24	$86.72	$116.23	$101.94	$0.00
$50,000 (41.65%)	47,605	$139.21		$172.85		$206.49		$240.14		$0.00
Targeted programs aimed at Large Traffic Generators										
Large Buildings [5]	8,345	$24.36	$17.68	$30.23	$21.28	$36.10	$24.87	$41.97	$25.18	?
Large Bldgs. & 250+ [5]	17,878	$53.60	$26.86	$67.33	$32.84	$81.07	$38.82	$94.81	$41.87	?
Unassisted deliveries		?	?	?	?	?	?	?	?	?

B) Carriers that shift to the off-hours

	Trips Shifted	Annual Benefits (millions) [1,6] — Average Value of Time Carriers that Shift to the Off-hours: $30	$35	$40	$45	$50	$55	$60	$65	Public Incentives (millions)
Financial incentives to Food and Retail Sectors and % of total truck traffic shifted										
$5,000 (6.49%)	7,262	$21.54	$25.13	$28.72	$32.31	$35.90	$39.49	$43.08	$46.67	$0.00
$10, 000 (14.10%)	15,982	$47.40	$55.30	$63.20	$71.10	$79.00	$86.90	$94.80	$102.70	$0.00
$15,000 (20.90%)	23,617	$70.05	$81.72	$93.39	$105.07	$116.74	$128.42	$140.09	$151.77	$0.00
$20,000 (25.34%)	28,634	$84.93	$99.08	$113.23	$127.39	$141.54	$155.70	$169.85	$184.01	$0.00
$25,000 (29.07%	32,856	$97.45	$113.69	$129.93	$146.17	$162.41	$178.65	$194.90	$211.14	$0.00
$50,000 (41.65%)	47,605	$141.19	$164.72	$188.26	$211.79	$235.32	$258.85	$282.38	$305.92	$0.00
Targeted programs aimed at Large Traffic Generators										
Large Buildings [5]	8,345	$24.75	$28.88	$33.00	$37.13	$41.25	$45.38	$49.50	$53.63	?
Large Bldgs. & 250+ [5]	17,878	$53.02	$61.86	$70.70	$79.54	$88.37	$97.21	$106.05	$114.89	?
Unassisted deliveries		?	?	?	?	?	?	?	?	?

C) Receivers and public sector

	Trips Shifted	Cost to Receivers (millions) [1,7]	Public Incentives (millions)[1,8]
Financial incentives to Food and Retail Sectors and % of traffic shifted			
$5,000 (6.49%)	7,262	($16.20)	$16.20
$10, 000 (14.10%)	15,982	($76.07)	$76.07
$15,000 (20.90%)	23,617	($172.91)	$172.91
$20,000 (25.34%)	28,634	($284.13)	$284.13
$25,000 (29.07%	32,856	($413.72)	$413.72
$50,000 (41.65%)	47,605	($1,244.39)	$1,244.39
Targeted programs aimed at Large Traffic Generators			
Large Buildings [5]	8,345	$24.75	?
Large Bldgs. & 250+ [5]	17,878	$53.02	?
Unassisted deliveries		?	?

Table 1 notes: (1) Estimated based on changes to congestion, operating costs, noise, and air pollution assuming 250 days/year; (2) the benefits depend on the composite value of time estimate used; (3) BPM refers to Best Practice Model, the benefits are calculated for all links in the 28-county NYMTC region; (4) MTS refers to Mesoscopic Traffic Simulation, and the benefits are calculated for links located only in Manhattan; (5) assume 100% participation in OHD; (6) assume 0.80 hours/tour saved due to faster speeds. 0.25 hours/stop savings in service times, and 5.5 delivery stops per tour; (7) estimated as the number of receivers that accept the incentive times the incentive amount; and (8) assumed to be equal to the incentive cost. The percent values next to the incentive amounts represent the percent of the total truck traffic that is shifted to the off-hours.

Table 2 and Figure 3 summarize the economic impacts for the case in which the composite VOT of roadway users is $30/hour, and the average value of time of delivery trucks is $40/hour. As noted previously, the costs to receivers have been assumed to be equal to the total incentive cost (i.e., the incentive amount times the total number of establishments that accept it). This is a reasonable and conservative assumption as it provides an upper bound of the receiver costs (if the incentive amount does not cover the costs, the receiver would not accept it). As shown, the economic benefits to carriers and roadway users increase with receiver participation in OHD though their rate of growth decreases. The costs to receivers—and consequently the incentive costs—increase rapidly as it becomes more difficult for receivers to participate.

It is worthy of mention that, in general, the benefits to the carriers are smaller than the costs to receivers, which is what economic theory predicts (Holguín-Veras, 2008). In this situation, the market left to its own devices will not reach the more preferable outcome (off-hour deliveries) because the carriers cannot compensate the receivers for their extra costs, and still themselves be better off. This market failure is what justifies public intervention via incentives or other policies.

The analyses of Table 2 and Figure 3 show that beyond the $17,500/year incentive, the total costs outweigh the benefits brought about by OHD. However, the optimal amount of incentive is in between $10,000-$15,000/year (14%-21% of total truck traffic).

Table 2 – Economic Analysis Results

	Cost to receivers	Benefit to carriers	Benefit to road users	Total benefits	Total Incentive Costs	Net benefits	Marginal B/C (ΔB/ΔC)
Financial incentive to food and retail sectors							
$5,000 (6.49%)	(16.20)	$28.72	$57.10	$85.81	($16.20)	$69.62	5.30
$10, 000 (14.10%)	(76.07)	$63.20	$84.42	$147.62	($76.07)	$71.55	1.03
$15,000 (20.90%)	(172.91)	$93.39	$100.24	$193.63	($172.91)	$20.72	0.48
$20,000 (25.34%	(284.13)	$113.23	$146.15	$259.38	($284.13)	($24.75)	0.59
Targeted programs aimed at Large Traffic Generators							
Large Buildings	?	$24.75	$24.36	$49.11	?	?	?
Large Bldgs. & 250+	?	$53.02	$53.60	$106.62	?	?	?
Unassisted deliveries	?	?	?	?	?	?	?

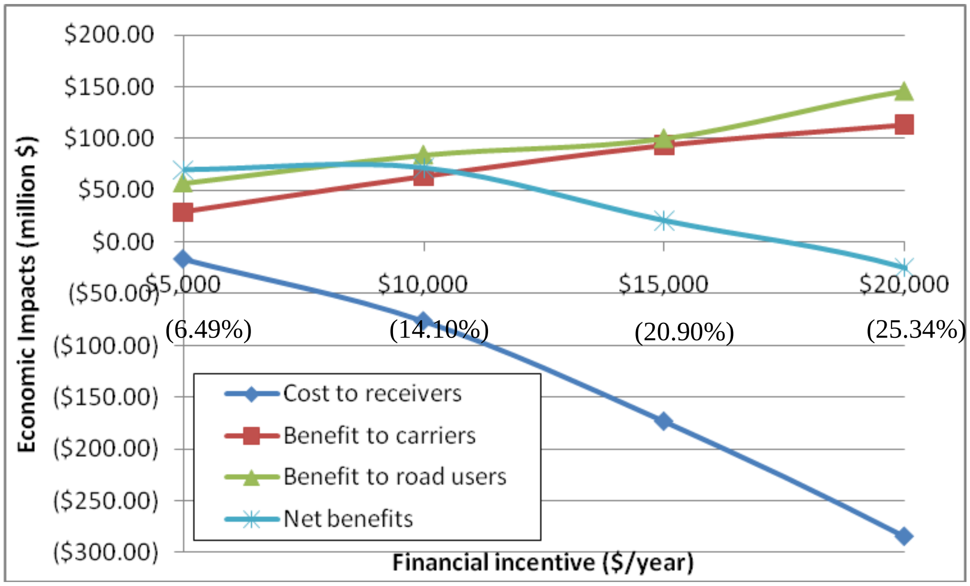

Figure 3 – Cost and benefits of proposed OHD program.

Note: The percents in the horizontal axis indicate the participation in OHD.

The table shows the marginal benefit/cost ratio which 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 $\Delta B/\Delta C = 1$. The results indicate that:

- In all cases, the economic benefits associated with increasing OHD exhibit diminishing returns though the incentive costs continue to grow.
- The optimal financial incentive is in between $10,000 and $15,000 per year (14%-21% of total truck traffic), depending on the composite value of time.
- Policies aimed at increasing OHD at LTGs have great potential. Switching to the off-hours the truck traffic generated by the 88 large buildings with own ZIP code, produces benefits comparable to the ones for the $5,000 incentive. Furthermore, if in addition, the truck traffic produced by the establishments with more than 250 employees is shifted to the off-hours the economic benefits produced would be comparable to the ones for the $10,000 incentive. These benefits would be achieved at a fraction of the cost associated with providing financial incentives to the receivers.
- Unassisted OHD represent a huge opportunity, thought not much is known about their market potential. However, a small survey of the receivers that participated in the pilot test indicated that 80% would do unassisted OHD if the liability issues are satisfactorily addressed. This could lead to a situation in which a small public investment could produce benefits similar to the ones brought about by the financial incentives.

Future research must tackle the design of policies and quantification of market potential, and implementation costs for both LTGs and unassisted OHD. Both concepts offer the potential to shift significant number of truck-trips to the off-hours at a fraction of the cost. This must be a high priority research area. It is important to mention that, since the costs to receivers doing unassisted OHD is much lower than those based on staffed OHD (which are shown in Figure 3), that the optimal amount of OHD would be much larger than the one in Figure 3.

CONCLUSIONS

The analyses conducted by the team indicate that: (1) financial incentives to receivers are very effective in inducing a shift of receivers and carriers to the off-hours; (2) the switch of truck traffic to the off-hours brings about substantial economic benefits; (3) on average, travel speeds from the depot to the first customer in Manhattan increase from 11.8 miles/hour in the morning peak hours (6-9AM), to 20.2 miles/hour in the off-hours (7PM-6AM); (4) on average, customer to customer travel speeds increase from below 3 miles per hour in the regular hours, to about 8 miles per hour in the off-hours; (5) there are substantial reductions in service times during the off-hours, from a maximum of 1.8 hours per customer at 10AM, to a minimum of 0.5 hours in the night hours; and (6) travel time savings to regular hour traffic are substantial as they amount to 6% travel time reductions in Manhattan (4% if the increase in travel time during off-hours is considered). The analyses indicate that the economic benefits of a full implementation of an OHD program are in the range of $147-$193 million per year. These are the result of the productivity increases to the freight industry, and travel time and environmental pollution savings to road users. The analyses also conclude that the optimal incentive amount is on the range between $10,000-$15,000 per year which corresponds to 14%-21% of total truck traffic. The analyses also suggest that, should unassisted OHD be used, the optimal amount of OHD would be much larger.

However, in spite of the concept's great promise there are a number of important questions that need to be answered before proceeding to a full implementation, most notably noise impacts on surrounding communities. Although no complaints were received during the execution of the small pilot test, it is natural to expect that community members would be concerned about noise impacts. In this context, it is important to both assess noise impacts, and define appropriate mitigation procedures to ensure that local communities are not negatively impacted.

The research also identified new avenues with great potential: unassisted OHD, and policies that target Large Traffic Generators (LTGs). The estimates indicate that about 4-8% of all deliveries are generated by LTGs, as a result, inducing them to do OHD could have a noticeable impact on traffic congestion. Equally important is that since the number of LTGs is small (between 90 and 500, depending on what definition is used), the coordination effort is insignificant when compared to the potential payoff. Unassisted OHD provide a unique opportunity to achieve the benefits attributable to financial incentives, at a fraction of the cost. In this context, public sector programs that successfully address the liability issues that deter businesses from doing unassisted OHD will increase off-hour activity. Over time, as the business sector gets accustomed to unassisted OHD, more establishments will join the practice. As an illustration of the potential of the concept, it suffices to mention that 90% of the receivers that tried unassisted OHD have continued to the practice even after the incentives ended; and that 80% of the participating receivers indicated that they would do unassisted OHD if the liability issues were resolved.

In essence, the work done has clearly and unambiguously established that the proposed concept: (1) is effective in inducing a shift of urban deliveries to the off-hours; (2) enjoys broad based industry support; (3) would bring about substantial reductions in congestion and environmental pollution thus increasing quality of life; and (4) would increase the competitiveness of the urban economy. The fact that this is win-win-win concept that benefits all the participants in urban deliveries provides a unique opportunity for expansion and full implementation that should not be missed.

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