FREIGHT IN A BICYCLE-FRIENDLY CITY:
AN EXPLORATORY ANALYSIS USING NYC OPEN DATA

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ABSTRACT
This project employs a variety of publicly available datasets to examine how New York City’s (NYC’s) growing bicycle infrastructure has impacted travel and parking conditions for commercial vehicles (CVs), and to investigate the interactions that occur between CVs and bicycles on multimodal urban streets. The project was conducted in three stages. First, a spatial analysis of the city’s dedicated bicycle and local truck routes was performed to quantify the extent of network overlap and changes that have occurred since 2000. Next, a spatial and statistical analysis of bicycle collisions extracted from the NYPD’s Motor Vehicle Collision database was conducted to explore infrastructure and demand characteristics indicative of freight-bicycle conflicts. Finally, CV bicycle lane parking violations were extracted from the NYC Department of Finance Parking Violation database to examine parking challenges in bicycle-friendly areas; GIS analysis was supplemented by field data collection in three locations. The project identified a number challenges for CV operations. Potential future research efforts to address emerging questions requiring further investigation are also discussed.
INTRODUCTION
New York City (NYC) has been a leader in the Complete Streets movement, rapidly transforming its streets over the last decade to better accommodate green passenger modes. A number of changes have been implemented with aim to reduce passenger transportation externalities and improve safety for all roadway users; these include:

- Installation of more than 400 miles of bike lanes since 2007, including more than 35 miles of protected paths (1);
- Launch of the Citbike bikeshare system in 2011, which now includes more than 300 stations on and off-street in midtown and downtown Manhattan and Brooklyn, a number expected to double by 2017 with expansion into uptown Manhattan and to new areas of Brooklyn and Queens (2);
- Implementation of more than 60 “Complete Streets” projects that have installed pedestrian islands, sidewalk extensions, and other pedestrian-friendly infrastructure throughout the city and 15 “Neighborhood Slow Zone” projects that lower speed limits and install speed-reduction infrastructure in residential neighborhoods (3);
- Reduction of the city’s default speed limit from 30 to 25 mph (4); and
- Implementation of SelectBus services with dedicated bus lanes along eight corridors since 2008 (5).

The recently launched OneNYC plan seeks to continue this trajectory, including goals to “massively expand” the transit network and to increase the size of the city’s bike network (6).

These measures have been considered widely successful in their intended aim; according to the Department of Transportation’s (DOT’s) own estimates, bike ridership is up (7) and cycling risk is down (8). Internationally, a number of studies have concluded that bicycle lane implementations are good for local economic activity; Jaffe (9) summarizes these. However, while studies have focused on the positive aspects of street redesign for non-motorized travelers and for local businesses, little critical analysis has been done to determine the broader impacts of these implementations on motor vehicle movements and resulting costs, including congestion, emissions, and in the case of freight, supply chain impacts. Advocates note some potentially positive impacts on congestion from Complete Streets implementations, such as potential to reduce signal time allocated for pedestrian crossings (10). A 2012 DOT analysis of midtown Manhattan using taxi GPS data suggested that average traffic speeds increased following implementation of protected bicycles lanes and dedicated pedestrian infrastructure; however, the study offers little information on if or how estimates controlled for the impact of other variables such as changes in traffic demand (11).

While this study does not aim to provide a detailed analysis of network-wide congestion impacts from street design changes, it does seek to offer a starting point in examining the consequences of recent street redesigns for a unique class of operators – commercial vehicles (CVs) performing first- and last-mile goods movements in the city. Previous researchers have already documented the extremely challenging conditions that CVs face in NYC; these include heavy traffic delays and related congestion costs (12), inadequate parking (13) and building access (14), and high parking fines (15). While CVs are critical to support economic activity and the livelihood of residents, they are often an afterthought in urban street redesign projects. For example, the popular NACTO Urban Street Design Guide explicitly states that trucks and large
vehicles should not be prioritized, noting that intersection designs should minimize pedestrian exposure and should not provide the wide turning radii required for unimpeded large vehicle turns (16). In discussing the arrangement of street space along multimodal corridors, the same document recognizes trucks primarily as a double-parking problem to be solved, ideally by shifting deliveries to off-peak periods. While off-hour deliveries have been proven to provide a number of benefits both for carriers and for cities, pilot studies have also identified a number of economic realities and practical constraints that have so far limited widespread adoption of this solution (15, 17, 18). The guide fails to note these limitations. While a few studies have noted that bicycles pose specific challenges for urban truck operations (19, 20), fewer have specifically explored broader interactions between CVs and bicycles on urban networks (21, 22).

Changes in street design and permitted movements along a designated truck network can have important consequences for truck movements, resulting in added costs to industry and to the surrounding network. Lane narrowing that reduces capacity and intersection designs requiring multi-point turns that obstruct travel lanes will cause delays to the driver and may increase congestion and related emissions on surrounding streets. Changes in street directionality on designated truck routes may add considerable distance to CV trips, adding time and fuel costs for the driver. Longer truck routes also increase total heavy vehicle mileage on the network, impacting congestion and accident exposure. Alternatively, trucks may choose to operate illegally on a non-designated truck route not designed for their use. At final delivery locations, curbside bicycle lanes and other pedestrian-friendly infrastructure that consumes limited parking may reduce or eliminate direct curb access. Illegally parked CVs are likely to obstruct through traffic and present a safety risk to pedestrians, cyclists, and drivers required to leave a protected lane, to change lanes, or to venture into traffic to see around the obstruction. Recognizing the potential consequences of street design changes on CV activity, this project seeks to better understand the potential operational impacts of widespread bicycle lane implementations on local goods movement in NYC via exploratory geospatial analysis of motor vehicle collision and parking violation data available from NYC’s Department of Finance and Police Department, supplemented with some field data collection.

PROJECT ORGANIZATION

This project consists of three separate but related analyses. First, a basic evaluation of the extent of overlap between the city’s designated bicycle and local truck routes was conducted to better understand the truck route mileage affected by bicycle lane implementations. Next, motor vehicle collisions involving bicycles were examined to identify their spatial distribution, to determine the extent to which they occur on truck routes, and to examine unique characteristics of collisions between CVs and bicycles. Finally, the spatial distribution of parking violations for CVs “stopping, standing or parking within a marked bicycle lane” was examined to identify challenging locations for deliveries. Field observation was conducted in three locations in Manhattan and the Bronx to examine the factors impacting driver decisions to park in the bicycle lane. While the specific vehicles examined in the safety and parking analyses vary slightly, results from all three analyses together provide a picture of how CVs operate on NYC’s new bicycle-friendly streets.

NETWORK OVERLAP

In NYC, trucks with trips originating in or destined to the city are required to travel on a designated network of local truck routes. CVs are permitted to use non-designated routes only to
reach a final pickup or delivery destination. This analysis seeks to roughly quantify the extent to
which NYC truck routes have been affected by bicycle lane implementations.

Method of Analysis

In order to quantify the extent of network overlap and changes that have occurred to the network
since 2000, affected mileage was estimated in ArcGIS using NYCDOTs 2014 local truck and
bicycle route maps. The bicycle map file includes lane installations and modifications through
April 2014. While both maps were developed based on the NYC Department of City Planning’s
LION centerline street map, the routes are not in perfect alignment; as a result, a 20-ft buffer was
created using the truck route file to approximate the total width of the street. Bicycle lanes
falling completely within this buffer were then selected to identify overlapping segments, and the
overlapping network was isolated for analysis.

To understand impacts on truck route capacities from bicycle lane implementations,
bicycle lane segments on this overlapping network were sorted by lane type. Bicycle lane
segments were sorted into three categories: known on-street lanes, known off-street lanes, and
unknown lanes. The unknown category includes segments with more than one lane type on a
block or segments for which no type is designated. Six “on street” lane types include: signed
routes, sharrows, bicycle-friendly parking, curbside lanes, standard lanes, and protected lanes.
Neither signed routes nor sharrowed streets include dedicated space for bicycles; rather, these
routes are designated with signs and pavement markings. Bicycle-friendly parking lanes are
wide enough (usually 14 ft) to permit a bicycle to ride next to parked cars. Streets with curbside
and standard lanes include at least one 4 ft wide dedicated bike lane, located at the curbside or
between parking and travel lanes. Protected lanes are physically separated from vehicle traffic,
either by a raised curb or by parked vehicles. Following this sorting, a limited on-street network
consisting only of known on-street segments was identified for further evaluation.

Results and Discussion

In 2014, the total bicycle route network extended over 604 miles, including both on and off-
street lanes. Of this, 378 miles (63%) were installed since the year 2000. Approximately 89
miles overlapped the city’s 794 mile local truck network, a length covering 15 percent of the
bicycle network and 11 percent of the truck network. Much of the overlapping mileage is on
major high-traffic thoroughfares in lower Manhattan and in Brooklyn neighborhoods closest to
Manhattan (Figure 1). About two-thirds of bike lanes installed on the truck network were
installed after 2000. For lane type analysis, the limited on-street network examined totaled 363.4
miles, including 70.5 miles of bike lanes on local truck routes.
Table 1 shows the distribution of lane types on the entire limited on-street network and on the truck routes segments of this. It is clear from the table that the majority of bicycle network implementations on the truck route network are lane types that require moderate to high allocation of dedicated space for bicycle use. More than 10 percent of all mileage installed on truck routes includes protected lanes, which generally require the most dedicated space of all bicycle lane types. The 10.6 percent share of protected lanes on the truck routes is nearly triple that on the overall on-street network. Since 2000, protected lanes have been installed at an even higher rate, constituting 12.1 percent of new mileage on truck routes.
BICYCLE COLLISIONS
Safety is a major concern when bikes and large CVs operate in close proximity. A number of international studies have recognized high fatality rates for bicycle collisions involving heavy vehicles (23, 24, 25, 26, 27). Previous research has also investigated relationships between traffic demand, built environment factors, and collision rates; Chen (28) provides a comprehensive summary of studies. While a few studies have identified relationships of overall bicycle collision frequencies with freight-related variables such as large vehicle demand (29) and commercial land uses (30), none have specifically evaluated freight demand impacts on CV-bicycle collisions. This analysis seeks to evaluate two separate but related questions: 1) to what extent do bicycle collisions occur on truck routes and 2) what unique characteristics of infrastructure and demand are related to collision frequencies.

Method of Analysis
Bicycle collisions were identified from a constantly updated NYPD Motor Vehicle Collisions database. This database includes only collisions that resulted in police involvement, and therefore may exclude minor incidents. Due to the low share of recorded collisions involving bicycles, and small percentage of those involving CVs, data from multiple years (July 1, 2012 – July 25, 2015) were evaluated. From the detailed records, these collisions could be sorted to determine involved motor vehicle types. While the primary vehicle types of interest are Large CVs (6+ tire) and Small CVs (4 tire), collisions involving buses, taxi or livery vehicles, and personal vehicles (passenger car, SUV, or pick-up) were also identified for comparison. Once a final dataset of collisions was identified and classified, maps were generated to examine the dispersion of different vehicle-type collisions.

In order to examine characteristics of infrastructure at collision locations, collisions were mapped to the limited on-street network described above. Collisions not occurring in an on-street bike lane were excluded from the lane type analysis. Via this mapping, the shares of collisions occurring on truck routes and in each lane type could be estimated. There may be small errors in lane type identification due to dynamic changes in bicycle lane configurations over the analysis period; however, these are not expected to significantly impact general conclusions.

### TABLE 1 Bicycle Lane Types

<table>
<thead>
<tr>
<th>Lane type</th>
<th>On Street Bike Lanes</th>
<th>Truck Route Overlap</th>
<th>Truck Route Overlap Installed Since 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Length (mi)</td>
<td>363.4</td>
<td>70.5</td>
<td>55.1</td>
</tr>
<tr>
<td><strong>Signed Route</strong></td>
<td>Length</td>
<td>Percent</td>
<td>Length</td>
</tr>
<tr>
<td>Signed Route</td>
<td>27.7</td>
<td>7.6</td>
<td>3.9</td>
</tr>
<tr>
<td><strong>Sharrows</strong></td>
<td>Length</td>
<td>Percent</td>
<td>Length</td>
</tr>
<tr>
<td>Sharrows</td>
<td>57.4</td>
<td>15.8</td>
<td>14.0</td>
</tr>
<tr>
<td><strong>Bike-Friendly Parking</strong></td>
<td>Length</td>
<td>Percent</td>
<td>Length</td>
</tr>
<tr>
<td>Bike-Friendly Parking</td>
<td>23.4</td>
<td>6.4</td>
<td>7.2</td>
</tr>
<tr>
<td><strong>Standard</strong></td>
<td>Length</td>
<td>Percent</td>
<td>Length</td>
</tr>
<tr>
<td>Standard</td>
<td>218.4</td>
<td>60.1</td>
<td>31.3</td>
</tr>
<tr>
<td><strong>Curbside</strong></td>
<td>Length</td>
<td>Percent</td>
<td>Length</td>
</tr>
<tr>
<td>Curbside</td>
<td>25.0</td>
<td>6.9</td>
<td>6.6</td>
</tr>
<tr>
<td><strong>Protected Path</strong></td>
<td>Length</td>
<td>Percent</td>
<td>Length</td>
</tr>
<tr>
<td>Protected Path</td>
<td>11.7</td>
<td>3.2</td>
<td>7.5</td>
</tr>
</tbody>
</table>
In the absence of local truck volumes and sub-metropolitan freight trip demand estimates, this study relied on a basic difference of medians test to investigate the relationship between freight activity and CV-bicycle collisions. Employment in freight-related sectors was used as a proxy estimator of freight trip demand; Holguin-Veras et al. (31) have demonstrated the relationship between these variables. Population estimates were obtained from the 2010 Census. Total employment and estimated employment in various NAICS sectors for each census tract were identified from Longitudinal Employer-Household Dynamics (LEHD) data. Sectors evaluated include Construction, Manufacturing, Wholesale Trade, Retail Trade, and Transportation and Warehousing. Employment categories for “Arts, Entertainment, and Recreation” and “Accommodation and Food Services” were combined to create a single “Entertainment” category, and remaining service sectors were combined in a general “Service” category. As collisions are coded by intersections, and those intersections frequently lie on the edge between two or more census tracts, collisions were labeled with average characteristics of census tracts intersecting a 50 ft buffer surrounding the intersection. Ultimately, collisions were labeled with nine characteristics: the percentage of employment in each of the seven sectors described above and the densities of population and employment. To examine the influence of these demand factors on CV collisions rates, two sets of collisions records were paired for comparison: large CV collisions vs. collisions not involving large CVs and small CV collisions vs. collisions not involving small CVs. Assuming non-normality for the variables, a Wilcoxon difference of medians test was employed to test whether the distributions of these variables were equivalent across the datasets.

Results and Discussion

Records from 15,437 bicycle-involved collisions (2.5 percent) were extracted from an original dataset containing 629,232 collisions involving all vehicle types. In all, 4,358 on-street bicycle collisions were identified, of which 68 involved a bus, 122 a CV, 2,948 a personal vehicle, 785 a taxi or livery cab, 21 only bicycle(s) and 446 another or unknown vehicle type. Some incidents involved more than one motor vehicle or bicycle. Notably, the percentage of CV-involved collisions is higher in the on-street bicycle lanes (2.9 percent) than as a share of citywide observed bicycle collisions (1.9 percent). Injury rates were similar across all vehicle types, with shares of collisions resulting in injury ranging from 66 percent for bicycle-only to 76 percent for other and unknown vehicle types. From Figure 2, it is clear that bus, CV, and personal vehicle collisions all appear to be concentrated in roughly the same areas of Manhattan and Brooklyn. However, both bus and CV collisions constitute a very small share of overall collisions. Collisions for these vehicle types appear to be frequently located along specific corridors; for example, truck collisions are concentrated along the Grand Street corridor, a local truck route which connects industrial areas in East Williamsburg to the Williamsburg Bridge into Manhattan. For taxis, a different pattern is observed, with the vast majority of collisions occurring only in midtown and downtown Manhattan.
FIGURE 2 Dispersion of Bicycle Collisions by Involved Vehicle Type
Table 2 shows the share of total collisions and CV-involved collisions occurring on each infrastructure type. Most notably, more than half of all bicycle collisions occur on truck route segments that make up only 19 percent of the on-street bicycle network. For CV-involved collisions, 65 percent occur on the truck routes. These high collision rates may be due primarily to higher traffic volumes of both bicycles and motor vehicles on these routes. The finding appears consistent with a Seattle study that found that bicycle collision rates are significantly higher on arterials compared to non-arterials (28). However, testing of this hypothesis is difficult due to the unavailability of bicycle count data or vehicle classifications for many local streets.

**TABLE 2 Collisions by Lane Type**

<table>
<thead>
<tr>
<th>Lane Type</th>
<th>On Street Bicycle Lanes</th>
<th>Truck Route Overlap</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Infrastructure Length (mi)</td>
<td>Number of Collisions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All</td>
</tr>
<tr>
<td>Total</td>
<td>363.4</td>
<td>4358</td>
</tr>
<tr>
<td>Signed Route</td>
<td>7.6</td>
<td>3.9</td>
</tr>
<tr>
<td>Sharrow</td>
<td>15.8</td>
<td>18.4</td>
</tr>
<tr>
<td>Bike-Friendly Parking</td>
<td>6.4</td>
<td>2.5</td>
</tr>
<tr>
<td>Standard</td>
<td>60.1</td>
<td>53.2</td>
</tr>
<tr>
<td>Curb Side</td>
<td>6.9</td>
<td>6</td>
</tr>
<tr>
<td>Protected Path</td>
<td>3.2</td>
<td>15.9</td>
</tr>
</tbody>
</table>

Examining collision distributions across lane types, a notable observation is that collision frequencies are very high on protected paths compared to their total mileage. This result is counterintuitive, as protected paths are installed to protect bikes from collisions. Further examination of collision locations reveals that this high frequency occurs primarily on major Manhattan avenue corridors, including First, Second, Eighth and Ninth Avenues, and Broadway. This high rate may be explained by extremely high motor vehicle and bicycle volumes along many of the streets with protected lanes. However, further examination is necessary to determine the cause of these collisions, as it is possible that factors such as driver visibility during turning movements may pose specific risks on protected paths. While the NYPD database does identify general contributing factors (e.g., driver distraction, alcohol involvement) for some accident records, this information is neither complete nor specific enough to reveal the actions of the involved parties that caused the collisions.

Results from the difference of medians tests (Table 3) suggest there is a relationship between freight demand and CV involvement in bicycle collisions. Large CV collisions occurred in locations with higher employment shares in freight dependent industries - Wholesale, Transportation and Warehousing, and Retail. Small CV collisions were also in locations with expected generators of freight demand - those with high employment shares in Transportation and Warehousing and Manufacturing and with high population densities.
### TABLE 3 Wilcoxon Difference of Median Results

<table>
<thead>
<tr>
<th></th>
<th>Large CV</th>
<th>Small CV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>50</td>
<td>4308</td>
</tr>
<tr>
<td>Population Density</td>
<td>29824</td>
<td>17194</td>
</tr>
<tr>
<td>Employment Density</td>
<td>51023</td>
<td>59104</td>
</tr>
<tr>
<td>Share of Employment in Sector</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>1.37</td>
<td>1.49</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>1.04</td>
<td>0.84</td>
</tr>
<tr>
<td>Wholesale</td>
<td>3.28</td>
<td>1.88</td>
</tr>
<tr>
<td>Retail</td>
<td>6.87</td>
<td>9.60</td>
</tr>
<tr>
<td>Transp. &amp; Warehousing</td>
<td>0.78</td>
<td>0.44</td>
</tr>
<tr>
<td>Service</td>
<td>60.91</td>
<td>58.32</td>
</tr>
<tr>
<td>Entertainment</td>
<td>12.19</td>
<td>14.34</td>
</tr>
</tbody>
</table>

* Significant with 95% confidence
** Significant with 90% confidence

### PARKING ANALYSIS

The third and final analysis conducted as part of this study was an evaluation of CV parking behavior on bicycle-friendly streets. Overall parking challenges for CVs operating in NYC have been documented in previous research (13, 14, 15, 32). However, no study has yet focused specifically on CV parking along bicycle routes. This analysis aims to characterize the parking options that drivers face and their resulting parking choices.

#### Method of Analysis

To begin this analysis, a NYC Department of Finance database of Parking Violations was evaluated. This database includes records only for illegally parked vehicles that were issued a citation, likely underestimating violations in low enforcement areas. The geocoded dataset included violations issued between July 29th and October 28th, 2013 (33). This database included detailed records on the vehicle to which a citation was issued, the location where the ticket was issued, and the violation for which the vehicle was cited. While the dataset does include a vehicle registration type variable, preliminary analysis revealed that this was inadequate to identify out-of-state CVs. CV violations were extracted from the database based on vehicle body type. The three body types examined include delivery vehicles, semi-trailers, and vans. This database was further constrained only to records for a single violation, #48 – “Stopping, standing or parking within a marked bicycle lane.” Once final violations were identified, they were mapped to the nearest street segment using DCP’s LION map to identify total violations issued on each block; Figure 3 provides an example.
FIGURE 3 East Broadway Commercial Vehicle Bicycle Parking Lane Violations by Block

After critical block locations were identified, field data was collected in three of these locations to investigate the factors contributing to the driver’s decision to park in the lane (see Table 4). The temporal distribution of observed parking violations was examined to identify appropriate observation times in each location. In the field, student research assistants observed truck arrivals and kept detailed records on vehicle and delivery characteristics, parking availability, and parking choices for every arriving CV, and the activity of enforcement officers. Six specific activity types were examined: grocery, which includes movement to grocery stores as well as directly to homes; other food and beverage deliveries; major parcel deliveries by UPS, FedEx, and the US Postal Service; other parcel deliveries by small, specialized companies; moving trucks; and service vehicles, which include contractors and plumbers, utility companies, and technology services among others. Results from this observation were then evaluated to characterize parking behavior and drivers of parking decisions.

Results and Discussion
Initial processing of the violation database containing 1,048,576 total parking violations yielded 4,452 CV bicycle lane violations. Of the 4,271 of these occurring on known on-street lane types, 80.9 percent were in standard lanes, 4.0 percent in protected lanes, and 3.0 percent in curbside lanes. Mapping these violations to individual blocks identified 23 blocks on which 20 or more violations were issued over the three month observation period; 19 of these blocks included standard bicycle lanes. Together these critical locations accounted for 616 violations.
Somewhat surprisingly, critical blocks were dispersed across four NYC boroughs, including fifteen in Manhattan, five in the Bronx, two in Brooklyn, and one in Queens. These areas have land uses ranging from heavily commercial to primarily residential.

Table 4 summarizes results from the three field observation locations. The highest average truck arrival rate was observed on commercial East Broadway, although arrival rates here were found to be variable over time with a clear peak in the early part of the observation period. Goods movements here included a large share of food and beverage deliveries, many made by single unit trucks. On W 77th St, a primarily residential street, demand was dominated by parcel delivery and service vehicles relying more on cargo vans. While in commercial areas parcel deliveries were dominated by the major carriers, on the residential street, a higher share of small parcel companies were observed. Interestingly, average demand was higher on W 77th St than on the Grand Concourse, a primarily retail area. On the Grand Concourse, an even greater share of parcel deliveries was observed, with 80 percent conducted by the major carriers.
1 TABLE 4 Parking Case Study Locations

<table>
<thead>
<tr>
<th>Primary Street</th>
<th>East Broadway</th>
<th>Grand Concourse</th>
<th>W 77th St</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross Streets</td>
<td>Catherine St. and Market St.</td>
<td>184th St and Fordham Road</td>
<td>Columbus Ave and Central Park West</td>
</tr>
<tr>
<td>Primary Land Use</td>
<td>Chintown commercial district; includes many independent food markets and small retailers</td>
<td>Major Bronx commercial corridor; observed blocks dominated by retail stores; some vacant buildings</td>
<td>Museum of Natural History spans block on north side; primarily mid-rise pre-war residential on south side; bordered by Central Park to the west</td>
</tr>
<tr>
<td>Motor Vehicle Travel Lanes</td>
<td>Local street with single travel lane in each direction</td>
<td>Separated arterial with single local lane in each direction</td>
<td>Local street with single travel lane in each direction</td>
</tr>
<tr>
<td>Bicycle Infrastructure</td>
<td>Standard bicycle lanes in both directions</td>
<td>Buffered bicycle lanes in both directions</td>
<td>Buffered bicycle lanes in both directions</td>
</tr>
<tr>
<td>Parking Regulations</td>
<td>1-hr meter north side; Commercial Meter (8 AM - 1 PM) 44% of south side, remainder 1-hr meter</td>
<td>1-hr metered parking w/ bus stops on both sides</td>
<td>Open parking on south side; School Bus Loading 37% of north side school bus loading, remainder open</td>
</tr>
<tr>
<td>Date (s) Observed</td>
<td>13-May-15</td>
<td>27-Apr-15</td>
<td>30-April 2015, 7-May-2015</td>
</tr>
<tr>
<td>Hours Observed</td>
<td>9:00 AM to 1:00 PM</td>
<td>9:00 AM to 1:00 PM</td>
<td>8:00 AM to 12:00 PM, 12:00 PM to 4:00 PM</td>
</tr>
<tr>
<td>Total Trucks</td>
<td>70</td>
<td>25</td>
<td>67</td>
</tr>
<tr>
<td>Avg Trucks/Hr</td>
<td>17.5</td>
<td>6.25</td>
<td>8.38</td>
</tr>
<tr>
<td>Min Trucks/Hr</td>
<td>11</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Max Trucks/Hr</td>
<td>26</td>
<td>12</td>
<td>21</td>
</tr>
<tr>
<td>Vehicle Type</td>
<td>Percent of Observed Vehicles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Unit Truck</td>
<td>65.7</td>
<td>52</td>
<td>35.8</td>
</tr>
<tr>
<td>Refrigerated Truck</td>
<td>2.9</td>
<td>0</td>
<td>1.5</td>
</tr>
<tr>
<td>Semi-trailer</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Van</td>
<td>28.6</td>
<td>40</td>
<td>52.2</td>
</tr>
<tr>
<td>Other</td>
<td>2.9</td>
<td>8</td>
<td>7.5</td>
</tr>
<tr>
<td>Delivery Type</td>
<td>Percent of Observed Vehicles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grocery</td>
<td>8.6</td>
<td>0</td>
<td>7.5</td>
</tr>
<tr>
<td>Other Food</td>
<td>38.6</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Major Parcel</td>
<td>21.4</td>
<td>32</td>
<td>20.9</td>
</tr>
<tr>
<td>Other Parcel</td>
<td>1.4</td>
<td>8</td>
<td>10.4</td>
</tr>
<tr>
<td>Moving Truck</td>
<td>0</td>
<td>12</td>
<td>4.5</td>
</tr>
<tr>
<td>Service Vehicle</td>
<td>10</td>
<td>24</td>
<td>25.4</td>
</tr>
<tr>
<td>Other</td>
<td>10</td>
<td>16</td>
<td>25.4</td>
</tr>
<tr>
<td>Unknown</td>
<td>10</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 4 demonstrates the parking available to and choices made by drivers at the individual observation locations. Categories of parking observed included: legal parking in a curbside spot; double parking in a travel lane - which is also legal for deliveries in the three observation locations; illegal parking at a bus stop, in a bicycle lane, or in front of a fire hydrant;
illegal parking in a “No Parking” or “No Standing” zone; and parking in any other illegal on-
street spot (e.g. in the median). From the limited observations, it appears that driver parking
align somewhat with availability. On East Broadway, dedicated Commercial Metered parking
provides time-restricted, dedicated access to storefronts for delivery; here about half of vehicles
had a legal curbside spot available directly in front of delivery location, and another ¼ had a
legal spot available on the block. As a result, a fairly high share of drivers were able to legally
park. Alternatively, on W 77th Street, unrestricted residential parking spaces experienced little
turnover during the observation period. In this location, very few CVs had the option to park
legally at the curb, resulting in higher illegal parking rates and bicycle lane obstructions.
FIGURE 4 Parking by Location
Table 5 describes observed parking behavior for vehicles making different types of deliveries. It should be noted that some parking durations may be truncated if the vehicle arrived before the beginning of the observation period or departed after the end. Results indicate that for both food and parcel deliveries, the majority of CVs parked for less than 10 minutes. Longer durations observed for these vehicle types included trucks making multiple pallet food deliveries and major parcel companies serving many locations from a single parked vehicle. Service vehicles and moving trucks parked for longer durations.

TABLE 5. Parking by Delivery Type

<table>
<thead>
<tr>
<th>Delivery Type</th>
<th>Total Vehicles</th>
<th>Percent of Observed Vehicles</th>
<th>Parking Duration (min)</th>
<th>Legal Curbside Parking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>&lt; 5</td>
<td>5-10</td>
</tr>
<tr>
<td>Grocery</td>
<td>11</td>
<td>18.2</td>
<td>36.4</td>
<td>27.3</td>
</tr>
<tr>
<td>Other Food and Beverage</td>
<td>31</td>
<td>46.7</td>
<td>26.7</td>
<td>16.7</td>
</tr>
<tr>
<td>Major Parcel</td>
<td>38</td>
<td>54.1</td>
<td>24.3</td>
<td>13.5</td>
</tr>
<tr>
<td>Other Parcel</td>
<td>10</td>
<td>40</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>Moving Trucks</td>
<td>6</td>
<td>0</td>
<td>33.3</td>
<td>16.7</td>
</tr>
<tr>
<td>Service</td>
<td>30</td>
<td>37</td>
<td>7.4</td>
<td>22.2</td>
</tr>
<tr>
<td>Other/Unknown</td>
<td>36</td>
<td>57.1</td>
<td>14.3</td>
<td>17.1</td>
</tr>
</tbody>
</table>

More than half of the drivers making grocery or other food and beverage deliveries had an option to park directly in front of their delivery locations (Table 5). Few drivers making parcel deliveries had legal curbside parking options available at their delivery location, and even when a legal spot was available, parcel companies did not necessarily choose to use it. Only four of seven observed parcel vehicles with available parking directly in front of a delivery location chose to use the space. Alternatively, service vehicles were the only delivery type to frequently use legal curbside parking located elsewhere on the block.

Enforcement rates were also observed to vary by location. On the Grand Concourse, where freight vehicle arrival rates were lowest, 32 percent of all parked vehicles were passed by an enforcement officer, and three of 14 illegally parked vehicles were issued a citation. In this location, several major parcel trucks were observed moving between multiple illegal parking spots throughout the duration of the data collection period, and none received multiple citations. Those cited reacted little, continuing with their unloading operations without notice of or reaction to the enforcement officer. On W 77th St and East Broadway, enforcement officers passed much lower shares (15 and 17 percent) of total parked vehicles; citations were issued to only to three of 57 illegally parked vehicles on the former, and none of the 36 illegally parked vehicles on the latter.

DISCUSSION AND FUTURE RESEARCH

Results from these analyses provide insights on the impacts of NYC’s growing on-street bicycle network for CV operations. About 11 percent of the city’s designated local truck route network now overlaps with its bicycle network. Many recently installed lanes have consumed previous
motor vehicle capacity to provide dedicated space for cyclists. Future research is needed to
measure the short and long term implications of these reduced capacities for CV operations,
costs, and externalities. One approach to address these questions may be simulation modeling of
the urban street network to quantify traffic delays and emissions from capacity changes; this
would require collection of traffic volumes, including vehicle classifications, for a denser
network of local streets than for which data is currently readily accessible. A second approach
could be evaluation of GPS spot speed data – whether from trucks or other vehicles – to measure
vehicle speeds and progression on truck routes with and without bicycle infrastructure. Direct
outreach to industry stakeholders is also needed to identify and evaluate downstream supply
chain costs resulting from related congestion and missed deliveries.

Bicycle collisions of all types are heavily concentrated on local truck corridors.  Particular
ly given the severe outcomes for non-motorized travelers from CV-involved collisions,
findings warrant future research to directly evaluate the relationship between vehicle and bicycle
traffic volumes and collision rates, to examine detailed accident causality on specific types of
bicycle infrastructure, to identify the resulting safety implications from redesigning high-traffic
corridors for multimodal operations, and to determine the congestion impacts, related
externalities, and downstream industry costs to carriers, shippers, and receivers from frequent
bicycle-vehicle collisions along major truck corridors. Each of these areas of focus demands
further data collection. Local street CV and bicycle volumes are also needed to adequately
assess the relationship between traffic demand and bicycle collision rates, and to estimate the
congestion impacts from these collisions. To assess collision factors and the severity of collision
outcomes on different lane types, either collision records or hospital records frequently evaluated
in accident severity studies must identify two important factors: a detailed description of the
bicycle and vehicle operator actions that resulted in a collision and the exact location of the
incidents, including the specific type of bicycle infrastructure on which the collision occurred.
As bicycle networks continue to expand, time-series analysis of collision data before and after
infrastructure implementations may also reveal trends regarding collision frequencies and
outcomes.

CVs in NYC struggle to access curbside parking at both commercial and residential
delivery locations; on multimodal streets; as a result, CV bicycle lane parking violations are
widespread and costly. Management strategies are required to provide adequate curb access, not
only on commercial and retail streets traditionally recognized as freight trip generators, but now
also in residential areas. However, the effectiveness of both curb management strategies and
enforcement to curb parking violations will vary for different carrier types. Future research is
needed to identify parking strategies appropriate for implementation on multimodal streets that
better take into consideration the behavior of specific types of operators. Direct outreach is
needed to better understand the constraints and costs that drive operator decision-making, and the
likely impact of these constraints on response to proposed regulations and enforcement.

In conclusion, this paper demonstrates that CVs in NYC do face new challenges
following massive expansion of the city’s bicycle network. These challenges should be given
explicit consideration when considering future street design changes. While only general
impacts are detailed here, much future research discussed above is needed to better quantify both
the costs to industry and the network-wide impacts on safety, congestion and related emissions
from further growth in truck-bicycle interactions.
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REFERENCES


13. Jaller, M., Holguín-Veras, J., and Hodge, S. Parking in the City: Challenges for Freight Traffic. In Transportation Research Record: Journal of the Transportation Research


