URBAN MICRO-CONSOLIDATION AND LAST MILE GOODS DELIVERY BY FREIGHT-TRICYCLE IN MANHATTAN: OPPORTUNITIES AND CHALLENGES

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ABSTRACT
New York City (NYC) must identify new strategies to address severe urban delivery challenges resulting from congested roads and inadequate loading space. One solution with the potential to achieve benefits for the city, for carriers, and for shippers while making use of the city's rapidly growing bicycle infrastructure is freight distribution from an urban micro-consolidation center (UMC) via human-powered or electrically-aided freight-tricycle. UMCs have been successfully implemented in Paris and London; this study details the results of a comparative analysis evaluating economic, infrastructure, and regulatory conditions in the three cities for the purpose of identifying opportunities and challenges for future implementation in Manhattan.
INTRODUCTION

Daily, more than 110,000 freight deliveries are made to businesses and residences in Manhattan (1). Traffic gridlock inhibits trucks from reaching destinations, and inaccessible curb space, inadequate off-loading facilities, and lacking freight elevators waste driver time and fuel (2). Carriers required to double-park accrue parking fines averaging $500 to $1000 per truck per month for deliveries made during business hours (1). Delivery vehicles vital to maintain livability and economic competitiveness emit noise pollution and particulate matter, greenhouse gases, and other noxious substances that impact air quality, public health, and the environment (3). Although truck drivers are often more cautious than other vehicle operators, recent NYC studies of accidents involving pedestrians (4) and bicyclists (5) found that trucks and other large vehicles contribute to a disproportionate share of fatal incidents.

To address multimodal safety concerns and environmental needs, the NYC Department of Transportation (NYCDOT) installed more than 200 bicycle lane-miles between 2006 and 2009 (6), including Class 1 protected lanes, Class 2 striped lanes, and Class 3 shared lanes (7). NYCDOT is continuing to pursue a long-term goal of 1,800 bicycle lane-miles by 2030 (6). Network growth has enabled a 154% increase in bicycle commuting since 2003. At the same time, installation of a Class 1 lane typically reduces parking by 4-6 spaces per block (7).

With vehicle and curb space inadequate and shrinking, options for improving freight access are limited. Capacity expansion is nearly impossible, and reducing demand is undesirable. As delivery trips vary by size, commodity, value, and industry sector, no one solution exists. Two potential strategies to improve last-mile delivery in Manhattan include implementation of a comprehensive off-hour delivery program and introduction of one or more urban consolidation centers (UCCs). Between 2009 and 2010, an off-hour delivery program was successfully piloted in Manhattan by Holguin-Veras et. al (1). Although not yet tested in NYC, a number of successful UCCs have been implemented internationally. New York University's (NYU) Panero, Shin and Lopez evaluated many case studies to understand suitability to New York conditions, and concluded that many aspects are transferable (9).

While specific operations vary, a UCC is essentially a logistics space located in or close to a delivery area, such as a city’s central business district (CBD), that receives goods from multiple carriers, usually by truck or van, consolidates these deliveries, and loads them onto smaller, cleaner vehicles for final delivery (10). UCCs can be operated privately or under a public-private partnership, and their use can be voluntary or mandated (9). With recent and expected growth in bicycle infrastructure, a UCC model that holds particular promise in NYC is an urban micro-consolidation center (UMC) that utilizes human-powered or electrically-assisted freight-tricycles for final delivery.

The NYU study specifically cited a Parisian UMC operated by La Petite Reine (LPR) as a relevant model for NYC application (9). With support from the city, LPR provides last-mile distribution for shippers via electrically-aided tricycle from a centrally located micro-distribution center (11). In London, Gnewt Cargo (GC) operates a smaller but similar UMC that distributes parcels for a major commercial shipper-carrier (12). Revolution Rickshaws (RR) already performs delivery in NYC using human-powered freight tricycles; however, their current shipper base is primarily limited to small, local, "green" businesses. The goal of this study is to identify opportunities and challenges for future micro-distribution of a broader range of commodities by freight-tricycle in Manhattan through comparative analysis of existing operations and economic, infrastructure, and regulatory conditions in Paris, London, and NYC.
STUDY METHODS
The first stage of this research included an extensive review of freight-tricycle operations in Paris, London, and the US. In addition to literature review, information was obtained through telephone interviews or email communications with representatives from LPR, the City of Paris, and GC. The research team also conducted a site visit to/interview with RR and completed a web-based review of operations for five freight-tricycle carriers operating in other US cities.

Next, population (13, 14, 15) and employment (16,17,18) data were evaluated to identify a target delivery area within Manhattan. Economic data from all three cities were aggregated into 10 industry sectors comparable across delivery areas. Specific customers served and commodities carried were also identified. Bus and bicycle lane maps from NYCDOT and land use data from the NYC Department of City Planning (19) were then analyzed in ArcGIS to identify neighborhoods favorable for delivery and UMC location. Vehicle and operator conditions were also examined to identify successful practices and observed challenges. Finally, lessons learned and recommendations applicable to NYC were developed.

OPERATIONS
Freight-tricycles are currently in limited use in NYC for local "green" freight deliveries; however, significant, primarily commercial demand currently carried by larger, diesel-fueled motor vehicles to locations in Midtown and Downtown Manhattan could be shifted to the mode for last-mile delivery. This section describes existing and potential customers that could be served by UMC implementations.

Services and Commodities
Since 2003, LPR has provided last-mile less-than-tricycle-load delivery for a variety of international and local shippers. They deliver goods from a UMC near the Louvre to businesses and residents in 10 municipal districts in central Paris (Personal communications (p.c.) with Thibaut Guilluy). Originating from a city-initiated effort, LPR first served several major third-party logistics carriers (3PLs) (11). When economic realities reduced 3PL demand, the company successfully diversified its shipping client base, which in addition to 3PLs now includes major electronics, pharmaceutical, and food distributors, grocery stores, and e-commerce and local small businesses (11, 20). Currently, LPR performs about 3,500 deliveries per day in Paris using 50 freight tricycles.

In November 2009, a major office-supply shipper-carrier contracted GC to pilot a new UMC and perform delivery and pick-up in a small area in central London (21). Prior to UMC implementation, seven diesel vans delivered about 1,200 parcels daily to the City of London (CoL) from a distant warehouse located at Heathrow Airport. Now, goods are delivered to a UMC on the outskirts of the CoL by an 18 ton (40,000 lb) truck, and are delivered to local businesses by either freight-tricycle or electric van. After successful completion of a pilot study from November 2009 to May 2010, the UMC was made permanent (21). GC now employs 15 staff who handle approximately 4,500 parcels per week (22) using 6 freight-tricycles and 3 electric vans (12).

Since 2005, RR, has provided pick-up and delivery service primarily for local "green" businesses in Downtown and Midtown Manhattan from a facility in Midtown West. Currently, major customers include a local non-profit that collects leftover food from restaurants for delivery to the needy, a bakery, and an organic, vegan food and beverage producer and retailer. RR noted that they prefer pre-scheduled delivery services, as it is difficult to employ vehicle
operators to serve uncertain on-demand customers and that cold-chain maintenance is a key
barrier to some food deliveries, as neither their vehicles nor their warehouse is refrigerated.
Using 10 freight-tricycles, the company averages 50-60 deliveries per day, reaching as many as
100 per day during peak periods.

A few relatively new freight-tricycle delivery companies operate in other US cities,
including Berkeley, California, Santa Cruz, California, and Eugene, Oregon (23), Boston (24),
Philadelphia (25), Alexandria, Virginia (26), and Portland, Oregon (27). Two are privately
owned delivery services (24, 27), one is a private venture cooperatively owned by its employees
(23), and two are not-for-profit organizations (25, 26). Although these carriers, like RR,
primarily serve local businesses, their scopes of operation vary considerably. Only one carrier
partners with major national shippers that include a grocery store chain and an office-supplier
(27). Food is clearly the most commonly moved commodity, especially restaurant deliveries,
baked goods, and locally grown produce. Unlike European carriers who focus on parcel
delivery, some US carriers deliver pallets. Commonly moved non-food products include dry
cleaning and flowers, and several companies pick up recyclables and food waste for composting.

With a single exception (27), all of the existing delivery companies in the US focus their
advertising almost entirely on environmental benefits. Whether as a cause or an effect, the
majority of their customers are companies already engaged in “green” industries, such as organic
food vendors or eco-friendly dry cleaners. For those commodities that can be efficiently moved
by freight-tricycle, services should appeal to a much broader range of shippers. Nationally, there
is demonstrated demand for sustainable shipping practices; the 236 shippers and 12
shipper/carriers that have sought and received SmartWay certification from the US
Environmental Protection Agency (EPA) include food and beverage distributors, clothing and
cosmetics manufacturers, and office-supply and electronics companies (28).

Receiver Demand
Since freight cycles require a dense concentration of receivers, delivery areas in both Paris and
London are heavily commercial. In Paris’ original 9 mi² delivery area, there are about 154,000
business establishments, 430,000 residents and the ratio of employees-to-residents is 1.8:1
(13,16). The 1.1 mi² CoL delivery area is home to London’s historic financial district, more than
16,000 local business units, and only about 11,700 residents, with a ratio of employment to
population of over 27:1 (14,17). While RR currently serves only Midtown and Downtown, ten
distinct neighborhoods of Manhattan were evaluated as potential delivery areas (Figure 1). An
employment-to-population ratio of one was used as a threshold value to identify commercial
districts (12, 15). In every Uptown neighborhood, the number of residents by far exceeds the
number of employees, with employment-to-population ratios ranging from 0.1:1 to 0.6:1; as a
result, Uptown Manhattan was excluded as a target delivery area. At 7:1, 5.7:1, 4.3:1, and 1.8:1,
ratios in Midtown West, Midtown East, Lower Manhattan, and the West Village/SoHo (WVS)
all identify commercial areas. In Midtown and Downtown, only the Lower East Side (LES) has
more residents than employees, with a ratio of 0.5:1. Because this area lies between two major
commercial areas and provides important truck connectivity to Queens, it was not excluded. For
the purpose of evaluation, the entirety of Midtown and Downtown Manhattan was identified as a
target delivery area. With about 82,000 businesses and 560,000 residents, this area encompasses
9.2 square miles, an area very close in size to that served by Paris’ first UMC.
Delivery area industry composition was examined to determine if the same types of freight demand exist in NYC that exist in Paris and London. While it appears that Paris has many more businesses than New York, it is important to note that the sizes of these businesses are not equal, as demonstrated by the greater number of employees in New York; total employment in the target NYC delivery area exceeds 1.7 million compared to only about 820,000 in Paris. In Paris, only about 1% of businesses have more than 50 employees (17), while in New York 7% exceed this value (16). The London delivery area is much smaller, and is comparable in size to Lower Manhattan, the home of New York's financial district. In London, like in Paris, there are many more businesses than in the similar area of New York; however, while in London, more than 80% of businesses employ fewer than 10 people, and only slightly more than 5% employ more than 50 (18), in Lower Manhattan only about 68% have fewer than 5 employees, and 9.3% have more than 50 (16).

The industry make-up is very similar between the Paris and New York delivery areas, as can be seen in Figure 2. The three largest industry sectors, encompassing more than 60 percent of the businesses in each city, are the same. In Paris, the share of businesses belonging to Technical Service Industries, Trade Industries, and Financial, Insurance, and Real Estate Industries, are 29%, 20%, and 15% (17). Comparable shares in New York are 25%, 21%, and 17% (16). Close to 47% of the businesses in the CoL belong to Technical Service Industries, and about 24% to the Financial, Insurance, and Real Estate industries (18). Unlike the New York and Paris delivery areas, the CoL is not a major trade center, with only about 5% of business belonging to Trade Industries. These values are very comparable to Lower Manhattan,
which contains about 35% Technical Services, 25% Financial, Insurance, and Real Estate, and only 9% Trade (16).

![Graph showing industry sectors in Paris, London, and New York]

**FIGURE 2** Delivery area industry sectors in Paris, London and New York

**Vehicles**

When it began operations, LPR designed a custom vehicle to carry parcels (11). Now, LPR produces and sells three vehicle models: the soft-topped Cargocycle V1; the Cargocycle V2 which carries a solid (plywood or pvc) container; and the refrigerated Frigocycle (29). The Frigocycle was introduced in 2009 to meet a customer need for food and medicine delivery (11). One of LPR's customers is GC in London (12). In New York, RR uses several models, but the workhorse vehicle is the human-powered Cycles Maximus (CM) General Cargo Trike (GCT), which is manufactured in the UK (30). RR does not operate refrigerated vehicles; however, they have tested and used a number of methods, including refrigeration plates, for temperature control of food deliveries. CM appears to be the most popular brand of freight-tricycle in the US, as the GCT is also used in at least two other cities (24, 26), and another US carrier uses an electrically-assisted CM Flatbed fit with a custom container (27). Table 1 provides the vehicle specifications for the three available models from LPR, as well as the CM models (27, 29, 30).
The LPR and CM vehicles are notably different in payload and volume. The LPR vehicles carry containers that are about 5 ft high (p.c. with Thibaut Guilluy), while the CM GCT container has a height of only about 3 feet (30). The lower center of gravity, in addition to a slightly wider base, allows the CM vehicle to carry more load without rollover. However, LPR’s added height significantly increases the volume of lighter goods that can be moved. With the wider CM base and a taller custom container (although the exact height is unknown), the customized CM Flatbed can carry higher weights and volumes.

Electrical-assistance is standard on LPR vehicles but optional for CM. There are benefits and disbenefits to each power type. Electrical-assistance reduces the physical burden on an operator, which becomes increasingly important as payloads and infrastructure grades increase. Electrical-assistance also increases maximum vehicle speed. However, the use of electrical assistance introduces costs and operational complexity. The electric motor adds significant weight to the vehicle itself, as can be seen for the CM GCT in Table 2. Electrically-assisted vehicles consume electricity, which is not zero-cost, and while human-powered vehicles are always zero-emission, depending on the source, upstream electricity generation for vehicle charging may not be. Electrically-assisted vehicles also have limited autonomy; a single charge lasts only about 4 hours (29), limiting trip and tour lengths. Vehicle maintenance may also be more difficult for electrically-aided vehicles; RR noted that in relatively flat conditions in Midtown and Downtown Manhattan, the speed benefits of these vehicles would not justify the added cost to maintain and operate them. Generally, freight-tricycle maintenance is performed in UMC facilities, or at remote locations along the route if necessary. Like LPR (11), RR has an on-site mechanic.

Use of electrical-assistance can also complicate vehicle regulations and limit the infrastructure on which a vehicle can operate. In Paris, LPR vehicles are classified as bicycles because of their low speeds and limited power (9); however, in London, because the vehicles weigh more than 60 kg, they are classed as motor vehicles (p.c. with Matthew Linnecar). As a result, in London, the vehicles are required to be registered, the drivers are required to be licensed, and operations are limited only to motor vehicle infrastructure. In NYC, no specific regulations currently exist for freight-tricycles, so classification is ambiguous. New York State (NYS) law prohibits the use of motor-assisted bicycles on public roads, although the law does not explicitly address electrically-aided tricycles (31). A bill that would not only explicitly legalize on-road operations but also define an electrically-aided tricycle with maximum speed of 20 mph and power output less than 750 watts as a bicycle was committed to the Rules Committee, a legislative stage preceding a floor vote in both houses of the NYS Legislature, in

<table>
<thead>
<tr>
<th>TABLE 1 Vehicle Comparison</th>
<th>La Patite Reine Vehicles</th>
<th>Cycles Maximus</th>
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<tbody>
<tr>
<td>Cargocycle V1</td>
<td>Electric-Assist</td>
<td>General Cargo Trike</td>
</tr>
<tr>
<td>Cargocycle V2</td>
<td>Electric-Assist</td>
<td>Electric-Assist</td>
</tr>
<tr>
<td>Frigocycle</td>
<td>Electric-Assist</td>
<td>Customized Flatbed</td>
</tr>
<tr>
<td>Power System</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle Weight</td>
<td>176 lbs</td>
<td>187 lb (human-powered)/ 298 lb (electric-assisted)</td>
</tr>
<tr>
<td></td>
<td>396 lb</td>
<td>243 lb + unknown container weight</td>
</tr>
<tr>
<td>Length</td>
<td>220 lbs</td>
<td>8 ft 6.4 in</td>
</tr>
<tr>
<td>Width</td>
<td>3 ft 4.6 in</td>
<td>8 ft 6.4 in</td>
</tr>
<tr>
<td>Max Payload</td>
<td>396 lb</td>
<td>551 lb</td>
</tr>
<tr>
<td>Max Volume</td>
<td>53.0 ft³</td>
<td>600 lb</td>
</tr>
<tr>
<td></td>
<td>42.4 ft³</td>
<td></td>
</tr>
<tr>
<td></td>
<td>49.4 ft³</td>
<td>55.0 ft³</td>
</tr>
</tbody>
</table>
June 2011 (32). Human-powered freight-tricycles are not required to be registered, and operators do not require a driver's license. Unlike freight-tricycles, pedicabs have recently become relatively heavily regulated in NYC; among other requirements, operators are prohibited from using electric-assistance and bicycle lanes and are required to carry a valid driver's license and to register their vehicle (33). If freight-tricycles reach volumes comparable to pedicabs in NYC, it is expected that city regulations will be put in place for these vehicles.

**INFRASTRUCTURE USE**

Where regulations permit, freight-tricycles are much more flexible in operation than trucks. Freight-tricycles can use a variety of infrastructure, on which they have essentially no structural impact, especially compared to heavy trucks that can cause significant pavement and bridge damage. They also require little space, allowing them to maneuver on bicycle paths, in pedestrian areas, and through congested traffic and to park in small areas both on- and off-street.

This section describes infrastructure requirements to support UMC implementation.

**Travelways**

In Manhattan, motor vehicle speeds average 9.3 mph during weekday business hours, and in much of Midtown and Downtown, speeds are even lower (6). With the ability to travel up to about 12 mph, freight-tricycles can bypass slower vehicles. Speed and travel-time reliability can be especially improved when freight-tricycles have access to preferential infrastructure like bus lanes and exclusive bicycle routes.

In Paris, where vehicle speeds average about 10 mph (11), LPR vehicles are classified as bicycles and permitted to operate on the city's bicycle infrastructure. Like New York, Paris has recently seen considerable growth in bicycling, with major network growth and a commuter mode share increasing from 1.3% in 2001 to 3% in 2009 (p.c. with Beatrice Ras). Citywide, the 277 mile long Parisian bicycle network includes about 37 percent off-street bicycle paths and only about 10 percent on-street bicycle lanes. Another 37 percent consists of bus lanes in which bicycles are permitted to operate, and about 6 percent of the network is made up of one-way streets on which bicycles and freight-tricycles are permitted to operate in the wrong direction.

Paris freight-tricycles are also permitted to access areas that are restricted for pedestrian use during certain periods (11). In London, where traffic speeds are similar, the exact same vehicles are classified as motor vehicles, and are only permitted to operate on local roads and in bus lanes signed for moped use (p.c. with Matthew Linneear).

RR's human-powered freight-tricycles currently operate on the local street network as well as bicycle infrastructure. At just under 4 feet wide, RR’s CM GCT fits within the standard designs for all of the city's Class 1 and Class 2 facilities (7). Close to 60 exclusive bicycle lanes-miles are open in Midtown and Downtown, with the highest concentration in the Lower East Side (LES), followed by the West Village/SoHo (WVS), and Lower Manhattan (LM) (TABLE 2). Bicycle infrastructure is more sparse in Midtown on both sides of Manhattan. The only major NYC infrastructure challenge noted by RR carriers was the plethora of potholes that can damage vehicles and tires and cause injury to vehicle operators. New York's limited, but growing, network of bus lanes cannot currently be used by any vehicles except buses and turning vehicles. However, with the heavy concentration of bus lanes in bicycle-facility-sparse Midtown (TABLE 2), available capacity should be evaluated to determine if freight-tricycle use could be permitted.
### TABLE 2 Neighborhood infrastructure and land use characteristics

<table>
<thead>
<tr>
<th>Area</th>
<th>Infrastructure</th>
<th>Land Use</th>
<th>2010 I/M Building Space Assessed Value (2010 $/ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bus Lane Miles</td>
<td>Bicycle Lane Miles</td>
<td>Total Building Space (ft²)</td>
</tr>
<tr>
<td>Midtown</td>
<td>18.7</td>
<td>8.6</td>
<td>8.0</td>
</tr>
<tr>
<td>Midtown East</td>
<td>11.38</td>
<td>3.1</td>
<td>2.3</td>
</tr>
<tr>
<td>Midtown West</td>
<td>7.3</td>
<td>5.5</td>
<td>5.7</td>
</tr>
<tr>
<td>Downtown</td>
<td>3.4</td>
<td>20.7</td>
<td>19.8</td>
</tr>
<tr>
<td>Lower Manhattan</td>
<td>1.88</td>
<td>7.7</td>
<td>0.9</td>
</tr>
<tr>
<td>Lower Eastside</td>
<td>0.34</td>
<td>9.4</td>
<td>11.0</td>
</tr>
<tr>
<td>West Village/SoHo</td>
<td>1.19</td>
<td>3.6</td>
<td>8.0</td>
</tr>
<tr>
<td>Proposed Delivery Area</td>
<td>22.1</td>
<td>29.3</td>
<td>27.8</td>
</tr>
</tbody>
</table>

a. Excludes routes with variable classes  
b. Includes lot value

### Parking

In Paris, London, and NYC, space available for vehicle loading and parking is extremely limited. In Paris, 99% of on-street parking spaces are metered (p.c. with Beatrice Ras), making it very difficult for both trucks and passenger cars to find a place to stop. In loading zones, trucks are limited to a maximum 30-minute time window (11). Freight-tricycles can park on streets or sidewalks, and also have the ability to park in building courtyards, which are common in French architecture and are not accessible to vehicle traffic (p.c. with Thibaut Guilluy).

In London, freight-tricycles are only permitted to use motor vehicle parking space (Personal communications with Matthew Linnecar). GC noted that even when parked legally in a loading zone or on-street, vehicles are often issued "penalty charge notices" by enforcement authorities unfamiliar with their operations. These require time and effort to be overturned. Despite limited flexibility, a University of Westminster study determined that the introduction of the freight-tricycles and electric vans used in the London pilot study reduced the total length of parking required daily for the office supply deliveries by 52 percent (12).

In NYC, RR noted that parking is relatively easy for freight-tricycles, and that common sense is employed in determining whether to park in the street or in an off-street location like a sidewalk. Vehicles do not park in areas that will obstruct pedestrian flows. Operators noted that the vehicles can often be parked perpendicular to the curb in four to five foot spaces between cars that cannot be occupied by larger vehicles.

### Access Restrictions

UCC success often increases when truck access restrictions, such as road pricing, time-of-day regulations or low emissions zones, provide a competitive advantage to clean vehicles (9).
Since 2006, Paris has limited truck access to the city during specific time periods (11). Vehicles that occupy more than 29 m$^3$ (312 ft$^3$) are allowed to circulate only between 10 PM and 7 AM. Smaller trucks can circulate during this period, as well as from 7 AM to 5 PM. Electric vehicles and those meeting "Euro 5" emissions standards can circulate at any time, including during exclusive evening hours. In London, trucks and vans are subject to the city's congestion charge (34). Trucks are also required to meet strict particulate matter emissions standards, or face a high daily penalty for traveling within the city's Low Emissions Zone (35). By 2012, vans will also be subject to this penalty. In New York, efforts to implement a congestion charge were unsuccessful, and no time- or emissions-specific restrictions limit truck access.

### Urban Micro-consolidation Center

UMCs serve as warehouses for consolidating and sorting freight and loading freight-tricycles. LPR's original 6,460 ft$^2$ UMC has been operational since 2003. This center includes space for short-term storage, sorting, freight-tricycle entry/exit, loading, and overnight storage, and limited warehousing (p.c. with Thibaut Guilluy). The consolidation center also includes space for vehicle repairs, offices, and a living area for drivers. Barcode labels provide information about destinations, commodities, and billing accounts, and are used for package sorting. Because the UMC in London is privately operated, little detail about operations is publicly available, except for its location in Tower Hill, on the outskirts of the CoL delivery area. In both London and Paris, the UMCs are located near major arterials (9).

RR currently operates a warehouse between 9th and 10th Avenues in Midtown West, the proposed delivery area's most industrial neighborhood (Table 2). Freight-tricycles are stored, maintained, and loaded in a partially-covered area behind a building that houses the main office. The warehouse location is only a few blocks from the West Side Highway and from the Lincoln Tunnel, which connects Manhattan to the I-95 corridor, the Port of New York and New Jersey, and Newark International Airport. While the existing space is adequate for current operations, additional space in Midtown West for parcel sorting and refrigerated storage could enable 3PL and office-supply deliveries via freight-tricycle to meet high Midtown demand, and would allow additional food deliveries to retail locations in Midtown and WVS.

Several major 3PL warehouses and JFK International Airport, which receives air cargo from a number of international 3PLs, are located in Queens (36). Although industrial space in Lower Manhattan is nearly non-existent and the LES has high industrial space costs and little commercial demand (Table 2), potential UMC locations in these areas should be evaluated. Trucks from Queens can access Lower Manhattan directly from the Manhattan Bridge, and the LES directly from the Williamsburg Bridge. Local truck routes also connect Lower Manhattan to the Queens-Midtown tunnel via the LES. While a large office market also exists in Midtown East, industrial space is both sparse and prohibitively expensive in this area.

### IMPLEMENTATION IMPACTS

UMC implementation has the potential to impact shipper and carrier costs and operations, as well as to affect local environmental and traffic conditions. While results are not directly transferable between cities or individual micro-distribution centers, this section describes the measured and potential impacts resulting from UMC implementation.
Financial

Exact cost structures for UMC and freight-tricycle operations are unclear due to business privacy concerns; however, it is clear that the most considerable costs for operation are space and labor. Rent and payroll each account for about 1/3 of RR's monthly expenditures. According to RR, freight-tricycle operators are paid a higher wage than standard bicycle messengers in NYC. However, since they are classified as bike messengers for taxation purposes, the company is required to pay worker's compensation insurance rates that increase wage costs by 15%. In Paris, where the city provides a centrally located space to LPR at a rate comparable to that for logistics facilities region-wide (11), payroll accounts for the majority of costs (9). UMC implementation also adds a transshipment cost for sorting and vehicle transfer (9). In the London pilot study, labor costs for electrically-aided tricycle and electric van deliveries increased compared to diesel-van deliveries, despite lower driver wages, due to an increase in the required number of drivers and the addition of operating staff at the UMC (21).

However, overall logistics costs in London were found to be about the same under both delivery schemes (21). Capital, fuel, insurance and maintenance costs all decreased for electrically-aided tricycles and electric vans compared to diesel vans. In addition to direct financial savings, the use of electric vehicles also provides independence from unstable energy costs (22). LPR also generates revenue by renting advertising space on the sides and rear of vehicle containers (11). Shifting delivery to smaller vehicles can allow shippers to diversify their clientele. In one US city, a shipper indicated that he was able to increase his customer base by serving small businesses using freight-tricycles that were previously uneconomical to deliver to using larger, partially empty vehicles (27).

In Paris, the city invests in UMC operations not only to improve traffic and environmental conditions, but also to create new local jobs that are not transferable to other localities (p.c. with Thibaut Guilluy). Since its inception, LPR's Paris operation has grown from eight employees to 50 (11). Unlike heavy vehicle operators, freight-tricycle operators do not require much previous training or, in Paris, even a license, so jobs can be filled by operators with little education. In Paris, 2/3 of those employed by LPR were previously unemployed (p.c. with Thibaut Guilluy). Last-mile delivery by bicycle was recognized in the UK as a method to mitigate the impacts of a shortage of heavy truck drivers (37), a problem soon expected to re-emerge for US carriers (38).

Environmental

Both LPR and GC claim significant environmental benefits from delivery using freight-tricycles and electric vans. According to LPR, one year of freight-tricycle operations allowed the city to avoid 203 metric tons (447,500 lbs) of CO₂ emissions and 84 kg (185 lbs) of particulate matter emissions, and saved 82.12 tonne oil equivalents (955 megawatt-hours) of energy (20). LPR also claims to have reduced annual truck travel by 599,393 tonne kilometers (410,551 ton-miles). The London study identified a 62% reduction in CO₂ emissions per parcel compared to diesel van delivery (12). Although all of the US carriers claim environmental benefits, only once company offers a measure of impacts, estimating CO₂ emissions savings of 54,000 lbs since beginning operations in 2009 (27).

Safety

Shifting freight from trucks to freight-tricycles can impact safety; however existing data is insufficient to quantify impacts. Removal of large trucks from the urban street network should...
decrease exposure of pedestrians and bicycles to fatal accidents. However, introducing a new, unfamiliar vehicle on mixed-use infrastructure could increase collisions rates, particularly during an initial learning period. Results from London indicate that while truck miles traveled decreased with UMC implementation, total freight VMT in the delivery area increased due to the need for additional vehicles to handle demand (21). The shift from truck to tricycle may also expose drivers to higher risks, as they are no longer protected by their vehicle. However, none of the operators in Paris, London, or New York considered safety to be a major concern in operations. GC did note that taxi drivers had to "get used to" the freight-tricycles, and that vehicle safety performance is improved through the use of brake lights and turn signals mandated by their motor vehicle classification (p.c. with Matthew Linnecar).

Security
Panero, Shin, and Lopez found that a common concern among NYC shippers in use of freight-tricycles is cargo security (9). However, operators in London, Paris, and NYC all indicated that theft is not a significant problem. According to RR, very fast delivery times limit theft opportunities, and because of the rarity of freight-tricycles in Manhattan, potential thieves may not even recognize that a vehicle is carrying cargo. Vehicles in Paris are equipped with anti-theft technologies, including cargo locks and GPS (9).

LESSONS LEARNED FOR NEW YORK
The following lessons learned and recommendations for future UMC implementation in NYC were developed based on the results of comparative analysis between existing operations in Paris, London, and NYC:

Operations
Shippers and Commodities
- Although current NYC operations serve a relatively narrow market of local "green" businesses, freight-tricycles can carry commodities ranging from parcels to food to small electronics for a vast array of industry sectors.

Receiver Demand
- With industrial activity that nearly mirrors conditions in successful delivery areas in Paris and London, NYC generates similar freight demand that could be served by freight-tricycle delivery.
- The need for cold-chain maintenance complicates delivery of food products through non-refrigerated storage space, sorting areas, and vehicles.

Vehicles
- A variety of vehicle models exist to serve both parcel and pallet deliveries by freight-tricycle; models best suited to serve the weight and volume needs of expected customers should be chosen for operation.
- While electrical-assistance provides speed benefits and eases operator effort, it also introduces maintenance and power costs and operational complexities.
- Regulatory classification impacts vehicle operations and infrastructure use; there is currently a bill in the NYS Legislature that would explicitly define an electrically-aided
tricycle with a maximum speed of 20 mph and power output less than 750 watts as a bicycle.

**Infrastructure Use**

*Travelways*

- Regulations that allow freight-tricycles to use exclusive infrastructure enable speed and reliability benefits.
- In NYC, freight-tricycles should be permitted to operate on NYC’s Class 1 and Class 2 bicycle infrastructure.
- Potential impacts on safety and bus level-of-service should be carefully evaluated to determine if freight-tricycles can operate in NYC’s bus lanes, especially in areas of Midtown that lack bicycle infrastructure.

**Parking**

- Freight-tricycles offer quick delivery turnaround and can park in small spaces unable to be occupied by larger vehicles.
- Regulations concerning vehicle classification, infrastructure use, and parking should be unambiguously defined for human-powered and electrically-aided freight-tricycles.
- Enforcement authorities should be educated on freight-tricycle regulations to prevent unnecessary costs from unwarranted penalties.

**Micro-Distribution Centers**

- Additional space in Midtown West for sorting of goods from multiple carriers could enable parcel deliveries to dense commercial developments in Midtown; refrigeration of sorting and storage space could also enable food deliveries to existing retail markets in Midtown and WVS.
- An East Side UMC location would provide easier access from major 3PL generators in Queens; however, industrial space is extremely limited in Lower Manhattan, and is more expensive in Midtown East and the LES than elsewhere in Manhattan.

**Implementation Impacts**

*Financial*

- Total labor costs for drivers and sorting operations are considerable; in NYC, mandatory worker's compensation insurance costs are high.
- Land costs in Manhattan are prohibitive to UMC implementation; NYC should evaluate the benefits and costs of providing financial incentives to operators such as tax abatements or reduced rents on city-owned land.
- Freight-tricycle operations can reduce capital, fuel, insurance and maintenance costs for carriers compared to heavy vehicle operations.
- Freight-tricycle operators can generate revenue from sale of on-vehicle advertising space.
- Freight-tricycles may offer shippers the ability to increase their small business clientele.
• UMC operations create new low-skill local job opportunities for drivers; shifting freight to vehicles requiring lower skilled operators may offer some relief to expected driver shortages.

Environmental
• Shifting freight from diesel-powered vehicles to human-powered or electrically-aided tricycles for last-mile delivery will reduce fuel consumption and resulting CO₂ and PM emissions.

Safety
• In theory, shifting freight from trucks to freight-tricycles should reduce the risk of pedestrian and bicyclist fatalities; however, gains could be offset by increased exposure due to growth in total freight VMT in the delivery area. Existing data are insufficient to draw statistically significant conclusions about safety performance.
• Safety of freight-tricycles can be improved through mandated use of indicators such as brake lights and turn signals.

Security
• Security is not currently a major concern for carriers delivering freight by human-powered or electrically-aided tricycle.

GENERAL CONCLUSIONS
With a commercial composition nearly mirroring that of UMC delivery areas in Paris and London, Midtown and Downtown Manhattan generate significant freight demand that could be served by electrically-aided or human-powered freight tricycle. These vehicles have the ability to carry a variety of commodities for shippers large and small, offering improved freight access to areas where space or regulatory constraints limit truck movement and improved travel time reliability in heavily congested urban areas. While exact costs are unclear and may not be directly transferable to US conditions, results from London indicate that even without public support, last-mile delivery operations for an individual shipper can be shifted to smaller, cleaner vehicles without increasing overall costs and at the same time reducing social externalities. While space and labor costs in Manhattan are prohibitive to UMC implementation, it is possible that public financial support for UMCs serving single- or multiple-carrier operations could be justified by traffic and environmental improvements and job creation. NYC should engage both carriers and shippers to identify potential private sector partners and feasible locations for future UMC implementation.

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