Apple's bobbing

NYC does well against Sandy, but still needs to improve

By Sarah Kaufman
Contributing Author

Superstorm Sandy, which hit New York City on Oct. 29, 2012, demonstrated the strengths and limits of the transportation infrastructure in the city and surrounding region.

As a result of the timely and thorough preparations by New York City and the Metropolitan Transportation Authority (MTA), along with the actions of city residents and emergency workers to evacuate and adapt, the storm wrought far fewer casualties than might have occurred otherwise.

The NYU Rudin Center for Transportation mobilized its research team during Superstorm Sandy. We were prepared to deploy our staff to analyze the short-term effects on New York City's transportation infrastructure: roads, bridges, commuter rail, tunnels, transit and ferries. Findings included strengths of public agencies in assessing and mitigating the vulnerabilities of the transportation systems, outdated floodplain boundaries, vulnerability of energy sources in physical buildings and adaptability by New Yorkers, who shifted modes and workplaces to continue business as usual. The following is a summary of the report.

Ready for a date with Sandy

Recent storms, as well as meteorological predictions, preceding Superstorm Sandy in October 2012 prepared New York City and the MTA for a high-magnitude storm. In two previous storms, in September 2004 and August 2007, heavy rain overwhelmed the subway pumps, causing subway closures. On a typical day, 700 pumps throughout the subway system drain 13 million gal of water—rain, groundwater and seepage from sewers—from the system and into storm drains. Seawater can corrode equipment or begin to boil after coming into contact with the 600-volt third rail. During flooding events in the previous decade, the subway pumps had been pushed to—and exceeded—their limits of pumping 1.5 in. of rainwater per hour. Through targeted planning for extreme weather, the subway system was upgraded for future storms: raising entrances above street level, improving sewers, modernizing pumps throughout the system and additional measures, at the cost of $30 million. In advance of Hurricane Irene in August 2011, the MTA closed the subway system

and implemented pumping, preventive and communications protocols, but still sustained damages estimated at $65 million.

In the days preceding Superstorm Sandy's arrival on Oct. 26, 2012, the city and MTA took significant preventive measures:

- Moved all buses and trains to higher ground;
- Ensured operability of all emergency-response vehicles, pump trains and portable pumps;
- Cleared storm drains of debris; and
- Covered subway street-level vents and barricaded subway entrances with plywood and sandbags.

In the 24 hours before the storm made landfall in New York City (8 p.m. on Oct. 29), preparations included:

- Mandatory evacuations for all residents in "Zone A" high-risk areas;
- Closure of all bridges and tunnels, on a case-by-case basis, in the one to six hours preceding landfall;
- Shutdown of the subway, bus, ferry and commuter rail systems; and
- Additional flights out of area airports, and eventual closure immediately before the storm.

By 9 p.m. on Oct. 29, record storm surges had flooded Lower Manhattan, numerous areas in Brooklyn and Staten Island, area airports and several traffic and train tunnels.

HOV3+ and bus bridges

The following day, as the storm eased, most of the city—infrastructure and businesses—remained closed, though the recovery effort had begun. The state of major transportation facilities was mixed:

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- All eight subway tunnels, major stations and rail yards were flooded in the worst storm damage in the MTA's history;
- Bridges and some sections of highways reopened at 11 a.m., but traffic tunnels (including the Hugh L. Carey, Holland and Queens-Midtown tunnels and the Battery Park Underpass) remained closed due to significant flooding. Despite preparations, flooding in the Carey and Queens-Midtown Tunnels was far worse than anticipated;
- Damaged suburban rail lines were covered in downed trees, water and debris;
- Limited bus service resumed with free fares in the afternoon, though most operated at or above capacity and heavy traffic slowed traffic significantly; and
- Airports remained closed as damage was assessed, and reopened on Thursday, Nov. 1.

One major impact of these transportation outages and openings was intense traffic gridlock, compounded by a severe gas shortage. Many businesses opened on Wednesday, Oct. 31, but the subways, which typically carry 5 million New Yorkers every day, were closed; local residents were stuck finding alternative modes, most depending on driving private cars or taking buses, taxicabs or bicycles. Gov. Andrew Cuomo declared a transportation emergency.

New York City implemented HOV3+ carpooling restrictions, requiring all vehicles to carry three or more passengers, on most bridges and tunnels to Manhattan (except the George Washington Bridge, from New Jersey and out of N.Y.'s jurisdiction), enforced by the New York Police Department. The widespread gridlock lessened but continued (with reported four-hour waits at the Lincoln Tunnel), and New Yorkers quickly took to less common transportation modes, including bicycles and ferries, in large numbers; the department of transportation estimated three times the typical number of bicycle commuters (30,000 on Oct. 31).

In response to the gridlock, the New York City DOT and MTA set up "bus bridges," or 330 buses linking Brooklyn and Manhattan over dedicated bridge lanes, to substitute for heavily used, closed subway lines. Users reported long waits, of up to three hours, but speedy service once buses were in motion; the buses carried 3,700 people per hour. Although in the subsequent days several

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subway lines reopened, service was limited to the parts of Manhattan with power (primarily north of 42nd Street), and portions of the outer boroughs, but often without connections between them. Free subway and bus fares continued.

Compounding the transportation woes was a shortage of gas, with approximately only 40% of gas stations in the metropolitan area open. Long waits and physical confrontations were reported at gas stations, and eventually the NYPD was called in to regulate gas lines. Due to power outages and a rapidly depleting fuel supply with limited access to restocking (as access roads were often gridlocked or damaged), the gas shortage lasted two weeks and required emergency gas rationing throughout the New York City region and in New Jersey.

In the subsequent days and weeks, transportation infrastructure began to reopen; by Saturday, Nov. 3, 80% of the subway system was back in operation. Subway tunnels were pumped out using pump trains, with some assistance from the Army Corps of Engineers' "Unwatering Team," and services were restored one by one, with the last tunnel opening (for the R train) on Dec. 20. However, some lines, like the A in Far Rockaway, Queens, and stations, like the South Ferry in Lower Manhattan, remain out of service for what appears to be the long term. With significant damage to the tracks connecting the Rockaway Peninsula to the mainlands of Brooklyn and Queens, the MTA responded creatively by revitalizing unused tracks along the peninsula to connect residents to regular bus service, calling this new route the "H" line.

The South Ferry subway station, serving the 1 line and a major connector to the Staten Island Ferry, is damaged and closed indefinitely. Reopening the station would cost an estimated $600 million.

Roads, bridges and traffic tunnels fared far better than portions of public transit; subways experienced issues from flooded tunnels, corroded signal equipment and a lack of power.

Gridlock eased with the renewed transit services, and traffic was more easily maintained once power was restored in all of Manhattan's traffic lights. The most heavily damaged traffic tunnel, the Hugh L. Carey in Lower Manhattan, opened only to commuter buses on Nov. 7 and finally to all vehicles the following week.

Finding a way

Another element of the NYU Rudin Center's research on Superstorm Sandy was an online survey we conducted about commutes in the immediate aftermath of the storm. Of the 315 respondents, the most popular modes of transportation to work on Nov. 1 and 2 were bicycling, telecommuting and walking. Commutes often took two or three times as long, and frustration levels were extremely high. Several survey respondents found more unusual modes of transport to work, including employer-run vans, relocated company offices, running and staying in homes closer to offices.

New Yorkers also remained on top of social media; in a geographic analysis by Floating Sheep, the most common tweeting location was Midtown Manhattan, even during and after the power outages. In fact, social-media communications in areas without power continued throughout and after the storm, many centering around the collapsed crane on 57th Street. While few postings emerged from areas heavily struck by the storm, the continuous distribution of tweets throughout the city meant New Yorkers were informed and sharing information, even during the crisis. Nearly two-thirds of survey respondents reported getting transportation information via social media (the second most popular choice) and 85% from official websites,

indicating that locals were continually plugged in to sources of web-based information, even without power and Internet access at home.

In the event of another hurricane

Based on this study, the NYU Rudin Center has determined several recommendations for the sustainability of roads, bridges and transit:

Roads

Porous pavement should be considered in flood-prone areas: Specialized pavement that allows for draining of floodwaters back to the nearby bodies of water could help prevent the standing water that remains after the storm and assist in the recovery of neighborhoods and streets that are especially hard hit by floods.

Consider sidewalk vents with elevated vents that double as street furniture: Following the 2007 subway flood, New York City began installing elevated vents that doubled as street furniture, such as benches and bicycle racks. This program should be considered throughout the city to reduce flooding through ventilation grates system-wide.

Evaluate the use of closeable ventilation ducts: While elevating sidewalk ventilation ducts helps in many cases, vents in the most flood-prone areas should be closeable to prevent floodwaters from entering the subway system.

Bridges

Maintain bus-priority lanes on bridges and major streets: The large numbers of buses traveling from the outer boroughs to Manhattan in lieu of subway service showed the potential for a long-term alternative to overcrowded subways. If buses continued to have priority on bridges and throughout the major arteries of Manhattan and the outer boroughs, large numbers of people could move through the city more efficiently.

After Hurricane Sandy hit, the New York City DOT and MTA set up "bus bridges," or 330 buses linking Brooklyn and Manhattan over dedicated bridge lanes.

Develop more extensive bridge-based bicycle infrastructure: Creating or expanding safe bicycle routes on bridges would help alleviate congestion on subways and increase New Yorkers' health through physical activity while commuting. During crisis situations such as post-Superstorm Sandy commuting, all modes of transportation would benefit from dedicated bicycle lanes on bridges, reducing car, bus and subway congestion.

Transit

Install backup power for pump systems: When power outages knock out subway pumps, subway flooding is exacerbated, and the potential for infrastructure damage is much greater. Backup power is an essential addition to the subway pump system so that tunnels may be cleared of water more quickly.

Install flood gates and raised entrances at flood-prone stations: Several major transit systems, including those in Bangkok, Thailand, and London, feature elevated subway entrances and built-in floodgates to allow the system to continue operations even during floods. These infrastructure upgrades, if implemented in New York, would significantly lessen the effects of flooding and damage to equipment during future storms.

Consider installing subway "plugs:" Currently under development by the Department of Homeland Security, the plug—which looks and works like a big balloon—helps prevent water from entering subway tunnels and can inflate in just a few minutes. These plugs could help prevent significant damage due to tunnel flooding.

Superstorm Sandy highlighted the great benefit of Manhattan's multiple modes of transportation on and off the island. Because Manhattan is connected throughout the length of its 9 miles by both bridges and tunnels, it remained possible to move on and off the island as needed, and populations could move throughout the city. Had Manhattan lacked either bridges or tunnels, and had an area lacked connectivity to an outer borough or New Jersey, the area may have been harder hit by traffic congestion or an inability to evacuate the necessary locations. In preparations for future storms, it is essential that New York continue to maintain its aboveground infrastructure of bridges and elevated roadways as a means of transporting people and goods in the event that tunnels are flooded again.

However, New York could not have emerged from this disaster without the disaster planning and preparation of the city of New York and the MTA, the efforts of its public workers and the innovative adaptability of its population. **R&B**

FACT FINDER

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Kaufman is a Research Associate and Assistant Adjunct Professor of Planning at the NYU Rudin Center for Transportation, New York University Wagner School, New York.