BUILDING RESILIENCE AND SUSTAINABILITY INTO THE STATEN ISLAND NORTH SHORE BUS RAPID TRANSIT

Columbia University in the City of New York
Graduate Program in Sustainability Management
Integrative Capstone Project

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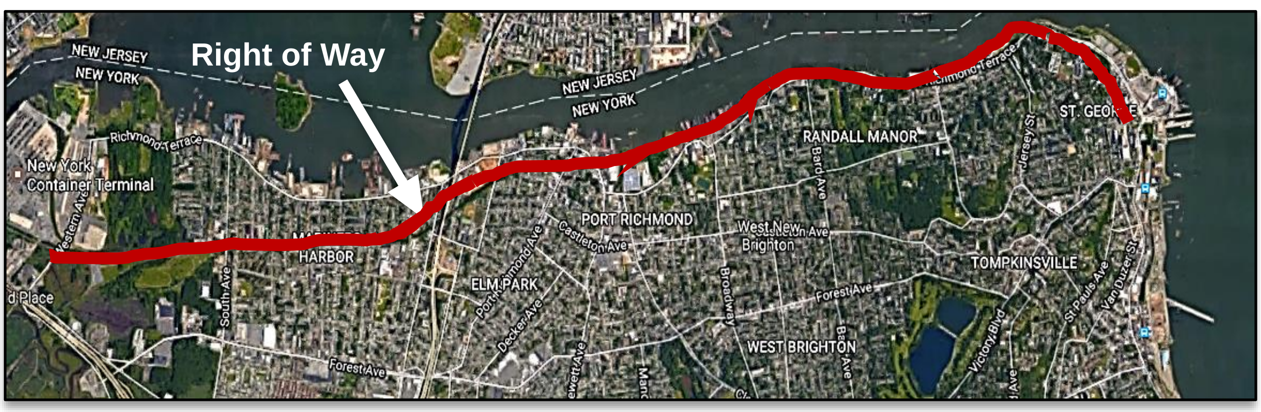
Executive Summary

This report presents an analysis of the potential traffic, environmental and health benefits of a proposed Bus Rapid Transit (BRT) system on Staten Island, and makes recommendations for features that would increase the sustainability and resilience of the BRT. These features are drawn from BRT systems in the US and internationally, and derived from best practices of other modes of public transit.

Traffic and Transit on Staten Island's North Shore

Residents of Staten Island have long been burdened by heavy traffic congestion, limited public transit options, and some of the longest commute times in the country. For decades, traffic has been a top complaint of Staten Islanders, two-thirds of whom are forced to rely on private cars, in contrast to just over a quarter of New Yorkers overall. The problem has been well documented by government reports, but as yet no comprehensive infrastructure solutions have been implemented.

A 2012 report by the Metropolitan Transportation Authority (MTA), the *North Shore Alternatives Analysis*, systematically reviewed a range of possible Staten Island public transit options with the goals of improving mobility, preserving and enhancing the environment, and being as cost effective as possible. It determined that the best solution would be a Bus Rapid Transit System (BRT) on the existing Right of Way (ROW) of the defunct Staten Island Railroad. The ROW, which is owned by the MTA, traverses the North Shore area of the borough, running roughly parallel to the northern waterfront and Richmond Terrace, a critical but frequently congested commuting route from the west side of the Island to St. George and the Ferry Terminal.



The proposed route of the North Shore BRT.

The Benefits of BRT

A BRT system across Staten Island's North Shore has the potential to significantly reduce the traffic congestion on the area's surface roads, meaningfully shorten commute times for residents working both on the Island and off, improve the health of Staten Islanders through a decrease in vehicle collisions and pollutants, and benefit the climate by avoiding the emission of tens of thousands of tons of CO_2 and other greenhouse gases every year.

BRT can also have a powerful economic impact. In Cleveland, a $200 million BRT investment has been credited with attracting $4.3 billion in housing and commercial development. On Staten Island, the North Shore BRT could extend the benefits of ambitious projects under construction in St. George across the island, and drive new retail developments, housing, artisanal industries, and recreation along the waterfront.

Model BRT, integrated with bike lanes and other sustainability features.
Source: Rockefeller Foundation

Building a Better, More Sustainable BRT

BRT surpasses conventional bus systems in sustainability because the vehicles spend very little time idling in traffic or picking up passengers. This report identified successful sustainability and resilience strategies from other cities. The ten BRT systems highlighted in this report were selected based on their comparability to the existing service, population, and route conditions in Staten Island. Additionally, five BRTs are presented here as model case studies. These were rated Gold, Silver, or Bronze by the Institute for Transit Development Policy (ITDP).

Clean and efficient buses are at the heart of BRT sustainability. Currently, leading BRTs are using hybrid diesel-electric buses (Pittsburgh, Cleveland) and compressed natural gas (Los Angeles), and seeing reductions in fuel use and up to 90% of GHG emissions avoided. Although not yet implemented by U.S. BRTs, electric buses are now used by many conventional bus systems, with great success. Electric vehicle technology has improved to the point that electric buses have surpassed diesel-hybrid and CNG fueled buses on every major point of comparison except initial vehicle cost, and that is more than offset by savings in fuel and maintenance costs over the life of the bus. Electric buses could be partially powered by solar PV on depot roofs, and the fit with New York State's Reforming the Energy

Vision plan to reach 80% renewable power by 2030. Given these benefits, the Staten Island BRT should opt for electric buses.

BRT station design offers many opportunities to build in sustainability, including through passive design and architecture that warms stations with sun and wind protection in winter (for example, in Pereira, Columbia) and cools with green roofs that absorb water in summer (which Philadelphia uses). LED lighting, solar PV-powered lighting and signage, and solar PV electricity generation on the roofs of depots and large stations, such as London's Vauxhall, all reduce demand for grid electricity. potential enhancements

Solar-powered sign. Green bus-stop roof in Philadelphia. Solar PV on London's Vauxhall station.

Many BRTs, including Los Angeles' Orange Line, have incorporated bike lanes adjacent to the busway, along with bike racks and shelters at stations. Several have also integrated greenways. Los Angeles's BRT route is landscaped with drought-tolerant native plants that provide a habitat for wildlife. Drainage swales line the route. In Eugene, the EmX incorporates rock gardens and public art into station bioswales. A greenway would fit well with Staten Island's plans to develop and increase access to parks, other green spaces, and the waterfront. Many stretches of the North Shore ROW are already wooded, and an existing elevated section of the route could become a park similar to Manhattan's High Line. Attractive plantings and hardscapes invite and relax riders, and contrast vividly with the experience of driving on barren highways in rush hour traffic. Landscaping along the ROW can also absorb CO2, lower temperatures of bus lanes and mitigate the heat island effect, dampen noise, and improve storm water drainage.

A route that is as close to sea level and as close to the waterfront, as is the North Shore BRT route must be resilient in the face of storms and sea level rise. A floodable roadway, using technologies being tried in the North-west, is more cost-efficient that building levees or elevating the route above 100-year flood levels. Raising and protecting the sections of the BRT route that run close to the water, either with revetments or the construction of an elevated roadway and esplanade supported by wave-calming structures or plantings, would remediate the eroded, deteriorating waterfront of the North Shore and open views of New York Harbor and the Kill van Kull to both visitors and residents.

The BRT that the MTA has proposed for Staten Island would be the first true BRT in New York City. It can be enhanced by a variety of sustainable and resilient design elements that will increase the health and environmental benefits it brings to the borough. With its placement along the shore and its appealing changes in elevation, it could be the core of a greenway that would link the North Shore’s neighborhoods, parks, waterfront and attractions. Adding sustainability features would transform the BRT line from being simply a fast, comfortable, safe and efficient way to get across the Island into a model of sustainable, resilient development and catalyst for connection and exploration.

Acronyms

ADA: Americans with Disabilities Act (1990)
AMVA: Area Metropolitana del Valle de. Aburrá/Environmental Authority of the Metropolitan Area of the Aburra Valley
APTA: American Public Transit Association
BRT: Bus Rapid Transit
CCIT: California Center for Innovative Transportation
CCTV: Closed Circuit Television
CNG: Compressed Natural Gas
CO2: Carbon Dioxide
CSO: Combined Sewer Overflow
DEC: Department of Environmental Conservation (NYS)
DLRT: Diesel Light Rail Transit
EDC: Economic Development Corporation
EMX: Emerald Express Green Line
EPA: Environmental Protection Authority
FTA: Federal Transit Administration
GHG: Greenhouse Gas
GM: General Motors
HC: Hydrocarbons
HOV: High Occupancy Vehicle
HUD: US Department of Housing and Urban Development
ITDP: The Institute for Transportation and Development Policy
ITS: Intelligent Transportation System
KWh: Kilowatt Hour
LACMTA: Los Angeles County Metropolitan Transportation Authority
LEED: Leadership in Energy and Environmental Design
LOS: Level of Service
LPG: Liquified Petroleum Gas
LRT: Electric Light Rail
LTD: Lane Transit District
MLK Jr.: Martin Luther King Jr.
MPH: Miles Per Hour
MTA: Metropolitan Transportation Authority
NBRTI: National Bus Rapid Transit Institute
NCHRP: National Cooperative Highway Research Program
NO2: Nitrogen Dioxide
NSAA: North Shore Alternative Analysis
NYCDOT: New York City Department of Transportation
NYCEDC: New York City Economic Development Corporation
NYCTC: New York City Transit Authority
NYU: New York University
ONENYC: One New York City
PANYNJ: Port Authority of New York and New Jersey
PM2.5: Particulate Matter
PPB: Parts per Billion
ROW: Right of Way
RTA: Regional Transit Authority
SBS: Select Bus Service

SI: Staten Island
SIR: Staten Island Railway - Heavy Rail
SIRR: Special Initiative Rebuilding and Resilience
Solar PV: Solar Photovoltaic
STE: Staten Island Expressway
TIS: Transportation Improvement Strategy
TIP: Transportation Improvement Plan
TPIS: Transit Passenger Information System
TSM: Transportation Systems Management
TSP: Transit Signal Priority
VKT: Vehicle Kilometers Travelled
VMT: Vehicle Miles Travelled
VOCs: Volatile Organic Compounds
WPCP: Water Pollution Control Plant
WWTP: WasteWater Treatment Plan

Introduction

Staten Island is the least populated borough of New York City, and the only one that is not connected to the rest of the City by subway. Transportation is a major quality of life issue for Staten Island residents. Approximately half of all employed Staten Islanders work off-island,[1] and both these commuters and those whose jobs are in the borough must contend with limited public transit options. Most must rely on their cars, and the result is heavy traffic congestion, poor air quality, and unsafe roads.[2] Government entities with responsibilities for the region, among them City agencies, New York State's Metropolitan Transit Authority (MTA), and the Port Authority of New York and New Jersey (PANYNJ), have conducted land use and transportation studies and made recommendations to mitigate the congested roadways and insufficient public transit. However, to date none of the major traffic infrastructure improvements recommended in these studies have been implemented.

Improved transportation infrastructure is necessary to support Staten Island's population growth and economic development. Investments of more than $600 million in public funding and $1 billion in private funding have been made to develop new housing and major retail centers in the Island's North Shore. Construction on three major projects, the 630' New York Wheel, the Lighthouse Point housing and hotel complex, and the Empire Outlets mall in St. George[3] are moving forward, but no unifying vision or practical plan for the North Shore's transportation infrastructure is yet in place to support these developments. Nicholas Siclari, the chair of Staten Island's Community Board 1, interviewed by *Politico* about rezoning the Bay Street Corridor, just south of St. George on the North Shore, said that transportation infrastructure "is the biggest concern of Community Board 1. We are so transit poor. We got this (nickname) for being the forgotten borough."[4] Staten Island is eager for more housing, business and industry, and recreational opportunities,[5] but the already over-capacity transportation network is not prepared for the influx.

In addition to its traffic problems, Staten Island's North Shore faces significant environmental challenges. Air quality is poor,[6]negatively impacting human health.[7] Climate change is causing rising sea levels and more extreme storms. Most of the Island's wetlands have been reduced by landfill, eliminating a natural buffer against storm surges, like that of Tropical Storm Sandy.[8] The coastline is eroding, and tidal flooding is damaging shore front properties and the transportation infrastructure along the coast.[9]Solutions to the borough's transportation infrastructure will have to contend with, and ideally increase Staten Island's resilience to, these threats.

In 2012, the MTA determined that building a Bus Rapid Transit (BRT) system on an unused railroad right-of-way (ROW) owned by the MTA was the most cost-effective solution to the North Shore's traffic problems.[10] This report reviews the area's environmental and socio-economic challenges and the ways a BRT could contribute to mitigating these problems, in addition to easing traffic congestion. A survey of BRTs in other cities presents features, technologies and operating systems that would maximize the sustainability, resilience and appeal of the proposed BRT. An improved public transit system in the North Shore[11] could help achieve greater equity, drive economic development, and support environmental goals outlined in Mayor de Blasio's OneNYC plan. [12]

Traffic and Transportation on Staten Island

Few Alternatives to Driving

The proposed BRT would alleviate some of the traffic congestion and commute time problems that are a by-product of Staten Island's transition from a scattering of rural villages to a bedroom community of Manhattan. The borough's roads were not designed to facilitate travel between the island's neighborhoods and the rest of New York City. The streets are typically narrow and curving, with bottlenecks at many intersections and on-ramps to highways and bridges. The narrow local roads create challenges for the existing bus lines in the North Shore. Some corridors have only one travel lane in each direction, forcing all vehicle traffic to wait behind buses at bus stops. The bus-only lanes are too narrow for passing buses, as can be seen in the photograph in Figure 1, and, during rush hour, private cars often use bus stops as an extra lane, further slowing traffic.[13]

Figure 1: Bus crowding on Victory Boulevard, westbound[14]

Staten Island residents have limited public transportation options. New York City Transit (NYCT) operates local, limited, and express buses on surface roads. The Staten Island Railway runs north-south on the east side of the Island between St. George and Tottenville.[15] The Staten Island Ferry operates between the St. George Ferry Terminal and Whitehall Terminal, Manhattan.

Staten Island's transportation problems have been thoroughly studied, as summarized in Table 1 below. In 1995, the Metropolitan Transit Authority New York City Transit (MTA-NYCT) published its *Transit Needs Assessment Study,*[16] an examination of the North Shore's dearth of public transit. Almost a decade later, the PANYNJ released the *North Shore Right Of Way Feasibility Study* (2004), exploring the possibility of a Light Rail project on the North and West Shores.[17] In 2013, the MTA framed the capital needs of the transit system as a whole in its *Twenty Year Capital Needs Assessment.*[18] The New York City Department of City Planning (NYCDCP) and the New York City Department of Economic

Development Corporation (NYCEDC) under the Bloomberg administration evaluated the economic, social, and transportation needs of the area. The outcome was a report, *North Shore 2030: Improving and Reconnecting the North Shore's Unique and Historic Assets*, released in 2011. The *North Shore 2030* report was designed as a framework for future public and private investment, and it identified a number of short and long term initiatives aimed to "increase waterfront access, improve mobility and strengthen neighborhoods."[19] A bus rapid transit system could make a major contribution to achieving those goals.

Year	Study	Agency	Summary
1995	Transit Needs Assessment Study	MTA NYCTA	Study of Staten Island's transit needs
2004	North Shore Right of Way Feasibility Study	PANYNJ	Commissioned by the Staten Island Borough President to analyze infrastructure in the North Shore and examine feasibility of improved transit service, including light rail
2011	North Shore 2030: Improving and Reconnecting the North Shore's Unique and Historic Assets	NYC Planning NYC EDC	A framework for future economic development and supporting transportation infrastructure on the North Shore
2012	North Shore Alternative Analysis (NSAA)	MTA NYCTA	Assessment and analysis of the North Shore aimed to enhance transit; recommended BRT on the ROW
2017	Station Island North Shore Transportation Improvement Study (TIS)	NYC EDC NYC DOT	Follow-up to the North Shore 2030; examines transportation conditions and makes recommendations to alleviate current and future traffic concerns

Table 1: North Shore Staten Island Transportation Studies

In 2012, the MTA released the *North Shore Alternatives Analysis* (NSAA), a study of the transportation problems in the neighborhoods and on the roads that compose the North Shore, featured in the map in Figure 2. Eight different transportation project options were analyzed in relation to three primary goals: improving mobility, preserving and enhancing the environment, and being as cost effective as possible.

The NSAA concluded that Bus Rapid Transit (BRT) constructed on an existing railroad Right of Way (traced in red in Figure 2) would best meet the stated goals.

Figure 2: North Shore neighborhoods and the Right of Way

Limited public transit options leave Staten Island residents dependent on their personal vehicles. In 2012, 67% of Staten Islanders commuted to work by car, 19% by bus, 3% on the Staten Island Railroad, and just 5% on the Staten Island Ferry (see Figure 3 below).[20] Five years later, the Staten Island North Shore Transportation Improvement Study found that an even smaller proportion, 12.5%, reported riding the bus regularly to get to work.[21] This may reflect the growing total number of commuters, not a decrease in total bus ridership.

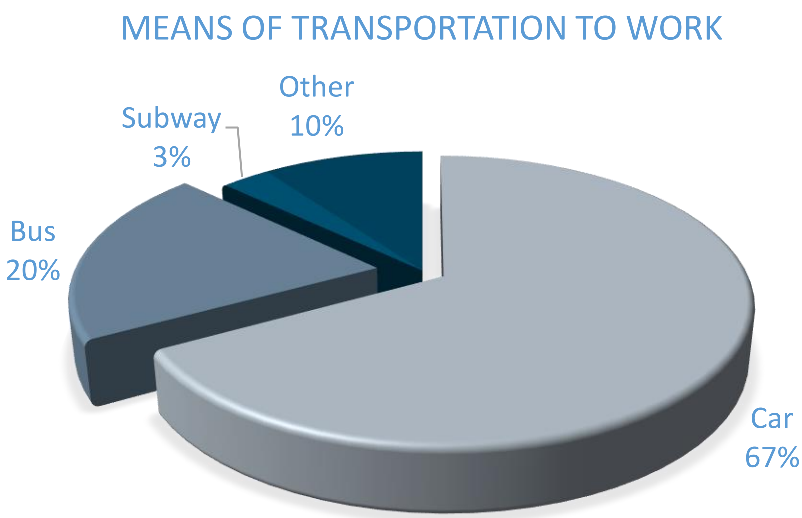


Figure 3:Staten Island North Shore Means of Transportation to Work. Source: NSAA[22]

The finding that two-thirds of SI commuters use their own cars is remarkable in the context of New York City, and is at least partly driven by the paucity of public transit options. By comparison, data collected by the American Community Survey between 2006-2010 and presented by NYCEDC found that only 28% of New Yorkers overall commute by automobile, and 55% relied on public transit.[23] Staten Island is the only NYC borough where bus transit increased overall between 2014 and 2015,[24] indicating growing demand for bus services. Staten Island is underserved by public transportation.

In January 2017, the NYCEDC and NYC Department of Transportation (NYCDOT) published the *Staten Island Transportation Improvement Strategy (TIS)*, conducted under the leadership of Mayor Bill de Blasio's office.[25] The report thoroughly reviews the transportation problems in the area and the current system's inadequacy to support sustainable growth, and proposes expeditious, low-tech traffic management strategies to improve safety, mobility, and the quality of life for residents on the North Shore. The *TIS* also recommends advancing study of the North Shore BRT, stating clearly, "BRT implementation would improve cumulative mobility along this corridor. The City supports the NYCT's continued study of BRT for the North Shore and recommends that the Borough President's BRT concept be evaluated as part of the MTA's upcoming effort."[26]

The Need for Resilient Public Transit in Staten Island

Resilience, according to climate risk evaluation expert Allan Lavell, is "the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a potentially hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures."[27] The changing climate presents significant threats to New York City's transportation infrastructure that must be considered in planning new transit systems,[28] especially those closest to the shore. Coastal cities everywhere are threatened by sea level rise and the increasing severity and frequency of storms, because of both their locations and the density of their populations and buildings. Coastal urban areas often have legacy transportation infrastructure investments—piers, railroads, and roads—associated with shipping, industry, and passenger transport concentrated along the waterside.[29] New transportation systems built on or aligned with existing coastal infrastructure, like the proposed North Shore BRT, must be made resilient.

The sea level along the coast of New York and New Jersey has risen between 0.5 and 0.7 inch each decade since 1900.[30] As the sea rises, the shore is eroded, beaches are submerged, and structures and roads adjacent to the coast are closer to the water's edge and more vulnerable to damage. Sea levels could rise by as much as 75 inches—over six feet—this century,[31] potentially inundating the waterfront where the BRT would be built. According to the 2015 Report by the New York City Panel on Climate Change, "It is virtually certain (>99% probability of occurrence) that sea level rise alone will lead to an increased frequency and intensity of coastal flooding as the century progresses."[32] But storms are also getting worse. Hurricanes, and the attendant storm surges, have been increasing in strength and number in the North Atlantic Basin since the 1980s, and will continue to do so.[33]

Figure 4: Projected high tides and floodplain in 2050. The BRT ROW is traced in orange. Source: NYC Floodplain Hazard Mapper[34]

The proposed route for the BRT on the North Shore is less vulnerable to storm surges and sea level rise than the western and eastern sides of the Island, as seen in the map in Figure 4, above. The eastern third of the route runs along the water's edge, and is vulnerable to erosion but less at risk of storms. The westernmost third of the ROW, where the flood risk is greater, is set further back from the water. The BRT must be designed to be resilient during storms and flooding events, and its construction could incorporate erosion prevention strategies along the waterfront, however the risks of flooding are not extreme.[35]

The Need for Transit Equity in Staten Island

The proposed North Shore BRT could contribute to a more equitable distribution of public transit options on Staten Island. The Mayor's OneNYC plan emphasizes "More than half of the city's neighborhoods with lower-than-average household income—representing 2.3 million residents—have a lower-than-average number of jobs accessible by transit."[36] New Yorkers with lower incomes spend, on average, more time commuting than others. Two thirds of the 750,000 New Yorkers who commute more than an hour each way earn less than $35,000 per year.[37] Rising rents in Manhattan and Brooklyn have driven low-income people into areas with lower rents, including the North Shore.[38]

Residents of Staten Island are among the New Yorkers with the fewest economic and transportation options. In the study *Mobility, Economic Opportunity and New York City Neighborhoods*, NYU ranked 177 New York City neighborhoods by access to job opportunities, household income, and population size. Staten Island neighborhoods were ranked in the bottom third of the distribution, and had some of the worst scores for access to jobs and opportunity. Port Richmond and North Staten Island, two North Shore neighborhoods, were ranked at 165 and 168 respectively.[39] The lengthy trips to work or college from the neighborhoods mentioned create additional barriers for people who already face significant challenges in finding good jobs.[40]

A Pratt Institute study commissioned by the Rockefeller Foundation found that there are fewer economic opportunities in neighborhoods without multiple transportation modes than in areas with more transit options. Commuters in transit deserts need to rely more on personal vehicles,[41] and Staten Islanders frequently complain that there are no alternatives to driving.[42] Car ownership costs Staten Island residents an average of $8,000 a year, comprising approximately 20-25% of the expenses of a moderate-income household. This extra burden, when compared to the average yearly transportation expenditure of $2,688 for two New York City adults who rely on public transit, demonstrates transportation inequity on Staten Island.[43]

According to the *North Shore 2030* report, the median income of residents in the North Shore is approximately 15% lower than the borough's overall average.[44] There is also a slightly lower education attainment rate in the area than in the rest of city: 18% of residents in the North Shore do not hold a high school diploma and residents are less likely to have post-secondary degrees than New Yorkers overall.[45] In Mayor de Blasio's OneNYC report, improving access to jobs and services for low to moderate level income communities is identified as a key equity issue.[46] A reliable, rapid transportation system could contribute to the solution to Staten Island's socio-economic equity problem.

Bus Rapid Transit

BRT is Right for the North Shore

Bus Rapid Transit (BRT), the system that the MTA identified in 2012 as the most cost effective solution to increase transit options and reduce commuting times for Staten Island residents,[47] could help mitigate traffic congestion, reduce emissions of greenhouse gasses, increase transportation equity, and improve the quality of life, health, and environment of the North Shore community.

BRT is designed to provide efficient, reliable, high quality express bus service in dense urban areas.[48] Although the vehicles are buses, BRT has features similar to those of a light rail or metro system, offering better capacity, speed, functionality, and efficiency than conventional bus transport systems. BRT systems can also be constructed more quickly—in a single mayoral term[49]—and much less expensively than subways or light rail trains. This is critical for New York City, where funding for public transit cannot fully meet the need for maintenance of the existing system.[50]

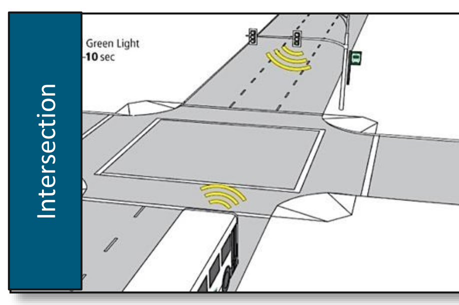
The Institute for Transportation and Development Policy (ITDP) is a non-governmental organization with the mission of working "around the world to design and implement high quality transport systems and policy solutions that make cities more livable, equitable, and sustainable."[51] ITDP created a global BRT Standard that establishes metrics and best practices for BRT systems. ITDP uses a scoring system and awards BRTs around the world with Gold, Silver, Bronze, and Basic BRT ratings based on both quantitative and qualitative data.

ITDP identifies a "true" BRT as having five distinct features, illustrated in Figure 5 below, that distinguish it from conventional bus systems. A true BRT has dedicated, bus-only lanes, busway alignment that keeps curbs clear of other vehicles, priority at intersections, off-bus fare collection, and platform-level boarding.[52] New York City does not now have a true BRT system. The MTA's Select Bus Service (SBS) is NYC's version of BRT. Because of the city's densely built environment and the impossibility of widening streets and avenues, NYC's SBS routes lack segregated lanes and platform-level boarding, and therefore are not categorized as true BRTs.[53]

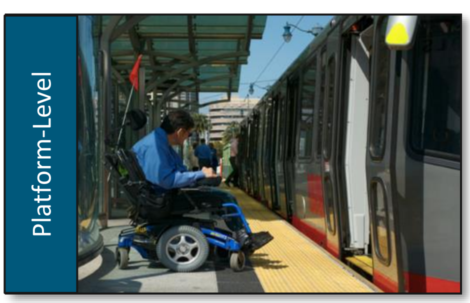
Dedicated lanes give priority to buses and enable them to avoid congested traffic pathways, ensuring rapid transit and decreasing commute times

Lanes designated for BRT transit are typically in the center of the roadway or have a designated bus-only corridor that is not located on the curbside, which may heavily trafficked with parked or standing cars

Fares are paid at the station, before boarding the bus or after disembarking, eliminating the delays caused by passengers waiting to pay on board



BRT buses have priority at intersections. Traffic is restricted so that no other vehicles can enter or cross the bus lanes, greatly reducing delays and travel times



BRT platforms are positioned at the same level as the bus for quick and safe boarding. This also enables disabled passengers to board with ease

Figure 5: The five defining features of BRT[54] [55] [56] [57] [58]

The benefits of BRT systems include decreased traffic congestion, reduced private vehicle-miles travelled (VMT) , faster travel times, increased traffic safety, and reductions in environmental pollution, resulting in improved street safety, environmental conditions, and better overall public health and quality of life.[59] BRT systems minimize crashes, and especially pedestrian and cyclist casualties, with segregated lanes, managed intersections, and mandated bus speeds. Coordination with other transit modes creates additional time savings and economic benefits. These benefits can be quantified and will be discussed more fully below.

BRT systems have positive environmental impacts. Older, less-efficient technology and smaller vehicles can be replaced with newer, high-capacity buses, burning cleaner fuel or using all-electric propulsion systems, and reducing local air pollutants and greenhouse gas (GHG) emissions that contribute to global climate change. Further emissions reductions can be achieved by integrating BRT with bicycle infrastructure, such as adjacent bike paths and racks on buses and at stations.[60] In addition, technological and design elements can further enhance the BRT's environmental and health benefits, including pedestrian paths and greenways adjacent to the BRT route, landscaping with native trees and shrubs, and using solar PV to power station signage and lighting. In the Pratt Institute report, Joan Byron and Elena Conte emphasized the importance of integrating BRT systems with such features and other transportation improvements, noting that "systems incorporating dedicated lanes, well-designed stations, and networked routes not only provide the greatest improvements in travel time and user satisfaction, their permanence can transform BRT corridors, leveraging residential and commercial density, economic revitalization, and environmental quality."[61] Staten Island community leaders are seeking to revitalize the waterfront with retail stores, restaurants, recreational activities, and open spaces, and the proposed BRT could help drive this transformation.

The benefits and consumer appeal of BRT open possibilities for alternative funding mechanisms, such as public-private partnerships and sponsorship opportunities, that bring in reliable funding streams and decrease reliance on federal and state dollars. NYC's Citi Bike bike share program is a local example of a highly successful public-private transportation partnership that relies on public funding. The HealthLine in Cleveland was the first transit system to sell naming rights sponsorships in the nation, leveraging a 25 year, $6.25 million sponsorship with both the Cleveland Clinic and University Hospitals. Similar opportunities should be explored for the North Shore BRT.

Agencies charged with implementing the North Shore BRT could leverage federal, state and city programs that provide assistance to clean up and redevelop contaminated sites, including two Brownfield Opportunity Areas along the ROW. The mechanisms include grants or tax credits for investigation, remediation, construction, and liability protections.[62]

The North Shore Right of Way

The proposed route for the BRT is the inactive right-of-way (ROW) of the defunct Staten Island North Shore Railway. The ROW runs roughly parallel to the Kill van Kull, and is a valuable transportation asset now owned by the MTA. The Staten Island Rapid Transit Company and the B&O Railroad operated trains along 15.3 miles of double-track from Cranford, NJ, to St. George from 1890 until 1989.[63] The BRT would run on a 5.1-mile stretch of this ROW from South Avenue to the Ferry Terminal, shown in Figure 6. The *North Shore Alternatives Analysis* identified the ROW as the most cost-effective route for the proposed BRT because it is a unique strip of undeveloped land in an otherwise built area, it is owned by the MTA, it intersects with major roads and bus lines in the area, and it would not require using eminent domain to purchase privately-held properties for a transit route.[64] A review of the placement and condition of the ROW can be found in Appendix C.

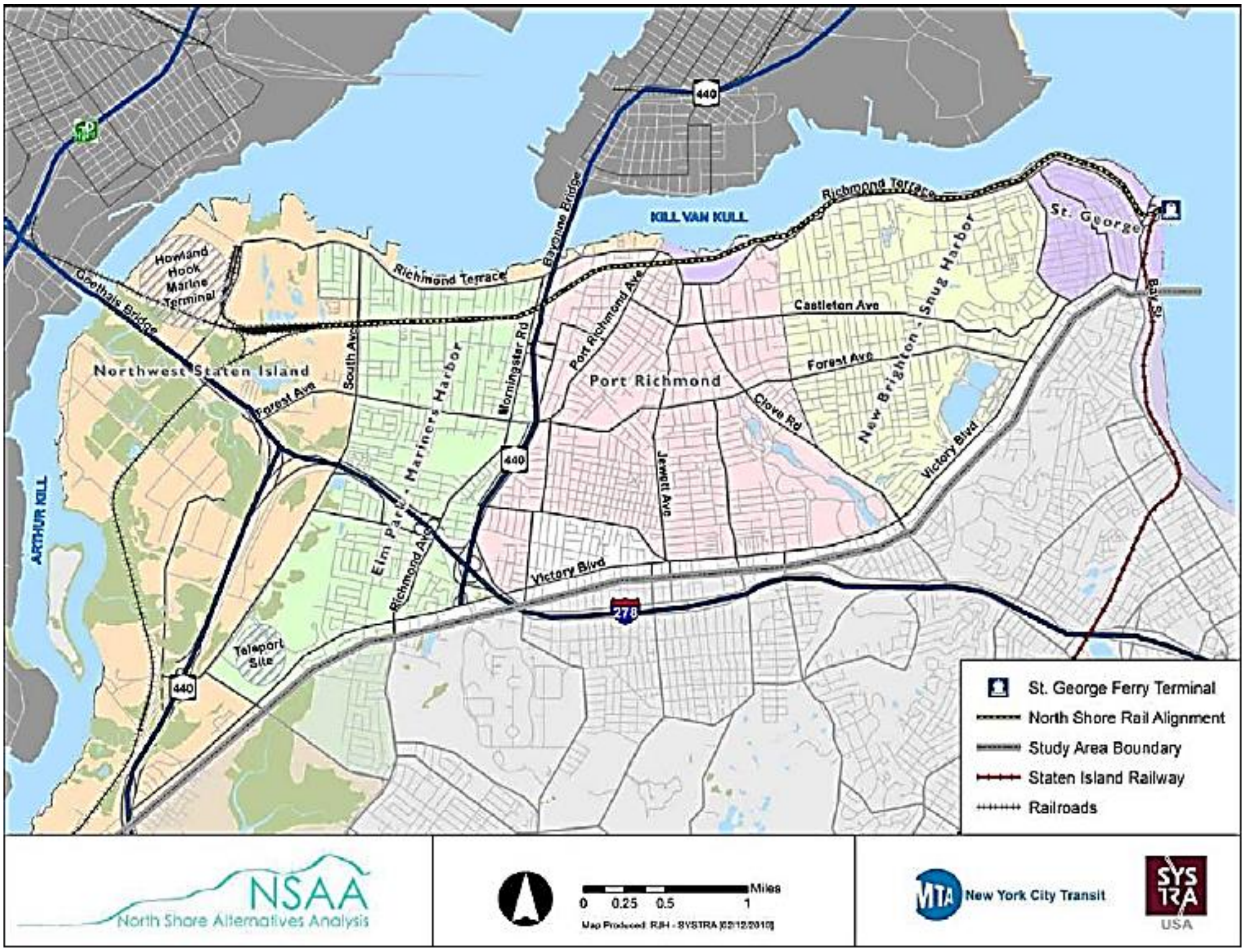


Figure 6: Staten Island's North Shore Source showing the NS Rail Alignment (dotted line). Source: NSAA

According to the 2004 *North Shore Feasibility Study*, the inherent challenges of the project are its varied levels of elevation, its width, its proximity to the shoreline, and the condition of the route. There are 2.3 miles of grade-separated alignment, (which include 1.5 miles of an open-cut section and an additional 0.8 that is elevated) and 2.8 miles that are at grade (see Figure 7).[65]

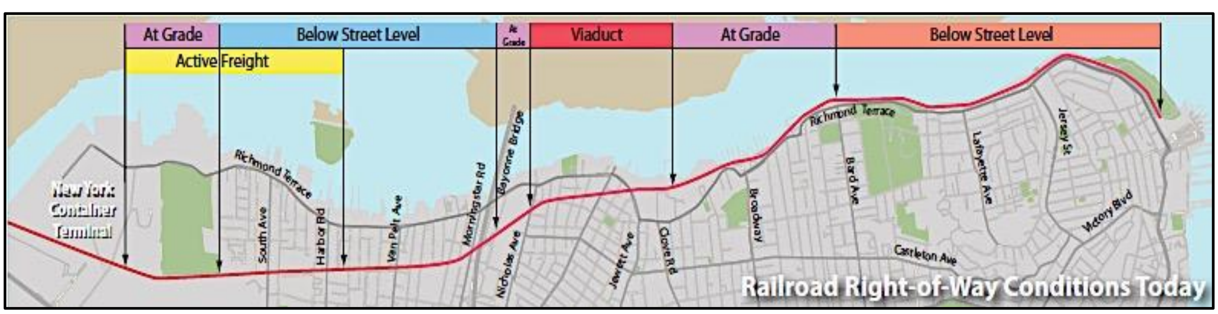


Figure 7: The North Shore Right of Way, with gradations. Source: 2004 North Shore Feasibility Study

Some sections of the ROW will require major rehabilitation and construction. The 2004 North Shore Feasibility Study found that the elevated viaduct in Port Richmond would have to be remodeled, reinforced or eliminated, while the .75-mile stretch of the ROW adjacent to Snug Harbor would need to be reconstructed. Several of the improvements would also require environmental permitting.[66] Additional improvements would require site clearing and restoration of the eroded shoreline, shown in Figure 8.[67] Strategies for the latter will be discussed in the Recommendations section of this report.

Figure 8: The eroded ROW, February 2017

The degraded condition and precarious locations of some stretches of the ROW can be overcome with strategies already in place or successfully implemented by BRT systems in other cities. These include the ROW's bisection with easements of several waterfront industrial properties, the narrowness of some sections, the built environment near the Ferry Terminal, and the depth of the cut in the western section.

The problem of the ROW splitting two important waterfront businesses, Atlantic Salt and the Caddell Dry Docks, can be managed by realignment. The 2012 NSAA recommended that the ROW be realigned for four reasons: to give businesses bisected by the ROW property entirely under their control and ownership, to move the BRT infrastructure inland from the Kill van Kull and associated flooding and erosion, to facilitate the development of, and access to, the waterfront for recreation and retail activities, and to relocate the BRT closer to potential riders. A "property swap" is expected to be acceptable to all parties.[68]

At some points, the North Shore ROW is too narrow for two bus lanes. This is primarily an issue in the waterfront section that bisects the waterfront businesses, and that would be realigned to resolve the easement problem, according to the *NSAA*. When the route is moved inland, towards Richmond Terrace, it can be widened. If there are stretches where widening the route is not an option, the City could develop a variation of the solution to a similar issued the EMX Green Line in Eugene, Oregon overcame with traffic signals and dedicated medians.

The easternmost stretch of the ROW as it enters St. George is no longer available for the BRT: it has been incorporated into parking garages, a service road and the Staten Island Yankee Stadium. In addition, construction of the New York Wheel, the outlet mall, and other developments is already underway. Exactly how BRT passengers will transfer smoothly to the Ferry Terminal and other bus lines that terminate there has not yet been detailed. However, other BRT systems have negotiated similar challenges of reaching the final transit destination without available dedicated roadway. The MLK Jr. East Busway in Pittsburgh and the Green Line in Oregon are BRTs face similar conditions. These two cities run the last stage of their BRTs on surface roads, adding signal prioritization at intersections, queue jumps, and headway-driven schedules. These features have increased service frequency and have reduced travel time for commuters. The Staten Island BRT may also require a stretch of shared (not dedicated) roadway with priority for BRT buses at intersections.

The westernmost stretch of the ROW is below grade, and, because of overpasses, the cut cannot be filled to create an at-grade bus route. The cut is clearly vulnerable to precipitation flooding. Building in green infrastructure elements, including permeable soils, pervious pavement, and rain gardens running alongside the BRT lane, as well as rainwater catchment for community gardens, could minimize the risk. If a pumping system is necessary, it could be solar powered.

Environmental Concerns: Land, Water, Ecologically Sensitive Areas, and Endangered Species

Despite its degraded state, the North Shore waterfront provides habitats for many wildlife species, especially birds and native plants. These fragments of a bygone world have established themselves at abandoned industrial sites and along roadsides, and the construction of the BRT should ultimately enhance, rather than destroy, these habitats. The urban forest here includes eastern cottonwood and black locust trees (both native), and sycamore maple and Japanese knotweed, which are non-native. Invasive Japanese knotweed is abundant on a stream flowing out at Snug Harbor.[69] Uninhabited Shooters Island, a bird sanctuary owned by New York City Department of Parks and Recreation, lies off Mariners Harbor: it is home to a breeding colony of herons.[70] The Mariners Marsh, a protected area, also supports native plants, birds, and other small wildlife.

Although the lush habitat and wildlife give an impression of a healthy environment, a 2006 report by the US department of Health and Human Services for the EPA showed that the Mariners Marsh brownfields are contaminated with industrial waste and chemicals from when they were heavy industrial sites.[71] The waters of the Kill van Kull are also fouled by Staten Island's combined sewer overflows (CSOs). Storm water runoff and raw sewage that together exceed the capacity of the wastewater treatment system are released into the waterways, polluting the water, harming marine life and making the area unpleasant for people hoping to relax by the shore. The map in Figure 9 shows the locations of combined sewer overflows and wastewater treatment plants, the majority of them on the North Shore.

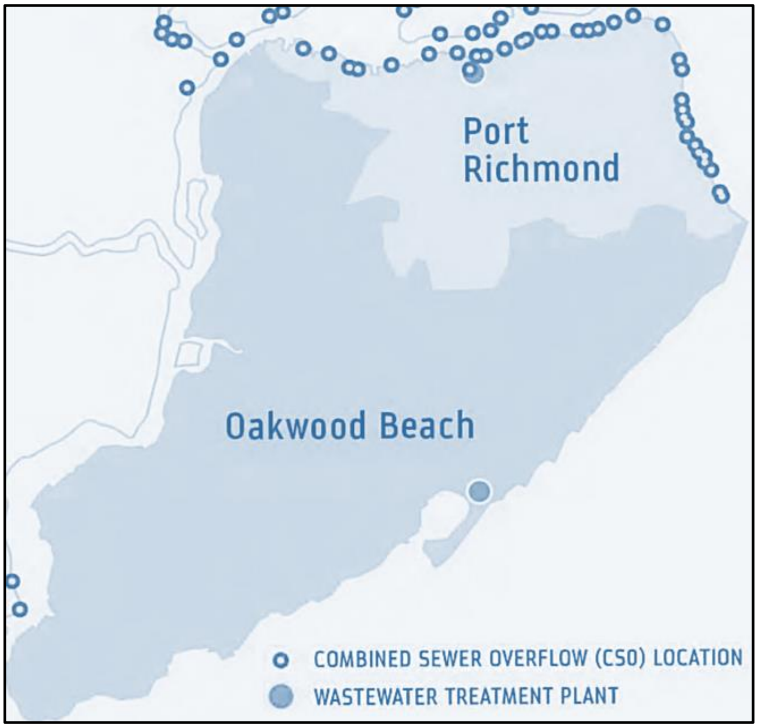


Figure 9: CSO locations on Staten Island[72]

The construction of the BRT along the shoreline will inevitably affect the delicate ecosystems and habitats of the waterfront, but it is simultaneously an opportunity to restore native ecosystems, improve storm water infrastructure, and increase the island's resilience in the face of climate change. The section on Recommendations will suggest strategies to achieve these goals.

BRT Case Studies

The Capstone research team examined global examples of BRT systems for best practices, maximum benefits, and comparable qualities to Staten Island in order to identify sustainability and resiliency measures which could be implemented in the SI BRT. A matrix of the below ten BRT systems comparing size, operations, cost, sustainability features, and resilience features is included in Appendix B-1.

Reya Vaya Bus System	Johannesburg, Republic of South Africa
Greenline	Curitiba, Brazil
MetroPlus	Medellin, Colombia
Orange Line	Los Angeles, USA
Guangzhou Bus Rapid Transit	Guangzhou, China
Metropolitano	Lima, Peru
Martin Luther King Jr. East Busway	Pittsburgh, USA
TransMilenio	Bogota, Colombia
HealthLine	Cleveland, USA
Emerald Express GreenLine	Eugene, US

Following are five BRT system case studies pulled from the above list, highlighted for best practices and relevance to the proposed BRT in Staten Island.

The case studies were drawn from systems that received a Bronze, Silver, or Gold *BRT Standard* rating developed by the Institute for Transit Development Policy. As previously discussed, the *BRT Standard* was developed by a committee comprised of the world's leading BRT experts. The systems which receive the highest rankings are those that combine efficiency and sustainability with "passenger comfort and convenience" in mind.[73] The 2013 and 2014 ITDP BRT Scorecard system scores are located in Appendix B-2. The scorecard features the systems that received the most basic rating, *Basic BRT* to *Gold.* On the scorecard in the 2013 tab are the systems evaluated in further detail in this report. ITDP rates systems using a point system, similar to the US Green Building Council's LEED system. At a minimum, a BRT needs to score 18 points out of 33 in the BRT Basics category (Bus Alignment, Dedicated Right-of-Way, Off-board Fare Collection, Intersection Treatments, and Platform-Level Boarding). Other categories include Service Planning, Infrastructure, Station Design, Quality of Service, and Integration and Access.[74] In addition to selecting for the *BRT Standard* rating, the report highlights systems that are comparable in size, and would therefore have similar budgets and potential ridership, to the North Shore BRT. While some systems, for instance in China, are maximizing the possible benefits, the sheer size and volume would not translate; therefore, those examples are included only in the matrix.

HealthLine

City: Cleveland, Ohio
BRT Standard Score: 76
Rating: Silver
City Population: 396,815[75]

Managing Entity: Greater Cleveland Regional Transit Authority
Year Opened: 2008
System Length: 9.2 miles[76]
Ridership: 15,800[77]

Key Characteristics: ROW, dedicated bus lanes, off-board fare collection, platform-level boarding, signal prioritization
# of Stations/Stops: 36
# of Buses: 24 hybrid-electric vehicles
Fuel: Diesel Electric[78]

Average Speeds: 12.5 mph
Time Savings: 12 minutes[79]

Project Cost: 200 million
Cost per mile: 7 million/mile
Funding Source: FTA New Starts, state, and local[80]

Awards: Grand Award: American Council of Engineering Companies in 2010, Award for Excellence: Urban Land Institute, 2011, Best in North America: ITDP, 2013.[81]

Environmental Impact: Between 2008 and 2011, the HealthLine created 4,445,000 additional transit trips, reduced fuel consumption by 3,386,300 gallons of gasoline from car trips, resulting in a reduction of 30,000 metric tons of carbon emissions.[82]

Figure 10: A landscaped HealthLine station[83]

The HealthLine in Cleveland Ohio is the "highest-quality corridor in the United States and Canada" with the Silver BRT Standard rating awarded by ITDP. [84] Operating on Euclid Avenue, the HealthLine connects two large employment areas, serving an average 15,800 commuters per day. [85] Also notable, the HealthLine was the first transit system to sell naming rights sponsorships in the nation. The "HealthLine" name is the result of a 25 year $6.25 million sponsorship with both the Cleveland Clinic and University Hospitals, providing an important revenue stream for the system.[86] New York City's bike share program Citi Bike, a public-private partnership, is also funded partially through sponsorships. Similar to the sponsors of the HealthLine, Citigroup maintains exclusive naming rights of the Citi bike program. [87] As MTA historically has had challenges securing necessary funding for subway improvements, a naming rights sponsorship may offer a valuable revenue stream for the North Shore BRT.

Planning the HealthLine

RTA met its transportation planning goals, by improving travel times, facilitating major economic improvements to the area, and improving the quality of life of residents along the Euclid Corridor. [88] A 40-minute trip on the corridor was reduced to 28 minutes[89] and according to the Center for Population Dynamics at Cleveland State University, the number of jobs nearly doubled along Euclid Avenue with 36,850 jobs in 2008, and 72,080 jobs in 2014.[90]

When developing the BRT, the RTA looked at existing roadway conditions, specifically problems with flow and efficiency. Similar to the North Shore's Richmond Terrace slow travel speeds, the existing bus route 6 in Cleveland was at capacity and was only running at about 5.5 mph at times due to congestion, and RTA wanted to address these problems. Bus speed averages increased by 34%, from 9.3 mph, before the BRT was implemented, to 12.5 mph since the HealthLine opened.[91]

Stations were designed to be well-lit and modern, with real-time updates of bus arrival times. In addition, stations were located at the far side of intersections, allowing more efficient boarding. The Healthline followed the ADA's rail standards using level boarding, and the gap between the vehicle and platform is no greater than 3" horizontally and 1" vertically. RTA installed over 400 ADA ramps, Braille signage, and tactile edges on crosswalks.[92]

The diesel hybrid-electric vehicles have a 25% reduction in fuel consumption over the Regional Transit Authority (RTA) standard vehicles, and have 90% less emissions than traditional diesel buses**.** Private development interest due to the new transit line has made EPA investment in brownfields and HUD investment in economic development and housing more successful.[93]

Design

The Euclid corridor accommodates multiple modes of transit by incorporating exclusive bike lanes and pedestrian safety elements such as bollards to protect ramps, sidewalks and improved lighting at street crossings.[94] Additional elements incorporated into the design firm Sasaki, include 1,500 streets trees creating an "urban forest" along the corridor. Public art was integrated into design elements along the corridor, such as paving and site furnishings, as well as a 1.2 million investment in public art projects along the corridor by RTA.[95] [96]

Figure 11: A dedicated bike lane along Euclid Avenue[97]

Costs

RTA looked to a number of different sources for capital funding; approximately half of funds were local, while the other half came from the Federal Transit Administration (FTA). Transit funding sources accounted for $168.4 and an additional $31.6 was spent on non-transit components, such as streetscapes, utilities, and art.[98]

Economic Impact

The $200 million BRT investment has been credited to attracting $5.8 billion in development investment along the corridor.[99] When the BRT was being planned, the downtown Cleveland area was being revitalized along with the historical and cultural assets along the corridor. That combined with the existing over capacity bus line made the BRT project even more appealing. Similar to the North Shore in Staten Island, a BRT could enhance the economic impacts of the Wheel and Empire Outlets development projects, while providing a connection to Snug Harbor cultural center, and improve travel times to the at capacity Richmond Terrace corridor.

Community Planning

Community engagement was an integral part of planning the BRT in Pittsburgh. In the early planning stages, the RTA held public meetings in gymnasiums and auditoriums to engage with community members and answer questions. To make the process more manageable, RTA transitioned into smaller group stakeholder meetings with specific groups such as church groups, healthcare workers and students. The RTA also created the Euclid Corridor Committee which consisted of 98 stakeholders and who engaged specifically with community development corporations in the area. This work was vital and helped gained support for the project in the local community. Finally, construction was a major concern to local businesses and the community. RTA worked closing with the local businesses reaching out months in advance of construction starting to update them on construction timelines and work through the inconvenience together. [100]

Martin Luther King Jr. East Busway

City: Pittsburgh
BRT Standard Score: 56
Rating: Bronze
City Population: 306,211[101]

Managing Entity: Port Authority of Allegheny County
Year Opened: 1983 (extended in 2003)
System Length: 6.8 miles, 2.3 mile extension
Ridership: 24,000 daily[102]

Key Characteristics: Busway alignment, dedicated ROW, intersection treatments
# of Stations/Stops: 9
# of Buses: 200 buses, 32 hybrid diesel-electric[103]

Average Speeds: 40 mph express, 30 mph local[104]
Time Savings: 30 minutes[105]

Project Cost: $183 million
Cost per mile: $20 million
Funding Source: FTA, City of Pittsburgh, Allegheny County, Commonwealth of Pennsylvania[106]

Figure 12: Pittsburgh MLK Jr. East Busway[107]

The City of Pittsburg can be credited for "paving the way" for BRT in the United States according to ITDP.[108] The planning process to improve congestion in the area began in the 1960s at a time when there were no BRT systems in the United States, but given the uncertainty around new light rail technology, a longer construction schedule, and cost being almost three times more, the City of Pittsburgh pursued BRT.[109] Now home to three BRT lines with a total of 18.4 miles, in March 2013, ITDP awarded the Martin Luther King Jr. East Busway (opened in 1983) with the Bronze BRT Standard rating. Pittsburgh is just one of five systems in the US that qualifies as receiving either the gold, silver, or bronze designation.[110]

The MLK Jr. East Busway BRT is similar to the Staten Island proposed BRT in that it runs mainly on the former Pennsylvania Railroad freight rail line. The buses continue into downtown but are not on a dedicated right-of-way for the critical last mile of the trip where the bus merges with vehicle traffic. This is may be a similar challenge to what MTA may face in Staten Island, where the eastern part of the island and ROW meets a commercial area, tourist attraction, and ferry terminal. Because of the built environment, space limitations, and future projects, the BRT will likely flow with traffic in some areas. Much of the land on either side of the BRT trunk corridor in Pittsburgh was either already built up, alongside hilly undevelopable land, or on old industrial land that the city had never made much of an effort to redevelop.[111]

Pittsburgh is unique in that it used a direct service model, rather than trunk feeder services which utilizes smaller vehicles in residential areas bringing customers to transfer stations to access a larger trunk vehicle. Most high quality BRT systems use the trunk feeder model to serve more people in commercial areas, however in terms of customer experience fewer transfers are preferred by customers and save time.[112]

Service Planning

The MLK Jr. East Busway service is open seven days a week, and buses run every two minutes during peak periods.[113] Two of the BRT lines, East and West lines, have adjacent park-and-ride lots with free parking spaces.[114]

Costs

Construction of the original MLK JR. East Busway took three years to build at $115 million. [115] While Public Transit is often subsidized through taxes, in Pittsburgh an alcohol tax is used to cover some of the operating costs.[116] According to a 2011 study by Carnegie Mellon's Heinz College Center for Economic the operating cost for the busway is $187 per hour and $1.15 per mile. [117] Fares range from free within the downtown area to $3.25, depending on the distance traveled and the time of day.

Economic Impact

The MLK busway system was developed with the intent to service the future economic developments planned along East Liberty road. While redevelopment of the area started in late 1980's, major changes in the area did not happen until 1994 when a mechanism to fund development in Pittsburgh was initiated by Mayor Murphy. The redevelopment of the East Liberty area of Pittsburgh has been slow but the City has leveraged $903 million in development.[33] Additionally, according to a study by the American Public Transportation Association, Pittsburgh residents who use public transit save an estimated $9,717 each year.[118]

Sustainability

In 2013, the Port Authority of Allegheny County published key findings that aligned with their Green Mission, that the "Port Authority is committed to sustainable measures that can help the environment, and encourage both transit use and muti-modal commuting."[119] The Port Authority has implemented standards that will help the environment as well as incentivize public transit. One key strategy is their use of a hybrid diesel-electric bus fleet. Hybrid buses produce fewer emissions from both nitrogen oxides and carbon monoxide and get 25% greater fuel mileage than diesel buses.[120] While there are no dedicated bike lanes, buses are furnished with bike racks to encourage bike-to-bus commutes.[121] Port Authority has also implemented the use of a smart transit card system, much like NYC's metrocard. Use of the plastic reusable card reduces the amount of paper needed to print single use disposable tickets.[122]

Metro Orange Line

City: Los Angeles, California
BRT Standard Score: 65
Rating: Bronze
City Population: 3.8 million [123]

Managing Entity: Los Angeles County Metropolitan Transportation Authority (LACMTA)
Year Opened: 2005 (extended in 2012)
System Length: 14.5 miles, 4-mile extension
Ridership: 33,000 daily [124] [125]

Key Characteristics: Busway alignment, dedicated ROW, off-board fare collection, intersection treatments, center lane stations
# of Stations/Stops: 14
# of Buses: 30[126]
Fuel: Compressed Natural Gas
Average Speeds: 11.2 mph[127]
Time Savings: 22% reduction[128]
Project Cost: $304.6 million in 2004
dollars Cost per mile: $21.0 million per mile[129]
Funding Source: FTA New Starts, state, and local sources

Figure 13: Metro Orange Line Bus with bike racks[130]

Conversations about expanding the regional rail system of the San Fernando Valley in California to meet the needs of the community and relieve congestion date back to 1980.[131] Because of rail funding limitations, the Los Angeles County Metropolitan Transportation Authority (Metro) proposed a BRT project that could provide a high quality transportation system at a lower cost compared to light rail or a subway line. While it took twenty years of planning, like Pittsburgh, the Orange Line was built in just three years, a major selling point for BRT systems as a bus route can be built in a single mayoral term.[132]

The Orange Line features a ROW that was converted from a former Southern Pacific railroad similar to the ROW in the North Shore project in Staten Island. Flanking the sides of the ROW are planting areas, with drought resistant plants and a dedicated bike path. The bus route runs along residential and light commercial and activity areas and isn't "grade-separated" so traffic is able to migrate into the lanes. Because the route doesn't run into downtown Los Angeles, there has been limited development along the route. [133]

Service Planning

The Orange Line operates on a "headway-based" schedule, improving bus schedule timing and reliability, and eliminating the bunching of buses at bus stops, and on route. It operates 7 days a week, almost 24 hours a day with buses running every 4 to 5 minutes during peak travel times and 10 to 20 minutes in off peak hours.[134] Time efficiency measures include Intelligent Transportation Systems (ITS) such as Transit Signal Priority (TSP) at intersections giving priority to buses, and GPS to track the location of the buses. This technically enables the Orange Line to provide real-time location and arrival information to customers. The service is coordinated with the 'Red Line' subway, 'Metro Rapid Ventura' bus line, and other numerous local buses for effective and smooth transfers.

Real time information is communicated to customers via a Transit Passenger Information System (TPIS). Each station has a canopy providing shade, covered seating areas, lighting, and security cameras. All of the stations, except for one have bicycle storage and racks encouraging multi modal sustainable travel and increasing environmental benefits as featured in the below image. Six of the fourteen stations also have park and ride provisions offering free parking spaces, thus incentivizing commuters to use the BRT.[135]

Figure 14: Orange Line station featuring bicycle storage

Also similar to proposed Staten Island the route, the Orange Line runs east-west, with feeder routes connecting the Valley and other north-south lines to the orange line and a 24/7 shuttle that connects passengers from the last stop of the orange line at Warner Center, to their work locations within the Warner center complex.[136]

Costs

Metro used state and local funds for the majority of project costs which totaled at 304.6 million including costs for Professional services, stations, buses, acquiring the ROW and the creation of a bicycle and pedestrian recreation path explained in further detail below. The fare is $1.50 for one way or $6 for unlimited rides per day.[137] Fares are purchased prior to boarding, a key BRT feature, for efficiency.

Reduced Travel Times

The Orange Line reduced travel times and increased service reliability. Data collected by Metro and the National Bus Rapid Transit Institute (NBRTI) show that the Orange Line has reduced average end-to-end travel time during peak hours in the corridor by approximately 7 minutes, equating to a 22 percent improvement over original travel times.[138] TSP and a dedicated running way are contributing factors to the decrease in travel time. According to a customer survey, more than 70 percent of users stated the Orange Line was faster than the previous service. 43 percent of survey responses indicated that the service was at least 15 minutes faster. However, travel time improvements within the corridor still fall short of Metro's original projected range of 28 to 40 minutes. The data also shows that 82% of customers think it's a reliable service, due to the schedule consistency and the overall bus line service. [139]

In 2005, the California Center for Innovative Transportation (CCIT) found that traffic congestion reduced and traffic flow going southbound increased by 7%, and northbound by 6%; also commute/congestion times reduced by

14%. According to a rider survey, approximately two-thirds of the riders who previously drove on US 101 said their travel time had been reduced by the Orange Line.[140]

Sustainability and Resilience

The Metro Line made a commitment to the environment and sustainability with its decision to use Clean burning compressed natural gas (CNG) a fuel efficient low NO_2 emissions option.[141] When designing the ROW, Metro Line converted the former southern pacific parcel into a greenway, performing soil remediation, and using thousands of native and drought-tolerant plants and vegetation to create the landscape. The 14.5-mile greenway runs from North Hollywood to Woodland Hills and features one of the largest plantings to ever occur in Southern California, with 850,000 plants and 5,000 trees. Additionally, six landscape art areas were installed along the 80 acres of the Orange Line busway. The greenway creates a habitat for wildlife, reduces air pollution, and by choosing drought resistant plants, conserves water use on irrigation, thus reducing maintenance costs. Metro Line also included leafy, climbing vines along the sound walls of the ROW to prevent graffiti in order to keep the area clean and pristine. Included in greenway is both a bicycle and pedestrian path flanking either side of the ROW with crosswalks and lighting for safety. Drainage swales, instead of traditional curb drainage, are used along portions of the busway allowing storm water runoff to percolate back into the soil, rather than flowing into pipes that would direct it to the ocean. [142]

Figure 15: Native plants along the Orange Line Corridor[143]

Emerald Express Green Line (EmX)

City: Eugene, Oregon
BRT Standard Score: 55
Rating: Bronze
City Population: 156,185[144]
Managing Entity: Lane Transit District (LTD)

Year Opened: 2007
System Length: 4 miles/1.6 miles dedicated right of way
Ridership: 10,000[145]

Key Characteristics: Busway alignment, partial dedicated ROW, off board fare collection, platform level boarding
# of Stations/Stops: 10
# of Buses: (6) 64 foot hybrid-electric buses [146]
Average bus speeds before: 11.5 mph
After bus speeds after: 15 mph
Time Savings: Up to 15 minutes[147]

Project Cost: $25 million
Cost per mile: $6.25 million
Funding Source: FTA Small Starts, State, and LTD general fund [148]

Figure 16: EmX Buses featured at Center Lane Station[149]

The Emerald Express (EmX) Green Line operated by Lane Transit District (LTD) in Eugene Oregon, started as a pilot project in 2007. The high ridership in the first year and overall success enabled completion of the line.[150] The route runs along the Franklin Corridor and replaced a standard bus service line. It features a dedicated ROW for only 1.6 miles of the route between Eugene and Oregon.[151] NYC has a long history of presenting changes in the streetscape as "pilot projects". Under leadership from Janette Sadik-Khan, during the Mayor Bloomberg Administration, NYC DOT transformed the Time Square area creating a public plaza space that has had positive impacts on local business and the community, as well as improving travel speeds.[152] Implementing the North Shore BRT in stages, moving east to west, providing an important transit connection to St. George may be a strategic and sustainable approach for MTA.

The limited ROW was because of the system planners and engineers traffic concerns. A mix of dedicated medians and signal priority was implemented instead. Another concern for the traffic engineers and planners were narrow passing lanes. Instead of having space for bus passing, the system was designed with only a single bus lane, forcing buses to wait at stations. Additionally, the system was designed around several clusters of trees because a local law preventing the removal of street trees aged fifty years or older.[153]

Majority of residents in Eugene choose non-motorized ways to travel to work.[154] Because of the preference for public transit, coupled with integration of existing transit and essentially a free transfer, the BRT system had high ridership from launch.

The EmX Green Line stations feature lighting, information displays, bike racks and real-time vehicle information. The bus shelters were designed for safety, to be visually appealing, and easy to maintain. The Springfield station features a rock sculpture garden that also functions as a bioswale, keeping runoff out of storm drains and filtering the water before it enters the waterway.[155] This could be an added benefit for the North Shore BRT project. The bioswale not only provides a necessary natural environmental infrastructure benefit, but also provides aesthetic benefits as the area was enhanced with glasswork by a local artist.

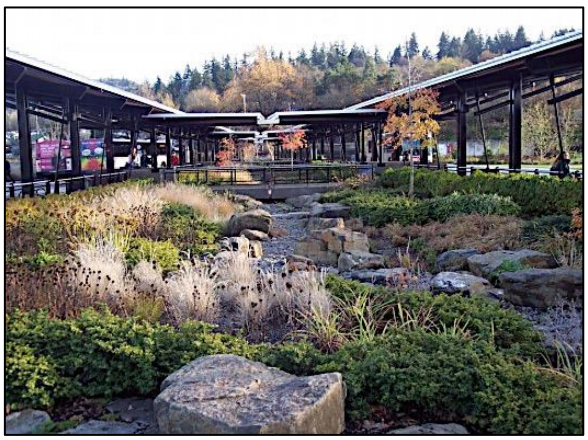


Figure 17: Springfield Station Bioswale[156]

The buses feature doors opening on both sides, and were designed with input from people with disabilities to ensure appropriate accommodations were made.[157] Each bus can accommodate two wheelchairs and three bicycles.[158]

Figure 18: Platform level boarding[159]

Service Planning

The EmX Green Line operates every 10 minutes during weekdays, and every 15 - 20 minutes during evenings and weekends. While the trip from Springfield to Eugene takes approximately 14 minutes on average, the return trip takes 1 minute longer.[160] With an easier access out of the Springfield Station and better signal progression, LTD was able to reduce travel time. The average bus speed increased by 30.4% from from 11.5 mph to 15 mph in 2011; whereas the daily ridership increased by 74% from 2,700 to 4,700 in 2011, and reached 10,000 in 2013.[161]

Costs

The EmX Green Line cost $25 million in total to build, at $6.25 million per mile. The total cost includes $12 million in system construction, $6 million in planning and designing, six buses at a cost of about $980,000 each. 80% of the funds came from Federal funding, and the remaining 20% came from local sources. A complete breakdown of construction costs is shown in the table below. [162]

	Original Budget	Actual Cost
Design/Consulting Services	$2,445,474	$2,619,500
Property Acquisition	$1,350,000	$1,006,450
Construction Costs	$12,797,246	$12,469,480
Miscellaneous Costs/Utilities	$476,000	$517,170
Plan Review/ Permits/Inspections	$250,000	$545,610
Construction Support Costs	$1,300,000	$1,463,840
Project Contingency	$930,936	$0
Total Scope	$19,549,656	$18,662,050
Vehicles	$5,500,000	$5,932,070
Total	**$25,049,656**	**$24,554,120**

Table 2: EmX Green Line Capital Costs[163]

Community Engagement

The local community of Eugene was engaged during the entire corridor design and construction planning process. In the early stages, meetings with elected officials and various stakeholders were held, along with public workshops, and public hearings.[164] LTD met with property owners along the corridor for detailed discussions regarding the project progress, as well as the potential impacts keeping in touch with the various stakeholders throughout the construction schedule. In addition, LTD encouraged input from people with disabilities. A mockup was created so that residents with wheelchairs could test out the layout of wheelchair bays. In addition, cyclists with bikes in hand participated and provided feedback on where and how bicycles could be placed. During the whole design process, feedback regarding all aspects from local residents was also encouraged.[165] Having a public engagement strategy is crucial to the success of any infrastructure project. Planning of the North Shore BRT should begin with public workshops to learn about community needs and create a mechanism for outreach and continued communication throughout the process.

Sustainability and Environment Impact

LTD's commitment to the environment was recognized with the 2008 Sustainable Transport Honorable Mention and 2013 Bronze IDTP rating. Appreciation of local culture and ecology were incorporated into designing the EmX Green Line. Grass in the center lanes not only adds greenery, but helps absorb noise, filters and absorbs rainfall, and the native landscaping choices benefit the entire local ecosystem.

By implementing a BRT system, the local environmental quality improved via technology affect, ridership effect, and system effect. Reducing vehicle emissions, increasing transit ridership, and facilitating fewer private vehicle trips, reduced congestion respectively.

Characterized by their GM Allison hybrid-electric propulsion system, the EmX Green Line performs at a 27% higher fuel economy on average compared to diesel buses. Its ridership effect was also significant with 16 percent of current EmX customers transferring from a private vehicle previously. Finally, the EmX Green Line contributed significantly to the reduction of congestion, with 19 percent of respondents claiming that their trip to be 15 or more minutes faster and 12.3 percent recording their trip as 11-15 minutes faster. [166]

MetroPlus

City: Medellin, Colombia
BRT Standard Score: 85
Rating: Gold
City Population: 2.2 million

Managing Entity: Empresa de Transporte Masivo del Valle de Aburrá Ltda. (Metro)
Year Opened: 2011
System Length: 11.18 miles (2 corridors)
Ridership: 60,000 per day [167]

Key Characteristics: Busway alignment, a dedicated right-of-way, off-board fare collection, intersection treatments, and platform-level boarding
# of Stations/Stops: 29
# of Buses: 67 buses

Fuel: Compressed Natural Gas[168]

Average bus speeds: 24.58 mph

Environmental Impact: A pre-project analysis estimated a reduction of 864,354 tonnes of Carbon dioxide emissions. Additionally, positive environmental impacts are expected including air quality improvements, emission reductions, and soil remediation. A reduction in NOx and HC emissions from the use of Compressed Natural Gas fuel engines, and also a change in transportation modes to public transportation that is more sustainable is expected to have a positive effect.[169]

Figure 19:MetroPlus in Medellin, Colombia[170]

When thinking of BRT, most transportation planners and sustainability managers think of the TransMilenio BRT system in Bogota, Columbia as the go to example for public transit innovation. The second largest City in Colombia, Medellin, also has a notable ITDP Gold Rated BRT system, the MetroPlus.[171] The City of Medellin, received the Sustainable Transport Award in 2012, for a variety of improvements including a public bicycle program, street safety improvements, improved public spaces, and the implementation of the MetroPlus BRT line. [172]

MetroPlus is the highest rated case study examined receiving 32 out of 33 points in the BRT basics category, featuring and 85 out of 100 points overall.[173] Managed by "Empresa de Transporte Masivo del Valle de Aburrá Ltda. (Metro)", MetroPlus is a public-private partnership delivery system where the government constructed and funds the development of the busways, stations, planning control of operations, and a private firm acquire operates the buses and fare collection operations.[174]

Service Planning

MetroPlus is comprised of two corridors, Linea 1, approximately 7.6 miles, commenced operations in December of 2011, and Linea 2, 4.3 miles opened in 2013.[175] The 29 stations along the route, are spaced approximately half a mile apart. Not all stations have elevated platforms, some stops are at street level, however there is handicap accessibility. GPS and Intelligent Transportation Systems are used to track the arrival of the vehicles and provide real time updates to customers.

There are 25 feeder routes within the system, which connect passengers from the lower density neighborhoods to the BRT stations along the ROW. The “with-flow” bus lanes are located both curbside and median of the ROW, there are partial passing lanes at the stations. The lanes are constructed out of asphalt and concrete.[176]

Costs

During the planning stage, Medellin estimated the operation cost savings from developing the BRT system would be $4,600,000, and the travel time savings would be $3,800,000. [177] Medellin received $250 million in funding from the World Bank’s Integrated Mass Transit System project, and $350 million bank-financed National Urban Transport Program. [178]

Sustainability and Resilience

The GHG emissions of the MetroPlus covers all the buses that constitute the BRT system in Medellin including the feeder buses that transport passengers from the less dense regions to the transfer BRT stations. The emissions reduction data for this project was calculated in 2011 as a pre-project analysis, prior to the development and construction of the BRT system. The emissions reduction data for this project was calculated in 2011 as a pre-project analysis, prior to the development and construction of the BRT system. It includes the reductions from both congestion and speed changes and from the entire BRT system (including feeder buses). In seven years, a reduction of 864,354 tonnes of Carbon dioxide emissions is forecasted from the implementation of the MetroPlus BRT system.[179]

The Medellin Metro expects a positive environmental impact including air quality improvements, emission reductions, and soil remediation. A reduction in NOx and HC emissions from the use of Compressed Natural Gas fuel engines, and also a change in transportation modes to public transportation that is more sustainable is expected to have a positive environmental effect. The reduction in emission based air pollution also may have a positive impact on trans-boundary air pollution such as carbon monoxide, PM10, and non-methane VOCs, responsible for ground level ozone and smog. A reduction in noise pollution from reduced number of personal vehicles was found. Additionally, during the construction phase, AMVA the environmental authority ensured there was minimal environmental impacts to the surrounding areas, and proceeded to issue environmental permits mandating the replanting of trees cut alongside the riverbed for the project.[180]

Quantifying the Value of BRT

The case studies in the previous section demonstrate that BRTs have been proven in many cities to deliver a cost-effective public transportation option that satisfies customers and has positive economic impacts and environmental benefits. BRT systems can reduce travel times, and with them the economic costs attributable to that time.[181] Other benefits that can be quantified are the costs of fewer crashes, improved public health, and reduced emissions of CO2 and other pollutants.

There are approximately 476,000[182] people living on Staten Island, of whom a third (175,800)[183] live in the North Shore corridor. According to NYCDOT's *Transportation Improvement Strategy,* 12.5% (59,502) of the population relies on the bus for transportation.[184] A BRT that could support 20% of the North Shore population would require a system able to accommodate an approximate minimum of 29,000 people a day. The Staten Island Ferry currently serves 70,000[185] riders a day. Therefore, a system that could support between 29,000 and 70,000 per day would fit well with the current public transit scheme. These ridership assumptions were used to quantify the projected benefits of the proposed BRT system.

The following is a projection of the economic and environmental benefits of a Staten Island North Shore BRT which strengthens the case for proceeding with the project.

Quantifying the Economic Benefits of BRT

BRT systems can combat congestion, provide connectivity, and offer "rail-like" economic impacts for less money and shorter construction schedules compared to more expensive transportation projects. ITDP, in its *More Development For Your Transit Dollar* report, analyzed 21 Light Rail, BRT, and streetcar corridors in 13 cities across the US and Canada and found that, "Per dollar of transit investment, and under similar conditions, Bus Rapid Transit leverages more transit-oriented development investment than Light Rail Transit or streetcars."[186] In order to determine the economic value of specific benefits, a series of informed assumptions guides the specific monetary value allocated to each factor in the BRT benefit being analyzed. A National Cooperative Highway Research Program (NCHRP) study, *Cost/Benefit Analysis of Converting a Lane for Bus Rapid Transit*, provides guidance on financial costs and benefits to entities that are considering BRT construction. The financial benefits from reduced emissions, accidents, and travel in the NCHRP study were estimated based on a theoretical conversion of a conventional street lane into a BRT lane.[187]

Although an exclusive ROW provides more efficient service than a street lane conversion, the base case scenario used for 40,000 daily users can be comparable to the proposed Staten Island BRT.[188] A comparison of benefits to users and nonusers of the system shows that benefits to BRT transit riders exceed the disadvantages (disbenefits) to automobile drivers.[189] It should also be underlined that smaller savings come from secondary benefits such as crash reduction. The resulting values for benefits were projected for 20 years of BRT operation and were measured to the BRT's peak usage, or busiest time of operation.[190]

Annual Peak Period Benefits for Covering an Aerial Lane to BRT (40,000 BRT riders/day)	
Annual Peak Period Benefits	Constant 2009 $
Benefits for transit riders using BRT	$4,107,426
Disadvantage for auto drivers using cars	-$1,189,190
Savings in crash costs	$425,733
Savings in emissions	$321,014
Total annual peak period (AM– PM) benefits	$3,664,982

Table 3: Annual peak period economic benefits of converting an arterial lane to BRT. Source: National Academy of Sciences[191]

Out of the seven BRT corridors operating in the U.S. as of 2013, Cleveland's HealthLine had the most positive economic impact, with a $5 million per mile transit investment that generated $5.8 billion in new transit oriented development.[192] As noted in the the related case study above, downtown Cleveland was being revitalized when the BRT project was conceived. It was a strategic decision by city planners to choose the Euclid Corridor for the BRT and work with community development organizations in the area to maximize the complementary benefits. The North Shore BRT could similarly enhance the economic impacts of local developments, including the Wheel, Lighthouse Point and Empire Outlets, and drive more development elsewhere along the waterfront, connecting residents and visitors to North Shore parks and the Snug Harbor cultural center, and creating more jobs.

Quantifying the Economic Value of Time Saved

The passenger time savings yielded by a BRT system are derived from the value of time costs of the existing transportation patterns in the study area. Factors in this analysis include the time residents spend traveling, average income per resident, travel population, and minutes saved from using a BRT in comparison to the existing method of public transit. The first step in this calculation is monetizing the time spent traveling. This value is derived from accounting for the average hourly wage of a resident in Staten Island, the type of trip taken (i.e. work trips or non-work trips on a bus or BRT), and the percentage of the hourly wage that can be equated to that trip. The worth of a person's time spent traveling to work can be represented in terms of what they are paid in at work. For example, when assessing the value per minute of a person's travel to or from work, that trip is valued at 100% of the wage per minute, as work is the sole reason for that travel.[193] This process has been adopted from the time-valuation theory, a method that is used as a standard means of assessing the value of time during transport.[194] The first step in this analysis is adopted from a study titled the *Transport*

2020 Bus Rapid Transit Report by the Madison Area Bus Advocates in Wisconsin. According to New York County wage data from the Bureau of Labor Statistics, the derived wage per hour and wage per minute is estimated at $21.63/hour and $0.36/minute.[195] The NSAA estimates the travel time savings comparison between the current bus travel time and BRT travel time in the North Shore from four major areas along the travel route to St. George, as shown in Table 4. More details on the average wage allocated to each method of transport can be found in on D1 in Appendix D.

Travel Time Savings Comparison		
Trip Origin (to St. George)	Current Bus Travel Time (min)	BRT Travel Time (min)
Arlington Station	39	14
WSP Station	56	23
Port Richmond Station	16	0
Manor Rd./Forest Ave.	25	13

Table 4: Current bus system and BRT travel time. Source: NSAA[196]

Accurate estimates are elusive, in that the possible 70,000 users would be scattered among the different origin stations and the time saved will differ depending on how many people travel from each station. However, if all 70,000 users were to use the BRT from the station closest to St. George, with the minimum number of minutes saved, the value of those savings would be least $176,604 per day (see Table 5). This value is the absolute minimum value of time saved from switching to a more efficient mode of public transport for those individuals collectively. For the community, this typically also leads to lower spending per capita on travel, less time in traffic, and more leisure time.

Value of Daily Travel Time Saved per Capita and Aggregated for 70,000 Riders						
Trip Origins (to St. George)	Current Bus Travel Time (min)	BRT Travel Time (min)	Time Savings Comparison (min)	Value per Capita (work trip)	Value saved for min users of BRT/day	Value saved for max users of BRT/day
Arlington Station	39	14	25	$9.01	$197,954	$630,729
WSP Station	56	23	33	$11.89	$261,300	$832,563
Port Richmond Station	16	9	7	$2.52	$55,427	$176,604
Forest Ave.	25	13	12	$4.33	$95,018	$302,750
An additional calculation for the value saved for the minimum and maximum users of the BRT was added to the analysis. The minimum number of users of the BRT was estimated to be 21,875 people/day. Given that the North Shore Population is 175,756[197] and the estimated percentage of Staten Island residents who use the bus is 12.5%,[198] that user percentage from the population was estimated as the minimum number of users.[199] The maximum number of users was assumed to be 70,000, as that is the number of passengers who take the South Ferry/day. [200]						

Table 5: Daily Value of Time Saved

Time savings are one of the most important benefits of BRT to the quality of life for residents.[201] Additionally, ease in travel usually also means less stress brought into the workplace, resulting in associated economic benefits. For example, the Metrobus Line in Mexico City estimates $141 million USD saved, in the increased economic productivity of the workforce as a result of lower travel times and related ease of travel.[202] Commuters using the BRT in Johannesburg, South Africa, have estimated to save approximately 73 million hours between 2007-2026, an equivalent of 9 million eight-hour working days.[203]

Quantifying Environmental Benefits of BRT

BRT systems have the potential to improve air quality and reduce GHG emissions by reducing personal vehicle use, using cleaner fuels, and implementing more efficient technology. Replacing automobile trips with BRT trips results in lower emissions per passenger mile. Further emissions reductions are achieved when features like signal priority are added, which lower fuel consumption by reducing idling time at intersections.[204] In Mexico City, studies of emissions reductions after the implementation of the MetroBus Line concluded that reduced air pollution would prevent an average of 6,100 lost work days, and the economic benefits have been estimated to reach $3 million per year.[205] In China, the impact of the Guangzhou BRT the emissions reductions are primarily the result of improvements to mixed traffic and operational improvements to buses, reflected as reductions in bus vehicle kilometers traveled, or VKT. [206]

The 2012 NSAA report used transportation trip counts and work destination to project the environmental benefits of a BRT on Staten Island. Over 29,000 trips daily were recorded for residents commuting to work either within the North Shore or to Manhattan.[207] The proposed BRT would allow these residents to change transportation modes from their personal vehicles to the BRT. Over 7,000 daily work trips to Brooklyn and Queens were identified as having a "medium" likelihood of switching from personal vehicle to the BRT. The rest of the North Shore commuters, over 12,000, commute to other areas in Staten Island outside the North Shore, or other NY and NJ counties. Because their work destinations are far from both their residences and the BRT, these commuters have been identified as having a "low" possibility of adopting the BRT instead of their personal vehicles.

If the BRT is able to capture 29,000 North Shore and Manhattan-bound commuters, it would eliminate over 242 million miles traveled (VMT) annually, resulting in approximately 99,611 tons of CO2 emissions and 21 tons of fine particulate matter (PM2.5) would be avoided, as shown calculations made for this report in Table 6.

Work Trip by Destination	Within North Shore & Manhattan	Brooklyn & Queens	Other Counties & other SI Areas Outside North Shore
Possibility of commuters switching to BRT	HIGH	MEDIUM	LOW
Vehicle Miles Traveled (VMT) Annually	242,362,848	56,940,260	49,537,124
Number of cars off the road daily	29,435	7,451	23,402
CO2 Emissions Avoided Annually (tons)	99,611	23,402	40,121
CO Emissions Avoided Annually (tons)	2,116	497	852
NOx Emissions Avoided Annually (tons)	136	32	54
PM2.5 Emissions Avoided Annually (tons)	21	5	4

Table 6: Summary of Projected Reduced Emissions from North Shore BRT

Quantifying the Public Health Benefits of BRT

The public health benefits of a BRT to Staten Island residents include improved air quality from cleaner fuel option, less traffic, and more green spaces; reduced traffic crashes, and improvements in physical fitness of residents through use of bike lanes and pedestrian paths.[208] The implementation of a BRT on the North Shore could also increase the accessibility and efficiency of transportation to the two main North Shore hospitals.

Using cleaner vehicle fuel options and technology will lower emissions, as shown in Table 6 above. A study conducted over three seasons (winter, summer, and monsoon) in Ahmedabad, India, found that commuters who traveled in air-conditioned BRT buses experienced a reduction of 25% in fine particulate matter (PM2.5) compared to commuters who rode in cars.[209] Another study shows that air quality also improved by 40% in Bogota, Colombia, with the implementation of the TransMilenio BRT.[210]

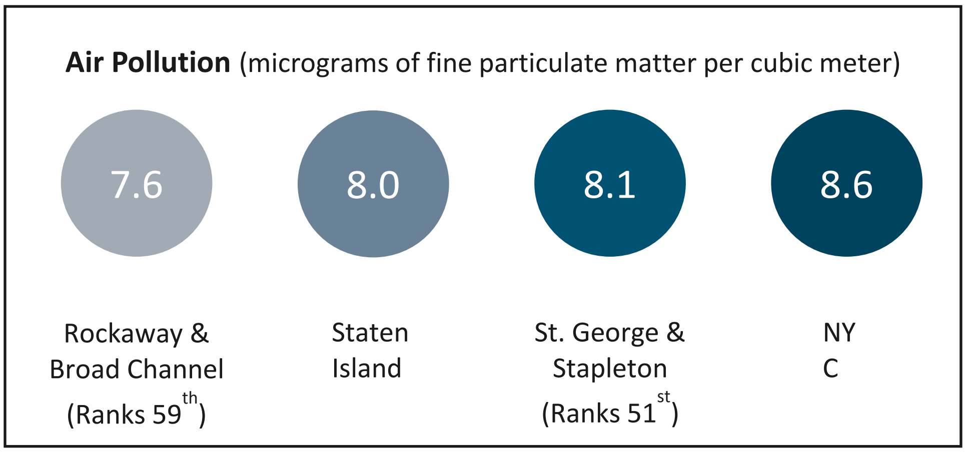


Figure 20: Levels of fine particulate matter in the North Shore are slightly higher than the rest of Staten Island. Source: NYC Health[211]

Fewer cars and cleaner buses produce less air pollution. The NYC health department estimates that fine particulate matter (PM2.5) cause on average 2,300 deaths and 6,300 emergency department admissions for lung, heart issues, and asthma in the city every year.[212] Other pollutants, including NOx, SOx, and ozone, affect both air quality and increase temperatures (see Appendix D). Depending on the bus propulsion system adopted and the number of reduced VMT, reductions in emissions could reduce hospital admissions burden, save health costs, and possibly prevent deaths. Mexico City saved 2000 days of lost work and prevented two deaths per year from air pollution reduction with the implementation of the Metrobús Line 3, yielding healthcare savings of $4.5 million dollars.[213]

The North Shore is a "hot-spot" for diabetes, with the highest rates in Staten Island.[214] Data correlates low physical activity in the borough to high rate of obesity (Appendix D). The NYC department of Health states that the "health benefits of regular physical activity, even in polluted air, outweigh the risks of inactivity. Estimates of the impact of switching from daily driving a car, to bicycle trips found biking significantly increases life expectancy."[215] According to Robin King, the Director of Urban Development at WRI Ross Center for Sustainable Cities, Metrobus passengers walk an average of 20 minutes more per week than they did before the BRT. [216] BRT passengers in Beijing were found to walk an additional 8.5 minutes per day.[217,218]

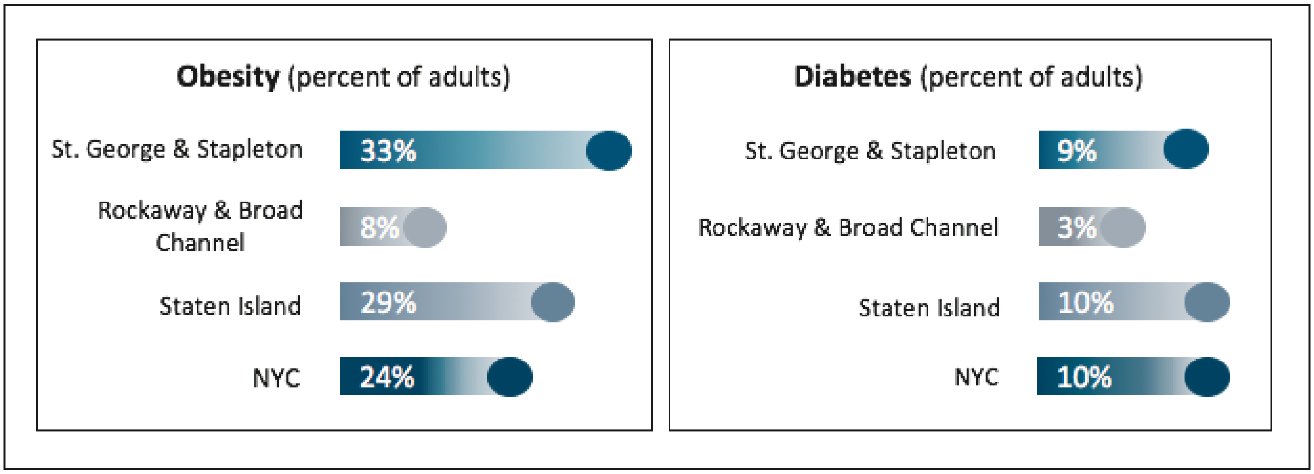


Figure 21: Rates of obesity and diabetes in the North Shore. Source: NYC Health [219]

Reducing traffic fatalities is the goal of NYC's *Vision Zero*,[220]and BRT can contribute to safer streets. In Latin American cities where BRT was implemented, there has been a 40% average reduction in traffic fatalities and crashes.[221] Applying this average reduction to Staten Island's 12,187 traffic accidents in 2016,[222]projects a reduction of 4,875 accidents. In Bogota, Colombia, the TransMilenio BRT system reduced traffic incidents by 79 %,[223]saving $288 million dollars between 1998 and 2017 as well as preventing traffic injuries and deaths.[224] The Metrobus in Mexico saved $289,119 per kilometer annually from fatal car crashes, and $213,154 per kilometer per year from vehicle injuries.[225]

Recommendations for a Sustainable and Resilient BRT

BRT is an inherently more sustainable form of travel than personal vehicles, as shown in the previous sections. BRTs use fewer resources and emit less climate changing gas and other pollutants. A range of built and operational features could further increase the sustainability of the system itself, strengthen the resilience of the surrounding area, and make positive contributions toward equity and quality of life in the North Shore communities.

There is a sustainable rating system applicable to BRT, in addition to ITDP. The Envision rating system for sustainable infrastructure is an important resource for designing and assessing BRTs.[226] Envision credit categories are Quality of Life, Leadership, Resource Allocation, Natural World, and Climate and Risk. The North Shore BRT could include elements contributing to all of these categories.

The 10 BRTs in the comparative matrix, the case studies referenced earlier, and the following section of this report contain recommendations based on best practices in sustainable design and examples from Gold, Silver, and Bronze ITDP rated BRTs from cities around the world. The following bus, station, right of way, bike lane and recreation examples were chosen intentionally to increase the sustainability benefits of the North Shore BRT and offer strategies to create a resilient system.

Sustainable Buses

Buses are the essence of BRT systems. BRT buses can use a variety of propulsion systems, including conventional diesel, diesel hybrid, compressed natural gas (CNG), battery-electric, propane, and biodiesel (see Table 7). Determining the most suitable and cost-effective option requires assessing many variables and projections of future costs in the context of local conditions, including weather and altitude.[227] Among BRTs studied, compressed natural gas (CNG) is used by a slight plurality, with diesel, diesel-electric hybrid, LPG, and biodiesel also in the mix. However, in this case the choices of existing systems do not provide the best guide. Electric vehicle and energy storage technology has now progressed to the point that electric buses are the best choice.

In 2013, Public Solutions Group conducted a study for NYCT analyzing CNG and Hybrid-diesel buses in use since 2006, comparing newer generations of these technologies against eight factors: vehicle cost, refueling infrastructure, maintenance facility modifications, compression electricity, propulsion-related system maintenance, cost of maintenance personnel training, fuel costs, and battery replacement. The analysis demonstrated that hybrid bus fleets rely less on expensive refueling infrastructure and maintenance; however, a diesel hybrid bus averaged over $299,000 more than a comparable CNG bus over the lifecycle of the bus,[228] and concluded that "the economics of hybrid-diesel buses still do not work."[229] Nonetheless, some BRTs use hybrid diesel-electric buses. Pittsburgh's MLK Jr. East Busway BRT uses a hybrid diesel-electric bus fleet that produces lower emissions of nitrogen oxides and carbon monoxide and achieves 25% better fuel mileage than diesel buses.[230] The EmX Green Line uses bus motors based on the GM Allison hybrid-electric propulsion system, which have 27% better fuel efficiency than diesel-only buses.[231]

Fuel/Energy Source	Advantages	Disadvantages
CNG	Low cost, low GHG emissions	Nonrenewable, produced by fracking, required new facilities and maintenance training
Diesel	High gas mileage	Expensive, highly polluting, non-renewable
Electric Motor-Battery	Easy maintenance, fuel cost savings, can use renewable electricity, quiet	10 minutes recharging time required every 4 hours
Biogas	Low GHG emissions	Unstable pricing, supply issues
Hybrid: Diesel & Electric	Saves on fuel, lower emissions, high gas mileage	Higher purchased and maintenance costs, less power
Solar Electric	No GHG emissions, quiet	Cnew Technologyost – new technology, variability in sunlight

Table 7: Comparing the major BRT propulsion options[232]

Electric bus technology has moved along the experience curve and improved to the point that electric buses have surpassed diesel-hybrid and CNG fueled buses on every major point of comparison except initial vehicle cost. According to a recent Columbia University study, while the initial investment in the vehicle and recharging infrastructure exceeds the purchase costs of conventional buses by $300,000, prices are falling fast and are more than offset by savings in fuel and maintenance costs of $39,000 annually over the 12-year life of the bus.[233] Electric buses are also carbon-neutral at the point of operation. The Columbia report calculated that if New York City switched its entire fleet to electric buses, the city could reduce $C0_2$ emissions by nearly 500,000 metric tons per year, or .5% of the United States' total annual commitment to the Paris climate agreement. Electric buses also reduce the health impact and health care costs caused by diesel emissions. Electric buses are quieter, and Proterra, one of the two largest companies, manufactures its buses in the United States.

Bus transit is very well suited to battery-electric vehicles. Bus routes are short and predictable, with regular returns to stations, where they can be recharged. The current generation of ProTerra buses can travel 350 miles on one charge of its 660 KWh battery[234]—the equivalent of seventy trips along the North Shore BRT route.

The Vehicle-Station Interface: Building Equity into the North Shore BRT

Access to BRT for people with disabilities, limited mobility, and strollers requires a smooth interface between the station platform and the bus floor. Platform level boarding, a basic feature of BRT, is critical to ensuring accessibility. The most wheelchair-accessible option for the vertical height of the station platform above the transit way is the level or near-level boarding option (see Figure 22). This essentially removes the gap between the vehicle and platform to eliminate the need for a small step up into the bus. Depending on the type of bus being used, the station platform is raised an average of 14-15 inches above the roadway to ensure ease of boarding. [235]

Figure 22: Level (Las Vegas MAX) and near-level boarding (EmX) platforms facilitate accessibility. Note that near-level requires a ramp and therefore a longer stop. Source: APTA

Benefits of level platforms include quicker boarding times, greater safety for all passengers, and the elimination of the need for a ramp or lift.[236] Because platform level boarding requires buses to pull up very close to the curb, a profiled (raised bumps) curb warning strip and appropriate driver training should be implemented to address these challenges.[237]

Platform width is contingent on the width of the right-of-way width. However, it should meet the entrance and exit requirements of riders with bikes or wheelchairs, to ensure safe and comfortable embarkation and disembarkation, including room to turn around.[238]

Sustainable and Resilient Stations

BRT stations have many options to increase the sustainability of the system and climate resilience of the area they serve. Stations can encourage patrons to entirely eliminate cars from their commutes by integrating bus stations with state-of-the-art “bike-and-ride” facilities, such as shelters or cages to protect bikes from weather and provide secure and safe bike parking. Oregon’s Green Line even accommodates bicycles inside the vehicles, further promoting sustainable travel. In 2011, Guangzhou

China won ITDP's Sustainable Transport award for integrating their new BRT with bike lanes and the bike share program.[239] This kind of innovation can increase BRT ridership, benefit the environment, and improve riders' health and fitness. Pleasant, safe, well-lit pedestrian paths and crosswalks encourage walking to stations. Mexico's Metrobus uses the spacing of its stations to promote physical activity for its passengers.[240] While Citi Bike expansion is not yet slated for Staten Island, Mayor de Blasio and NYC Council Transportation Chair Ydanis Rodriguez have called for a five borough system.[241] Integrating space for bike share stations and bike parking with BRT station designs will enhance sustainability benefits and increase station accessibility.

A safe, accessible, appealing station is fundamental to a good BRT. Figure 23 summarizes the American Public Transit Association (APTA) Recommended Practice Standards for Bus Rapid Stations and Stops.

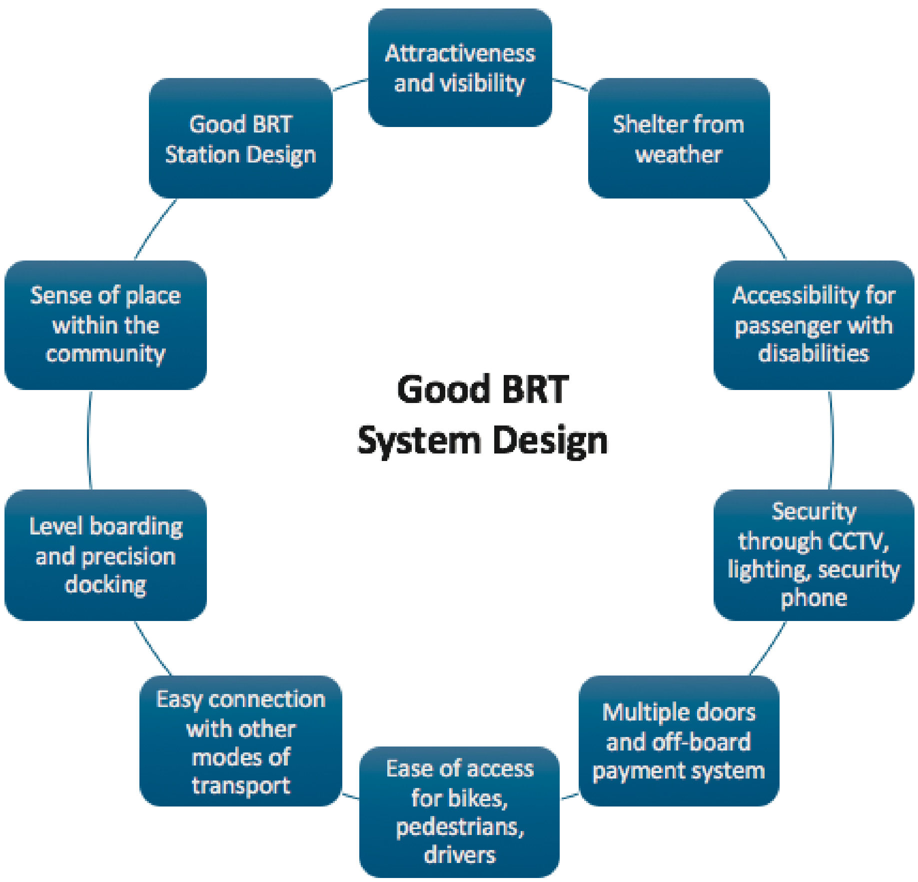


Figure 23: Best practices of BRT station design. Source: APTA

BRT stations can be designed as simple bus stops or fully developed, high capacity stations, depending on the available budget, passenger demand, land zoning, and the ROW. Examples of station design models are shown below. More than one option can be chosen depending on the station's location along the ROW.

Location and Image	Type and Description Summary
 Los Angeles, Orange Line	Type: Station This station design provides shelter, level boarding, advanced fare collection, lighting, security, and space for waiting passengers. It is a common choice when higher demand is expected and when weather protection is a priority.
 VIVA Richmond Hill Transit Center (York Line)	Type: Transit Centers This model allows passengers to transfer to another transit line or service without leaving the stations. It is used when the route aligns with other modes of transit. Existing points in the Staten Island bus network, where north-south bus lanes intersect with the BRT, could be converted to transit centers.
 Cleveland Healthline	Type: Near-Side Platform This option is appropriate when there is limited property available, as in narrow sections of the North Shore ROW.
 Los Angeles, Orange Line	Type: Far-Side Platform This model can improve travel time as signal priority is integrated within design. It also can be aligned with left-turn lanes, making efficient use of space along the ROW.

Table 8: Station designs. Source: APTA[242]

Architectural design is fundamental to customer acceptance.[243] Well-designed stations not only helps the BRT stand out from other bus systems, but also can represent the surrounding neighborhood's culture. Small additions to stations, such as art that is representative of the diverse cultural backgrounds of the surrounding communities, can make New Yorkers feel included and visitors feel welcomed. Design features can also highlight local history--for example, by including elements referencing Staten Island maritime industry in the physical structure, and by incorporating recycled materials from the waterfront and old railroad into structures and street and station furniture --in ways that integrate the BRT stations' character with plans to develop the waterfront for recreation and retail.

Weather Management

Weather management is one of the main constraints of station design. Weather resilient BRT stations can shelter customers and withstand extreme conditions, including heavy winds, rain, snow and intense summer heat. In Utah, which has both very cold winters and very hot summers, the Utah Transit Authority developed a set of Bus Rapid Transit Design Criteria. These include using non-skid material on the surface of platforms, and canopies that fully cover the platform, allow snow and ice to melt, and redirect the meltwater away from waiting areas. The canopies should also be supported by columns in order to provide ample entrance and exit access for all riders.[244]

The BRT station in the Königsbrunn Municipality in Germany, a city with high annual rainfall, offers a good example of weather resilience. The roof of the bus station is made up of a central membrane and a smaller arched roof to cover parked bicycles.[245] Steel columns and arches support the structure, and a PVC-coated polyester membrane is stretched and tightened over the them in a way that enables ventilation (see Figure 24 below).[246]Additionally, low power lights are placed within the wings of roofed area to provide a feeling of safety for riders at night while they are simultaneously protected from rain by the membrane.[247]

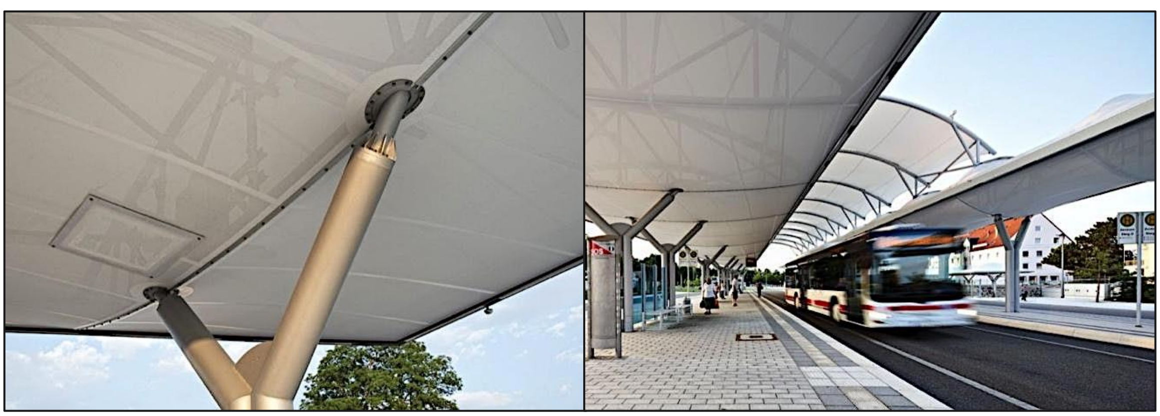


Figure 24: The Königsbrunn BRT station. Source: Temme Obermeyer[248]

subsection of weather control is management of the climate within the stations. This provides an opportunity for sustainable and efficient additions to a station. A few sustainable options that can be considered for Staten Island are outlined below. Other considerations in designing station shelter can be found in Table 7 of Appendix D.

An open design, rather than enclosed, is an adaptable option in that it allows for the outside weather to be the source of ventilation. This could be used in the North Shore during the spring and summer months; however, other design additions may be needed to protect passengers during colder months. Figure 25 presents a BRT station design in Pereira, Colombia, that is open to allow for cooling from breezes. When the station's passengers need protection during strong winds, the foldable louvers integrated into the walls of the structure can be folded down by staff.[249]

Figure 25: BRT Station in the Municipality of Pereira. Source: ITDP[250]

Controlled Cooling

As important as it is to protect passengers against cold weather conditions, ensuring a comfortable and safe environment for warmer months is just as vital. Air conditioning in stations is a cooling method that cities with year-round warm climates may need to consider. But for Staten Island, an array of alternatives that demand less electricity can be used. Nonetheless, it should be noted that air conditioning in stations is cited as an incentive to use public transit for those potential customers who previously relied on their cars.[251] Instead of cooling the whole station, a smaller "refuge area" within the station could be air conditioned, as can be seen in Figure 26 below. Such refuge areas, or fully cooled stations, could also provide emergency cooling areas for vulnerable Staten Islanders during heat emergencies. With a higher budget, geothermal heating and cooling systems using heat exchangers could be installed at enclosed North Shore BRT stations to limit energy use and long-term costs, as is implemented in the BRT in Mexico City.[252] Incorporating paving materials with high reflectivity can also reduce the heat island effect of parking areas.[253]

Figure 26: Cooling refuge area in Osaka Monorail. Source: ITDP[254]

Passive Design

Passive design uses natural air flow, insulation, sunlight and shade to maintain comfortable temperatures within a space. This is a good option for the BRT stations in Staten Island as it reduces the costs of cooling. There are many passive techniques that can be implemented. One the construction of an overhang from the roof in a location which that receives the most direct sunlight; this overhang can also be folded down to seal the station during closing hours.[255]

Figure 27: Passive design in a station in Barranquilla, Colombia. Source: ITDP

Deciduous trees can be planted around stations and park-and-ride lots, cooling them in the summer and allowing sun to warm the stations or vehicles when the trees are bare in winter. Similarly, deciduous vines can be planted to climb over station roofs, providing shade in summer and sun in winter. Station roofs can also be planted with vegetation, absorbing heat and providing even greater passive cooling. The City of Philadelphia has already installed small green roofs on some of its bus shelters, as can be seen in Figure 28. This small garden is planted with species that have retain moisture in the roots, thus not requiring much maintenance.[256] The absorption capacity of green roofs also contributes to controlling stormwater during rainy seasons. We have not identified a BRT station with green roofs, but the North Shore BRT could borrow the feature from more conventional bus systems.

Figure 28: Green roof at Philadelphia's 15th and Market bus stop. Source: Leggitt[257]

Additionally, green roofs can be combined with solar panels. The green roofs cool the panels, improving performance, and the panels provide electricity for the station, and for BRT bus depots. A London project (not a bus station) boasts native wildflowers on its green and solar roofs to add another dimension of sustainability to the structure. [258]

Figure 29: Solar panels and a pollinator park on a London roof. Source: Green Infrastructure Consultancy

Building in Solar Power

Many elements of a BRT station's operating systems, such as fare collection, route schedule screens, and lighting, require electricity. The North Shore BRT can maximize sustainability by meeting this need with epower generated by on-site solar PV panels. The cost of solar is now at parity with grid electricity in many states.[259] and decreasing every year. This option, if backed with adequate electricity storage, also eliminates the need and costs of managing connections to electrical grid, thus ensuring the functionality of electric-systems during blackouts.[260]

London’s transportation network has been using solar energy to power some of its stations for over 10 years. The Vauxhall Bus Station in London installed 168 solar PV units that have the ability to generate up to 32.4 Kw of energy (see Figure 30 and Figure 31).[261]

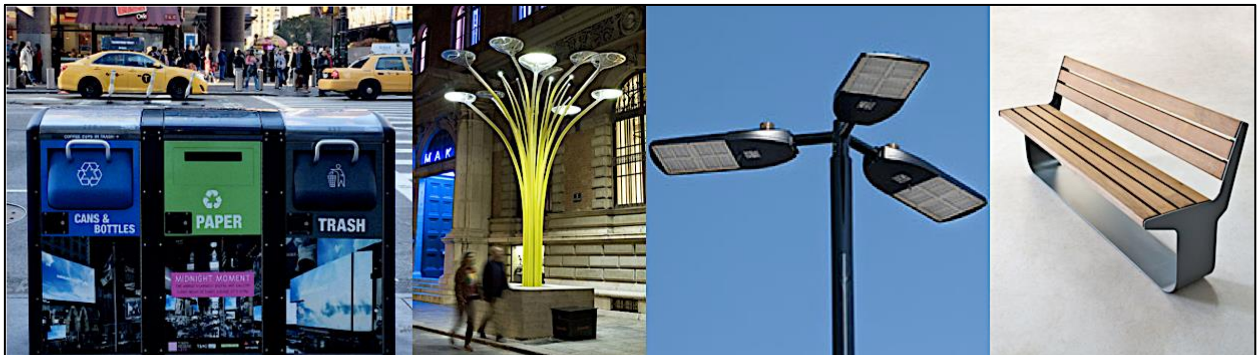
Figure 30: London Vauxhall Bus Station Panels. Source: Solarcentury[262]

Figure 31: London Vauxhall Bus Station. Source: Solarcentury[263]

Solar PVs require a lot of space to produce a large amount of energy. Solar PV could be installed on the roof of the bus depot, providing renewable energy directly to the BRT buses, and solar canopies can be incorporated into park-and-ride lots, providing electricity for private EV charging stations. The City is including solar parking canopies as an important element of its efforts to produce 100 MW of solar PV on municipal building by 2025.[264] Energy-saving devices lower demand for electricity, and so reduce the surface area that is required to meet a station’s electricity needs. For example, low power screens which show maps and timetables can be powered by small solar panels integrated into their design,[265] as is shown in Figure 32.

Figure 32: Screens in London, use e-ink to present information, and 3G to send scheduling and map data. Source: New Atlas[266]

Energy savings in bus stations, park-and-ride lots and along the route can be achieved through the use of solar-powered and high-efficiency lighting. The environmental impacts of manufacturing and transportation of furnishings could be mitigated by choosing locally sourced, recycled and sustainably harvested materials. Solar-powered recycling and trash receptacles harness the sun’s energy to compact discarded items, reducing trips needed to empty bins and to landfill. Solar-powered lighting reduces reliance on fossil fuels and reduces energy costs, while high efficiency LED lighting sharply cuts electricity needs and provides cost savings. Products that incorporate recycled materials reduce environmental impacts resulting from extraction and processing of virgin resources. A selection of these products is shown in Figure 33. Locally manufactured furnishings reduce the distance items must be shipped and it also contributes to the local economy. [267]



Solar-Powered Trash and Recycling Receptacles | Solar-Powered Lighting | High-Efficiency LED Lighting | Furnishings

Figure 33: Sustainable station devices and fixtures[268] [269] [270] [271]

The North Shore has storm water management challenges, including the many CSO outlets that dot the shoreline, as discussed earlier in this report. Using permeable paving materials, rain catching shelters, swales and rain gardens in parking lots and stations would allow rainwater to filter into the ground slowly, and divert water from storm drains, the Port Richmond Water Pollution Control Plant and the CSOs (Figure 33).

Development of uncontaminated green spaces surrounding the BRT stations should be integrated into the design. Plantings should include primarily native species: native species are well suited to the local climate and provide habitat and food for wildlife. Landscaped stations and greenways will not only beautify the BRT, but also contribute to Vision 3 of the OneNYC Plan, which calls for the creation of parks and greenspaces in areas where they are scarce.[272] Design-forward stations that incorporate comfortable seating, indoor art installations, outdoor sculpture and play areas, and pop-up coffee and snack vendors invite other development activities to the area.[273] Generously landscaped outdoor spaces at stations and along the BRT route should be a central goal of the design.

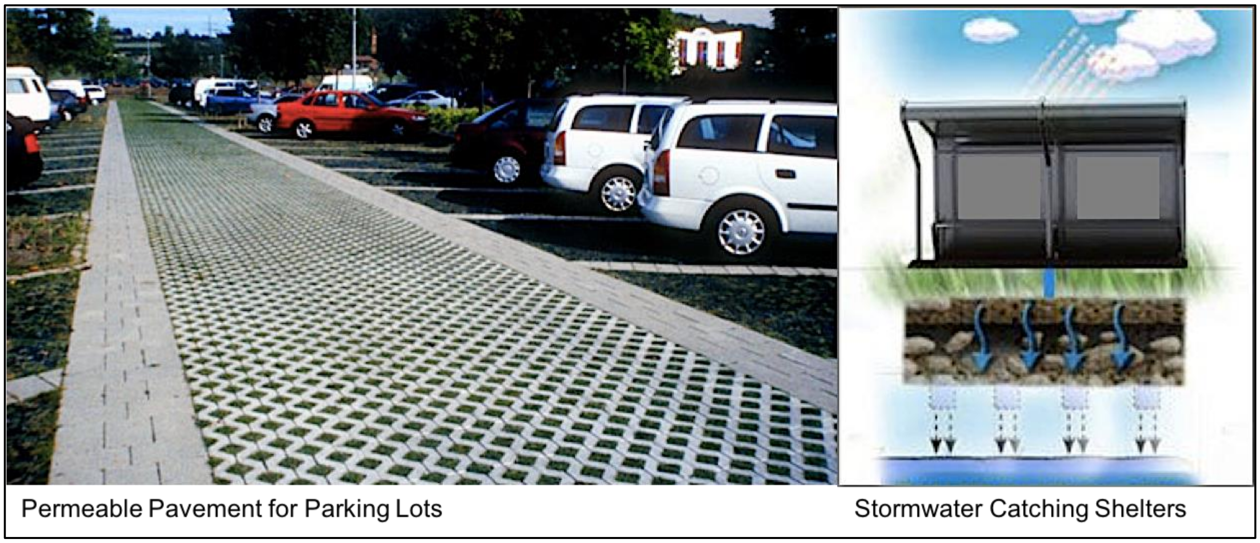


Figure 34: BRT stormwater management [274] [275]

BRT accessibility has many dimensions. BRT signage should be in Spanish, Chinese and English.[276] The BRT must be fully accessible to residents with physical disabilities. This is especially important for New York City, where the transit systems, especially the subways, have been inconvenient or inaccessible to people who use wheelchairs or have limited mobility.[277] BRT accessibility should exceed ADA requirements and integrate easy, seamless access into the essence of the system. BRT stations should facilitate efficient, simple, and well-coordinated connections with other transportation modes, including bus lines, ferries, light rail, bicycle paths and park-and-ride lots, to fully realize their potential. New York City has stated that it will "work closely with the MTA to identify significant savings and improve operational coordination in areas of common interest, such as bus rapid transit, other bus services, and Access-a-Ride."[278]

Build Flood-Resilient Roadways

The design of the North Shore BRT roadway will have to take into account the challenges of the condition and location of the ROW described earlier (for reference see Appendix C), and also built in resilience in the face of flood risks to the system. Ideally, it would also increase the ability of the surrounding area to withstand extreme weather and climate change by providing safe and reliable transportation and contributing to the ability of the region to manage storms, flooding, and other emergencies. Achieving these goals will require both major infrastructural elements and soft design features.

There are several resilience strategies to slow the erosion that has eaten away the earth below the old train tracks and submerged parts of the ROW, and that will worsen with continuing sea level rise, as described earlier in this report. In 2012, following Hurricane Sandy, the city launched a new Special Initiative Rebuilding and Resilience, or SIRR. In the SIRR report issued in 2013, the City's intention to "bulk up its defenses, improving the coastline with protective measures" to mitigate the effects of storm waves and sea level rise was clearly laid out.[279]

Erosion of the Staten Island shoreline, as for other New York tidal communities, is a consequence of sea level rise and storms.[280] One approach to reducing the effect of these is to develop or restore wetlands, swamps, and marshes along the waterfront. Historically, there were wetlands and living shorelines along the North Shore, and some remain, especially at the north-east corner of the island.[281]As noted in the SIRR, wetlands offer offer significant ecosystem and water quality benefits; they also moderate wave force and limit the influx of stormwater, reducing the severity of flooding. [282] The Kill van Kull is one of the locations targeted by conservation groups for this resilience work,[283] which could be done in coordination with the construction of the BRT.

A strategy that may be especially appropriate for the damaged and submerged eastern stretch of the ROW is hardening the shoreline with revetments—boulders and stones piled on a slope.[284] Revetments, also called rip-rap, are low maintenance, provide habitat for marine flora and fauna,[285] and are already in use on many stretches of NYC shoreline. This may be particularly useful on the North Shore if the waterfront ROW is built up to its original elevation with the BRT roadway running along the top. Revetments could be used to raise and protect the edge elevations of the waterfront.[286]

Figure 35: Revetments or riprap on the beach at Montauk. Source: NY Times.[287]

Bulkheads are more solid than revetments. Made of stone, concrete, wood or metal, bulkheads are essentially seawalls designed to preserve shoreline properties against the eroding forces of the sea. They are also often used to support waterfront esplanades and roadways.[288] While in theory bulkheads could mitigate the effects of rising sea levels on the low-lying North Shore, these vertical walls can also increase wave reflection and turbulence and ultimately contribute to greater erosion as the force of the water scoops sand, rock and earth from in front of, and then below, the bulkhead.[289] Therefore, they are not recommended for the BRT route.

A fundamental question for this study was how best to manage flooding of the BRT roadway. As explained in an earlier section on the need for resilient public transit in Staten Island, most of the North Shore is not in a floodplain and is less at risk of storm surges and catastrophic flooding than the

Island’s western, eastern and southern coats. Nevertheless, the impact and risk of storm-related flooding is real, especially if the timing of the tide in relation to the peak surge were less fortunate than during Sandy. A floor-resilient BRT would be prudent.

Three alternatives were considered: a high levee that would protect Staten Island from flooding, with the BRT lanes running along the top of or alongside the levee, an “Airtrain” model, which would raise the BRT route and allow storm surges to pass underneath, and a surface-level route that would be designed to withstand flooding. Both the levee and Airtrain versions have serious drawbacks. A levee might prevent flooding, but when it is eventually breached it would hold the flood water behind the berm, resulting in a bathtub effect, prolonging the flood and increasing damage. Expensive drainage and pumping systems would need to be built into it the levee. In addition, a levee would be, by design, a barrier between the community and the sea, and prevent access to the waterfront that is an important goal for Staten Island residents and businesses. The Airtrain model would be very expensive to construct, would require stations with elevators to lift riders to the BRT level, and would not be compatible with adjacent bike and pedestrian lanes.

A design that would allow flood waters to flow over the BRT lanes and recede again would probably be the most cost-effective approach and also integrate well with other business, recreation, and sustainability goals. In the event of a major storm, buses could simply leave the route for higher ground, possibly transporting residents as well. After the water has receded, the roadway would be ready as soon as it is cleared of debris. Floodable streets have not been fully tested, although they are being experimented with in Seattle and Portland, sometimes with temporary flood walls and water plazas.[290] Alternatively, or for some sections, the BRT and adjacent bike and pedestrian paths could be built on concrete pilings, at a height comparable to that of the Hudson River Esplanade,[291] above the projected level of most storm waves.

Integrate Bike Lanes, Pedestrian Paths and a Greenway along the BRT Route

Incorporating protected bike lanes and pedestrian paths into the North Shore BRT design will increase environmental, health and socio-economic benefits to the North Shore area. Many BRT systems, such as the Los Angeles Orange Line, Guangzhou BRT, and the Cleveland HealthLine, have adjoining bike lanes and pedestrian paths. Placement of bike racks and bike share docks at stations is discussed above. Cycling and walking are both activities that can protect or improve the health of residents who are living with diabetes, heart disease, obesity, and other chronic illness.

Beautiful landscaping is a vital feature many BRTs, and a greenway would fit well with Staten Island’s plans to develop and increase access to parks, other green spaces, and the waterfront. Many stretches of the ROW are already wooded, and the elevated Viaduct section could include an elevated Greenway, following the example of Manhattan’s High Line.[292] Attractive plantings and hardscapes invite and relax riders, and contrast vividly with the experience of driving on barren highways in rush hour traffic. Landscaping along the ROW can also absorb CO2, lower temperatures of bus lanes and mitigate the heat island effect,[293] dampen noise, and, because the soil is not compressed, provide storm water drainage.[294] As noted above, the use of native trees, shrubs and wildflowers will create habitats and provide food for pollinators, birds, and other wildlife. Trees must be carefully selected to ensure that their lower branches will clear the height of the buses, and that their roots will grow vertically to prevent buckling the pavement.[295]

Los Angeles' Orange Line includes a "greenway ribbon" that is a model for excellence in BRT landscaping (Figure 36). An FTA report on Community-Oriented BRT noted that the LA Metro recognized the "one-time opportunity" to transform the urban landscape with a $20 million project that installed 850,000 plants, 5,000 trees, and six landscape art areas on 80 acres along the Orange Line." [296]

Figure 36: Landscaping along bike path and BRT route, Orange Line, Los Angeles. Source: FTA[297]

Building in Equity

Equity is critical to putting reliability, safety, equal access, and sustainability into practice. Equity demands affordability and accessibility of transit services for people of all socioeconomic backgrounds and abilities. Mayor de Blasio's One NYC plan states, "New York City will have an inclusive, equitable economy that offers well-paying jobs and services for all New Yorkers to live with dignity and security."[298] That plan, however, recognizes that 45% of New Yorkers still live in or near poverty. As noted earlier in this report, transportation plays a critical role in a community's access to jobs, schools, and health care services: BRT could help reduce poverty in the North Shore.

Fares should be in reach of lower income residents. Affordable transit protects the ability of low-income residents to remain in the North Share as it is improved: transportation investment should not displace lower income populations due to potential increase in property value, but instead improve social mobility of the area's residents, by connecting residents of the western half of the North Shore to jobs and essential services and by including strategies for preserving affordable housing near the transit system.[299] The North Shore BRT has the potential to support the vision of New York City's transportation network in becoming "reliable, safe, sustainable, and accessible, [while] meeting the needs of all New Yorkers and supporting the city's growing economy."[300]

Community outreach and stakeholder engagement are routine and required for publicly funded capital development projects, but, given the history of reports of Staten Island transportation that did not result in improvements, as discussed earlier, and the resulting skepticism, serious and transparent community consultation should guide the development and implementation of every stage of the BRT project. According to the Sustainable Cities Institute, "An inclusive approach to policymaking utilizes the broad diversity of ideas and abilities a population offers. It anticipates roadblocks, allowing for proactive, constructive solutions. Taking the time to cultivate authentic community engagement will deliver 'triple bottom line' results: sustainability that impacts economic prosperity, environmental quality and social equity."[301]

A majority of the BRT case studies featured in this report had community input strategies built into the design of their projects. Cleveland's HealthLine development team took a conventional but thorough approach, holding large public meetings in the early stages of planning, transitioning into smaller meetings with specific groups, and then creating a Euclid Corridor Committee which consisted of 98 stakeholders and who engaged specifically with community development corporations in the area.

The City of Eugene, Oregon, took engagement a step further, building a mockup of the BRT and inviting residents with wheelchairs to test out the layout of station and wheelchair bays. In addition, cyclists with bikes in hand participated and provided feedback on where and how bicycle racks could be placed. Throughout the design process, feedback regarding all aspects from local residents was encouraged. Closer to home, the MTA can look to New York City's Citi Bike outreach process for best practices in engaging residents in the design and implementation process in the *NYC Bike Share Designed by New Yorkers* report. The multi-year public planning process of Citi Bike was "most extensive ever undertaken for a transportation project in NYC."[302]

The City's Social Indicator Report should be reviewed and equity metrics built into the project, even if those metrics are not yet a requirement. For Staten Island, developing a process that has leaders from low-income and underserved communities convene and lead listening sessions for planners, designers and officials would be important to ensure that all voices--not just the loudest--are heard.

Conclusion

At its most basic, a BRT system across Staten Island's North Shore has the potential to significantly reduce the traffic congestion on the area's surface roads, meaningfully shorten commute times for residents working both on the Island and off, improve the health of Staten Islanders through a decrease in vehicle collisions and pollutants, and benefit the climate by avoiding the emission of tens of thousands of tons of CO2 and other greenhouse gases every year. Public transit generally is more sustainable than private transportation, and BRT surpasses conventional bus systems in sustainability because the vehicles spend very little time idling in traffic or picking up passengers.

The North Shore BRT would be even more sustainable if it is enhanced with the features recommended in this report and already tested by BRT and other transit systems in cities around the world. These features include the system's energy profile: it can power signs and station lighting with solar PV electricity, and use clean, quiet electric buses that will increasingly be powered by solar and wind energy as New York State moves towards its goal of 50% renewable power by 2030. It can adopt passive heating and cooling strategies, including insulation, sun-warming of stations in winter, and lush green roofs that absorb water and cool passengers in summer. Its roadways and station areas could incorporate pervious pavements, bioswales and rain gardens to manage stormwater and reduce the flow of toxic runoff through CSOs into the Kill van Kull. It can provide bicycle shelters, bike racks on busses, and bike share stations to encourage commuting by bike, with all the health and sustainability benefits that cycling can bring. Construction materials salvaged from the old Staten Island Railroad and from abandoned maritime industrial sites (if they aren't contaminated) could be recycled into outdoor furniture and design elements at BRT stations, reducing demolition waste and linking the new transit system to the Island's transportation past. Planted with native trees, shrubs and wildflowers, the land adjacent to the BRT lanes would provide habitat and food for pollinators, birds, and small wildlife, absorb rainwater, and gradually restore elements of the Staten Island ecosystem. Lower income neighborhoods that have lacked both decent public transportation and access to safe, uncontaminated, appealing green spaces and recreational would have both.

A busway that is as close to sea level, and as close to the sea, as is the North Shore BRT route must be resilient in the face of storms and sea level rise. Raising and protecting the sections of the BRT route that run close to the water, either with revetments or the construction of an elevated roadway and esplanade supported by wave-calming structures or plantings, would remediate the eroded, deteriorating waterfront of the North Shore and open views of New York Harbor and the Kill van Kull to both visitors and residents. The BRT route could be an inviting greenway, with a high line section on the Viaduct, beautiful native landscaping, and bike and walking paths that connect neighborhoods and stations to parks, wetlands, the Museum of Staten Island, playgrounds, and emerging retail and cultural centers along the waterfront, as well as to the New York Wheel and other exciting new developments in St. George. It would transform the BRT line from just a fast, comfortable, safe and efficient way to get across the Island into a model of sustainable, resilient development and catalyst for connection and exploration.

Residents of "the forgotten island", the nickname referenced by Community Board chair Nicholas Siclari at the beginning of this report, have long felt neglected by the rest of New York City, and particularly underserved with respect to infrastructure, development investment, and public transit. [303] That may be changing. The proposed North Shore BRT would be grounded in Staten Island's history, built literally on the foundation of the old railroad that was essential to the island's industrial past. It would also be New York City's first true bus rapid transit system, and could be a model of sustainability, resilience and equity in design, operations and impact. Staten Island would be forgotten no more.

Appendix

Appendix A: Institutional Introductions

Columbia University's Sustainability Management Program

Columbia University in the City of New York is the oldest institution of higher learning in the State of New York. The University's Master of Science in Sustainability Management Degree Program, co-sponsored by the Earth Institute and the School of Professional Studies, offers an interdisciplinary education that focuses on the integral role that sustainability plays in all organizations and businesses. The curriculum incorporates both the qualitative and quantitative approaches to sustainability, policy, management, and environmental science. The program prepares students for the inherent challenges in implementing actionable and effective sustainability policies. These policies are designed to allow businesses, both public and private, as well as governments- local, municipal, state, and federal - to flourish economically without depleting the finite and fragile natural resources of the planet.

The Integrative Capstone Workshop

The Integrative Capstone Workshop is the culminating project of the Columbia University Master's of Science in Sustainability Management Program (SUMA). It is designed to integrate the diverse fields of the program's curriculum and provide practical experience as consultants for real-world project that draws on the skills and the analytical knowledge the students have gained in their studies. This project was conducted by a team of seven graduate students under the guidance of faculty advisor Susanne DesRoches. At the end of the 12-week period, the team presents its findings and recommendations in separate briefing to the client and to the faculty and students of the SUMA program.

The Metropolitan Transportation Authority

This report was prepared in Spring 2017 for the Capstone Project's client, the Metropolitan Transportation Authority of the State of New York. The MTA is the largest transportation network in North America, covering a 5,000-square mile area across New York City, Long Island, southeastern New York State and Connecticut. The MTA's subways, buses, and railroads provide service to a population of 15.5 million and provide 2.73 billion trips per year. The MTA's bridges and tunnels carry over 297 million vehicles each year. The MTA's vast network of transit options is essential to the local and regional economies and vital to the city as a whole. Without it, New York City could not operate and prosper.

The MTA's public transportation options offer powerful and effective ways to offset greenhouse gas emissions. Mass transit alone helps New Yorkers avoid nearly 17 million metric tons of pollutants, while emitting only 2 million metric tons, which makes MTA mass transit one of the largest sources of greenhouse gas mitigation in the United States. For more information, please see www.mta.info.

Appendix B-1: Comparative Matrix

A matrix of ten BRT systems comparing size, operations, cost, sustainability features, and resilience features. See **Appendix B-1.**

Appendix B-2: BRT Case-Studies Additional Details

The five BRT Case-studies are scored using the ITDP 2013 version BRT score-card. See **Appendix A-2.**

Appendix C: The Position and Condition of the Staten Island North Shore Right of Way

Staten Island's Topography and Geography

In 2012, the Metropolitan Transportation Authority determined that the most cost-effective solution to Staten Island's traffic problem was to build a bus rapid transit system on the defunct Staten Island Railroad right of way (ROW) that runs across the North Shore.[304] As the proposed route of the new BRT, the ROW offers many advantages, but it also poses some challenges to the project. This appendix describes the current location and condition of the ROW.

The North Shore of Staten Island is roughly the top third of the Island, bounded by South Avenue in the west and the St. George Ferry Terminal in the east, and by the Kill Van Kull to the north and Victory Boulevard to the south, and comprises five contiguous neighborhoods (see Figure B1). From west to east, these are Northwest Staten Island, Elm Park, Port Richmond, New Brighton, and St. George. The area includes residential, industrial and open spaces, some of which are parks.[305] Commercial operations are mainly concentrated in Forest Avenue, Castleton Avenue, Port Richmond Avenue and St. George. Industry, much of it maritime, is located along the shoreline New Brighton, Port Richmond, and Elm Park.

The St. George area is relatively hilly, appealing to early New Yorkers who wanted to fine homes and taller buildings designed to take advantage of the views of New York City and the water.[306] This architecture, along with the retired streetcar lines and small industry, resulted in a network of narrow streets, which are now shared by private motorists, delivery trucks, bicyclists, and busses.[307] The neighboring New Brighton sub-area features a largely industrial shoreline and neighborhoods of single family and duplex homes housing, hospitals, schools, and parks.[308]

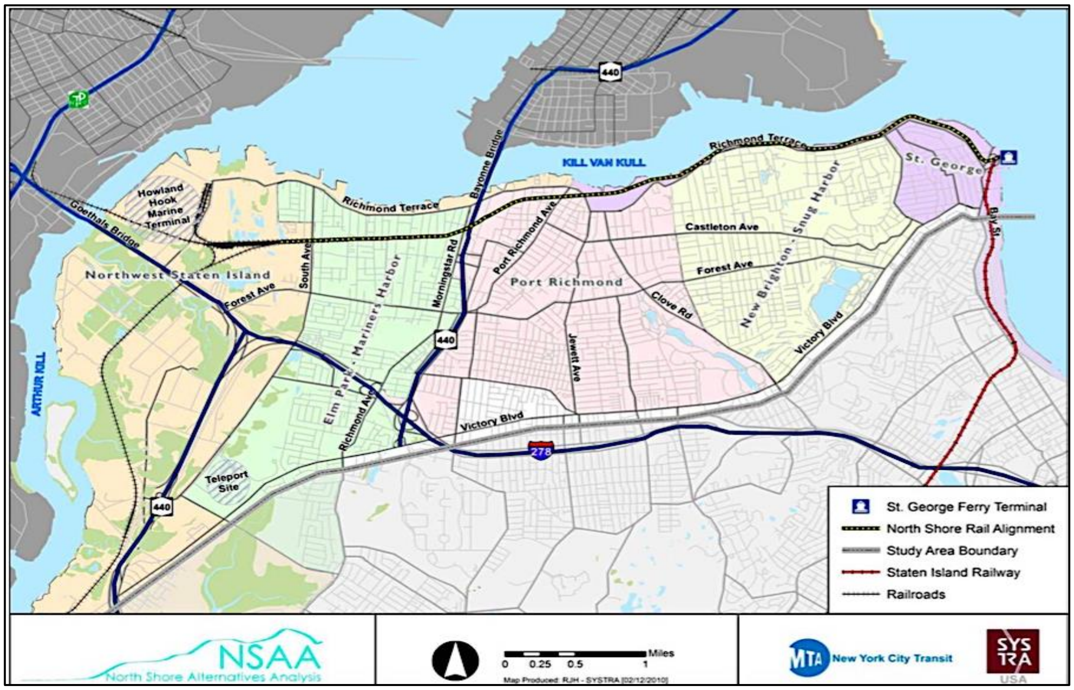


Figure B1: Staten Island's North Shore Source showing the NS Rail Alignment. Source: NSAA

The ROW runs roughly parallel to the Kill van Kull, and is a valuable transportation asset now owned by the MTA. The Staten Island Rapid Transit Company and the Baltimore and Ohio Railroad began operation of freight and passenger service along a 15.3-mile stretch of double-track from Cranford, NJ, to the St. George in 1890. Passenger service was discontinued in 1953; freight traffic continued until 1989.[309] This report will focus on the 5.1 mile study area from South Avenue to the Ferry Terminal, shown in Figure B:2. The North Shore Alternatives Analysis identified the ROW as the most cost-effective route for the proposed BRT, because it is a unique strip of unbuilt land owned by the MTA, it intersects with major roads and bus lines in the area, and it would not require using eminent domain to purchase privately-held properties for a transit route.[310]

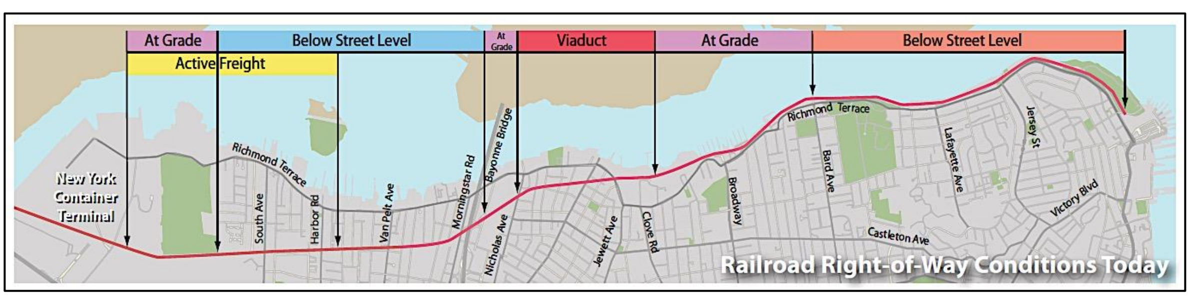


Figure B2: The North Shore Right of Way, with gradations. Source: 2004 Feasibility Study

According to a feasibility study released by the Office of the Staten Island Borough President in 2004, the inherent challenges of the project are the varying levels of gradation, width, proximity to the shoreline, and condition of the route. There are 2.3 miles of grade separated alignment, (which includes 1.5 miles of an open-cut section and an additional 0.8 that is elevated) and 2.8 miles that are at grade.[311] It is difficult to imagine the ROW in its current state as a smooth, dedicated, rapid busway.

The ROW from West to East

The Travis Branch section of the Staten Island Railroad (SIRR) that ran north-south along the Island's west shore was renovated in 2005 and remains active for very local freight. The renovation project increased the number of lines within Arlington Yard, replaced three bridges, and added a new wye (Y-shaped) connection and 6,500 feet of track. The NYCEDC reported that "The improvements were part of the City's plan for rail transportation of containerized solid waste from the proposed department of Sanitation transfer station now being built at the site of the former Fresh Kills Landfill."[312]

To the east of Western Avenue and the wye, there is a stretch of tracks on which freight cars are stored. No cars are present east of South Street, which is regarded as the westernmost point of the proposed BRT route. The route continues east, narrowing to three tracks and then to one track at the Union Road underpass, 0.4 miles along the route (Figure C3 below). The ROW here is at grade, as shown in Figure C4.

Figure C3: The eastern end of the ROW begins at South Street.

Figure C4: The western ROW. Source: Feasibility Study

At the next overpass, Harbor Road, the rails are blocked by a bollard. The abandoned line gradually descends into an open, sub-surface cut, increasingly shaded by trees until, by the Union Avenue Overpass, it is no longer visible. The ROW here runs through a primarily residential area. It is adjacent to, but lower than, Heusden Street, passing under Dehart, Van Pelt and Van Name, and Simonson Avenues. From Union Avenue to Morningstar, the cut is about 100 feet wide. The route narrows and curves northward, moving diagonally towards the northern shoreline and passing below underpasses at Lake Avenue, Granite Avenue, and the Bayonne Bridge ramp (see Figure C5). Here, the ROW is about 1,000 feet from the shore, in a combined use area with light industry, repair shops and small retail stores as well as residential blocks. It then rises gradually from the cut. At this point it is only 50' wide.[313] While the width of this section is sufficient for a BRT, the depth of the cut could result in flooding, and it would probably require drainage and pumping systems.

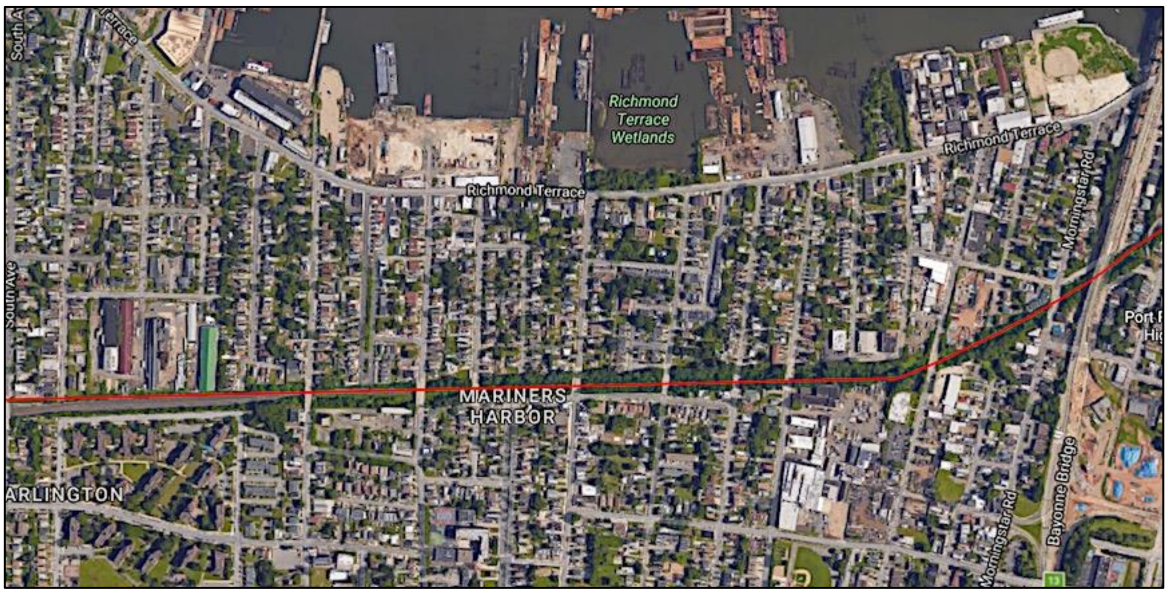


Figure C5: The Cut, from Union to the Bayonne Bridge, passes through residential neighborhoods and near a high school and playing fields.

By Nicholas Avenue the ROW has risen onto the concrete trestles of the mile-long Port Richmond Viaduct**.** The elevated Viaduct passes 13' over Treadwell and Sharpe Avenues, Faber Street, Maple Avenue, Port Richmond Avenue, and Park Avenue, all mostly residential areas. It then runs between the yards of Reinauer Transportation, the tugboat company, and MV Transportation, which provides a range of transport and mobility products and services for people with disabilities, and for the first time crosses Richmond Terrace (see Figure C6).

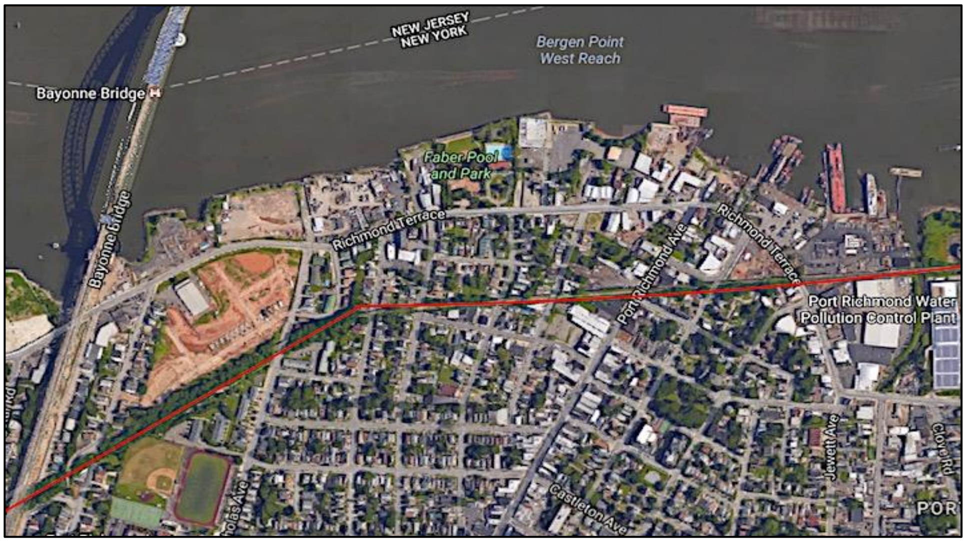


Figure C6: The elevated stretch of ROW known as the Port Richmond Viaduct

After crossing Bodine Creek with a bridge, the ROW descends to surface level on the north side of the Port Richmond Water Pollution Control Plant, which now has one of NYC's largest rooftop solar PV arrays, part of a OneNYC Plan commitment to reaching net-zero energy at the City's wastewater treatment plants.[314] This visible commitment to renewable energy on Staten Island fits well with the emphasis on a sustainable BRT. Along this 0.8 mile long section, the ROW is between 40 and 70 feet wide.[315] The wooded T-shaped undeveloped greenspace immediately east of the water treatment plant is owned by the MTA.[316] (See Figure C7 below).

Figure C7: The Port Richmond Water Pollution Control Plant with solar array (lower left) and wooded lot owned by the MTA (upper right)

Land use in the eastern section of the waterfront ROW is mainly zoned for light (M1) industry and manufacturing, with some green spaces and some M3-1 zoning districts, as well as motels, office buildings, and retail).[317] This section of the ROW, between the Port Richmond Water Pollution Control Plant and Jersey Street, is at ground level and, where it is visible, is only 20' wide. Local businesses use this stretch for parking, storage and occasional dumping (see Figure C8).

Figure C8: The industrial stretch of the ROW

The waterfront section of the route runs very near to the shore, and cuts through three businesses: Caddell Dry Dock and Repair (visible in Figure C9), Snug Harbor Cultural Center and Botanic Gardens, and Atlantic Salt, Inc. (formerly the home of U.S. Gypsum, at 561 Richmond Terrace, and visible in Figure B10).[318] The MTA has an easement for the ROW through these businesses; they use the ROW for access, parking, and salt storage. According to the Alternative Analysis, two of the businesses, Caddell Dry Dock and Atlantic Salt, "...have expressed interest in expanding operations and creating jobs, but have been prevented from doing so due to the uncertainty about the future of the ROW. While NYCEDC has agreements with Caddell Dry Dock and Repair and Atlantic Salt for the maintenance of the ROW and for the provision of material storage in its path, the firms are prohibited from erecting permanent structures on the ROW. Continued uncertainty surrounding the ROW is seen as a potential threat to maritime expansion on the waterfront, with both Caddell and Atlantic Salt advocating for its removal or realignment."[319]

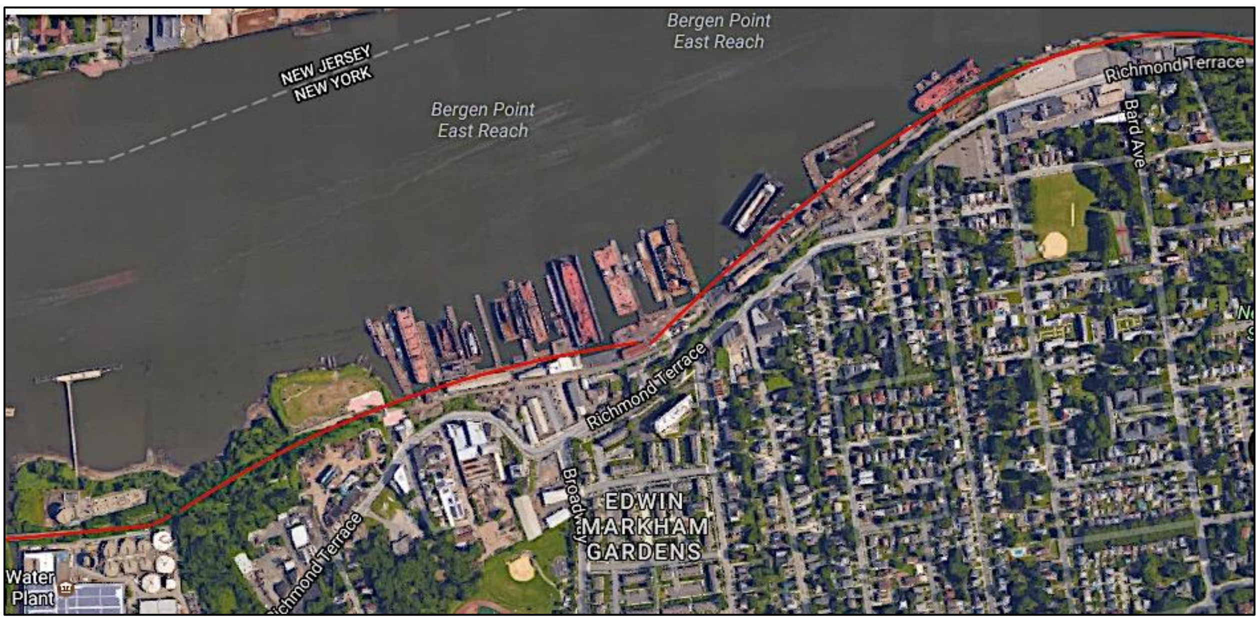


Figure C9: The piers of Caddell Dry Dock and Repair. The ROW is visible as a thin, light brown road running parallel to the shoreline.

Figure C10. Bard Avenue to Jersey Street, with Atlantic Salt in the middle. The ROW is to the north of the trees, running right along the water's edge.

Figure C11: Atlantic Salt Yards, 561 Richmond Terrace.

The last 1.1 mile of the ROW, from Atlantic Salt to St George, is considered to be 30-50 feet wide,[320] but use of this stretch for a BRT will require substantial planning. The ROW disintegrates and slopes into the water at around 1200-1262 Richmond Terrace at Davis Avenue. In some areas the earth and rock underneath the steel rails has been eroded away; in others the ROW is underwater, or marked only by decaying pilings (see Figure C12).

Figure B12: The eroded ROW

At Jersey Street, the ROW is apparently conterminous with the service road that leads to Parking Lot C of the Ferry Terminal and the Staten Island Yankees stadium (see Figure B13). Beyond that, construction of the outlet mall and the Ferry Terminal's infrastructure have buried the ROW, and present significant design challenges for connecting the proposed BRT to the Terminal.

Figure C13: The eastern end of the ROW. The Ferry Terminal is at the lower right, below the baseball stadium and a parking area.

The 2004 Feasibility Study found that the 0.8 mile elevated structure in Port Richmond would have to be remodeled or eliminated, while the 0.75-mile stretch of the ROW adjacent to Snug Harbor would need to be reconstructed. Several of the improvements would also necessitate environmental permitting.[321] Additional improvements would require site clearing, reconstruction and reinforcement of the elevated tracks and restoration of the shoreline. [322]

Appendix D: Methodology

Appendix D lists any additional definitions, and supporting information for the general understanding of quantitative information either highlighted, mentioned, or described. The methodologies and calculations of quantitative data mentioned in the report, especially pre-empting the recommendations is also shown/elaborated.

Environmental Benefits: Calculations

The environmental benefit of BRT's detailed in the report are based upon emission reductions through avoided personal VMT in Staten Island. This was calculated using

Emissions avoided from Work Trips

North Shore population and demographic Data

Work destinations to the five boroughs and New Jersey.

Note: See **Appendix D-1 spreadsheet** for additional data and calculations

Economic Value of Time Saved: Calculation Methodology

The wage per hour and wage per minute of a resident in Staten Island were derived from data from the Bureau of Labor Statistics; the statistic stated the average weekly wage per capita in Staten Island is $865.00 as of Quarter 1 of 2016, resulting in $21.63 as the average wage/hour.[323] The columns outlining the type of trip and the assumed percentage of hourly wage allocated to that trip in Table D1 are taken from the Transport 2020 Bus Rapid Transit Report.[324] The percent of the gross hourly wage percentage allocated to each method of transport is multiplied by the derived average wage/hour to result in the value of travel per minute and per hour. The bolded row is the focus of this analysis as it can be assumed that a majority of the time spent traveling is for going to or from work.

Table D1: Time Values of Travel Time (Staten Island)			
Bus & BRT Users	Percent of gross hourly wage	Per hour	Per minute
In vehicle non-work trip (local)	50%	$ 10.81	$ 0.18
In-vehicle non-work (internally)	70%	$ 15.14	$ 0.25

In-vehicle work trip	100%	$ 21.63	$ 0.36
Excess for work-trip (walking, waiting, transfer)	100%	$ 21.63	$ 0.36
Excess for non-work trip (walking, waiting, transfer)	100%	$ 21.63	$ 0.36

Given that a large portion of the Staten Island traffic is due to the populations' commute to and from work, the per minute value for an in-vehicle work trip was used in the calculation. The travel time savings were derived from the difference between the Current Bus Travel Time (minutes) and the BRT Travel Time (minutes) sourced from Table 48 of the NSAA Report. The minutes for each saving comparison were multiplied by the time value of $0.36 from Table x to result in the value saved per capita.

Note: See **Appendix D-2** for additional data and calculations.

Public Health Data: Air Pollution and Air Quality Maps

In addition to Particulate Matter (PM2.5) highlighted in the report, three other main pollutants; Nitrogen oxide (NO_2), Sulphur Oxide (SO_2), and Ozone (O_3) affect both air quality and Public health.

$PM_{2.5}$

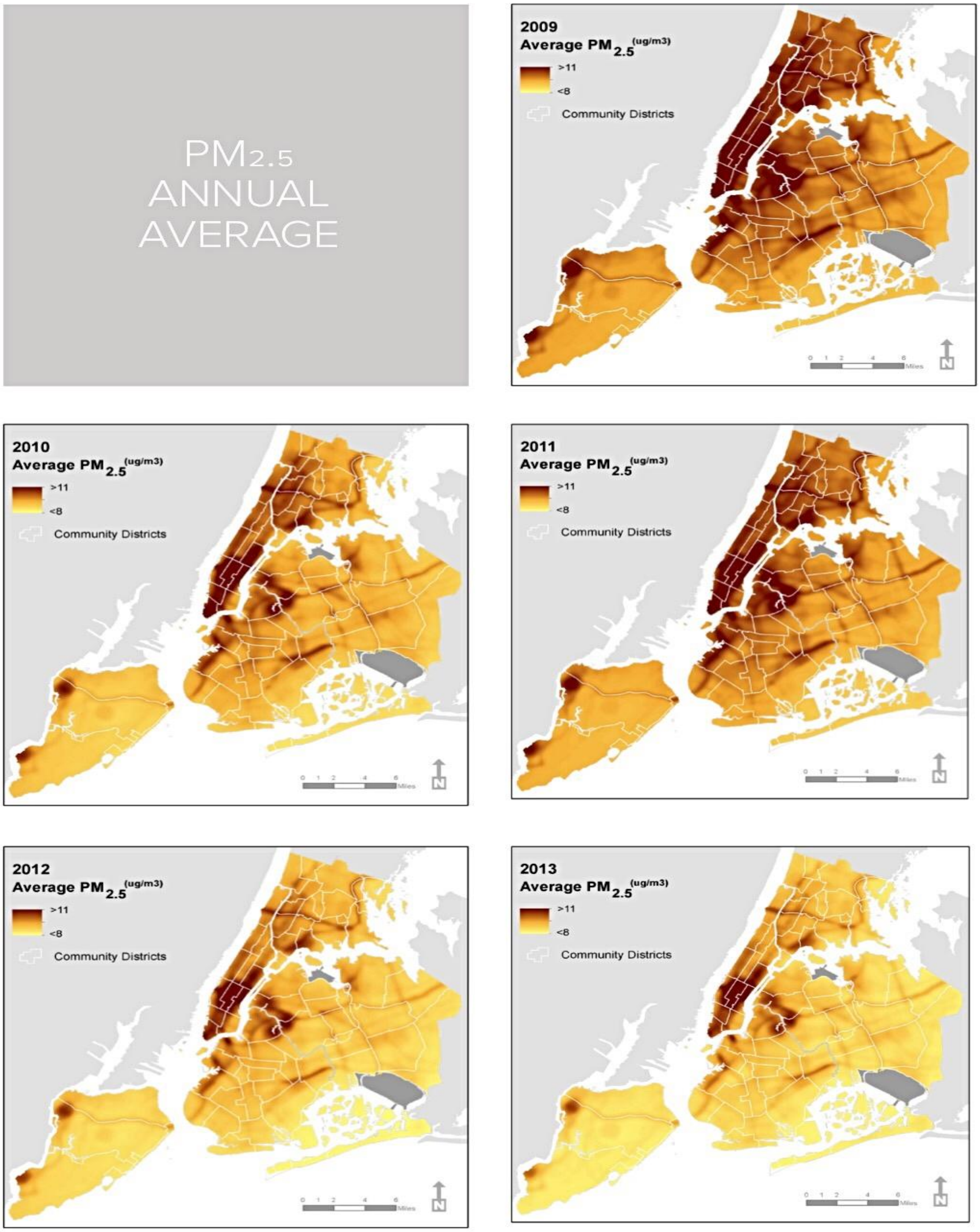
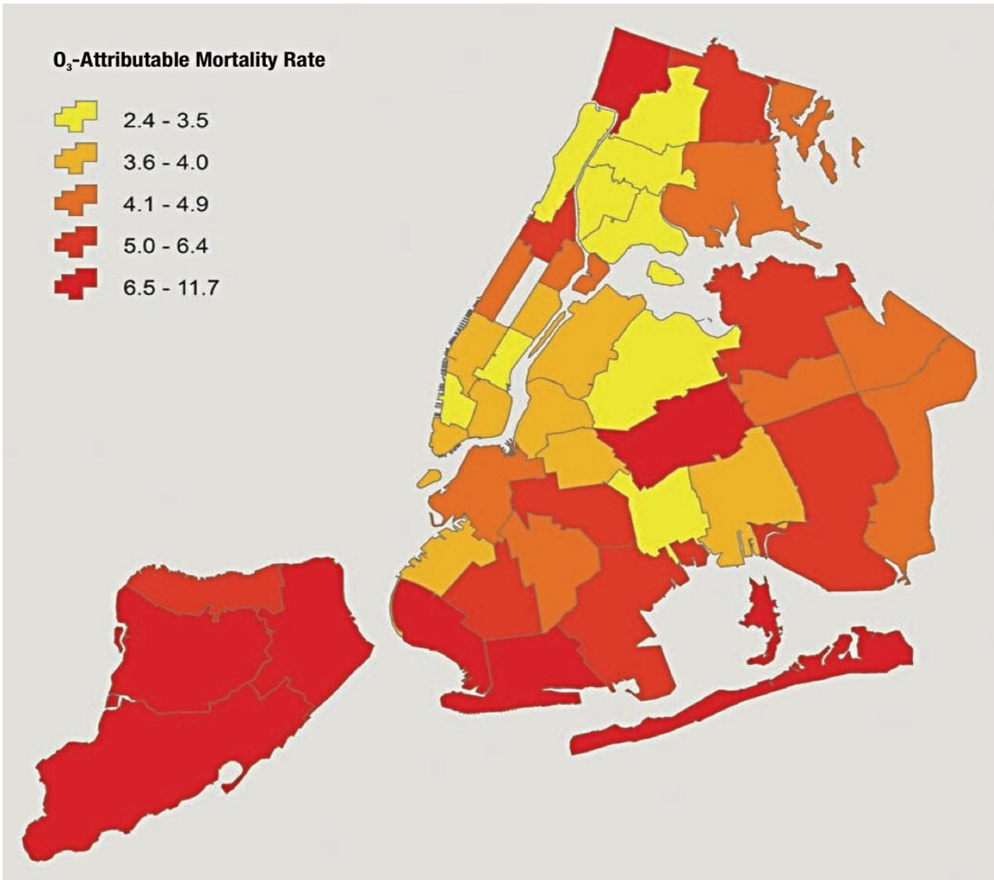


Figure D1

Figure D1: Average Annual PM2.5 levels in NYC through five years. Staten Island has lowest micrograms per cubic meter through all years, but North Shore is not less than 8 micrograms per cubic meter. Source[325]

O_3



O_3=ozone

Figure D2: Ozone attributable mortality rates across New York City Neighborhoods. Source[326]

Ozone, another GHG emission causes an estimated 400 deaths annually in the US[327]. Figure D2 above maps out these deaths per 100,000 persons. Staten Island has the highest mortality rates of 5.0-11.7 persons per 100,000 persons, with the North Shore area on the lower end. Majority of the deaths are persons 65 and over.[328] Ozone pollution, also contributes to asthma hospitalizations of children and adults, with the SI North Shore having the highest in the borough, with children hospitalizations between 19.5 and 34.5 per 100,000 persons.[329]

	Health Effect	Age Group	Annual Health Events Attributable to Current Ozone Compared to Background Levels			Annual Health Events Prevented If Ozone Levels Reduced by 10%		
			Number of Events (95% CI)**	Annual Rate per 100,000 people	Percent (%) of Events*	Number of Events (95% CI)**	Annual Rate per 100,000 people	Percent (%) of Events
O_3-Related Health Effects	Premature mortality	All Ages	400 (200,600)	4.9	3.1	80 (40,120)	1.0	0.6
	Hospital admissions-asthma	Less than 18 years	420 (260,580)	21	11	90 (50,130)	4.4	2.4
	Hospital admissions-asthma	18 and older	450 (240,650)	7.2	6.1	90 (50,130)	1.5	1.2
	Emergency department visits for asthma	Less than 18 years	1,800 (1300,2200)	91	10	370 (260,470)	19	2.0
	Emergency department visits for asthma	18 and older	2,900 (2100,3600)	45	11	600 (430,770)	9.5	2.2

O_3=ozone

* Annual Percent of April through September health events of a given type and in the specific age group that is attributable to O_3

** CI=Confidence interval

Figure D3: Health Effects Ozone compared to health effects of reduced Ozone quantities in New York City Neighborhoods. Source[330]

NO_2

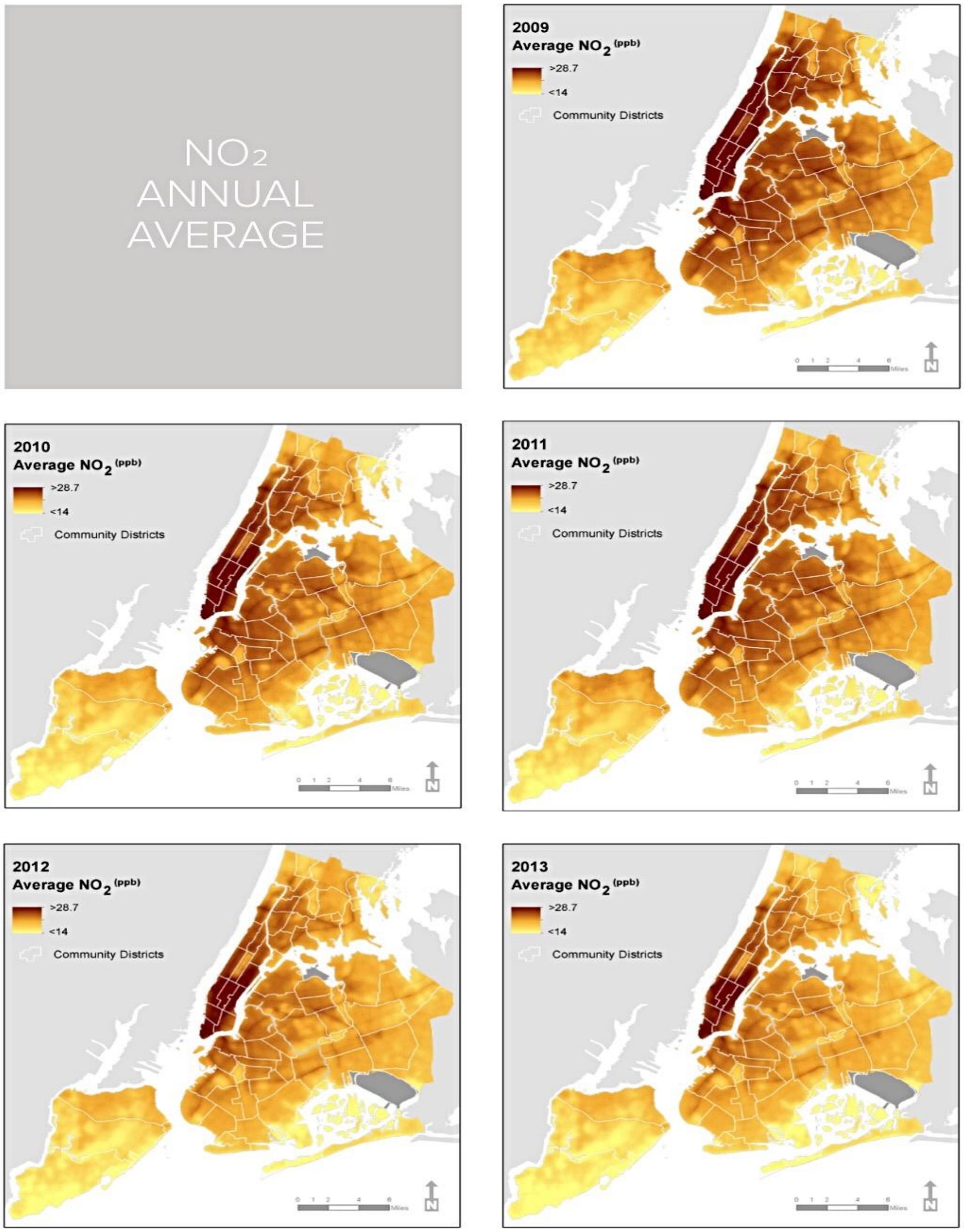


Figure D4

Figure D4: Average Annual PM2.5 levels in NYC through five years. Staten Island’s averages in parts per billion are low compared to the rest of the city. The North Shore concentration levels are higher than the rest of the borough (greater than 14 ppb) Source[331]

SO_2

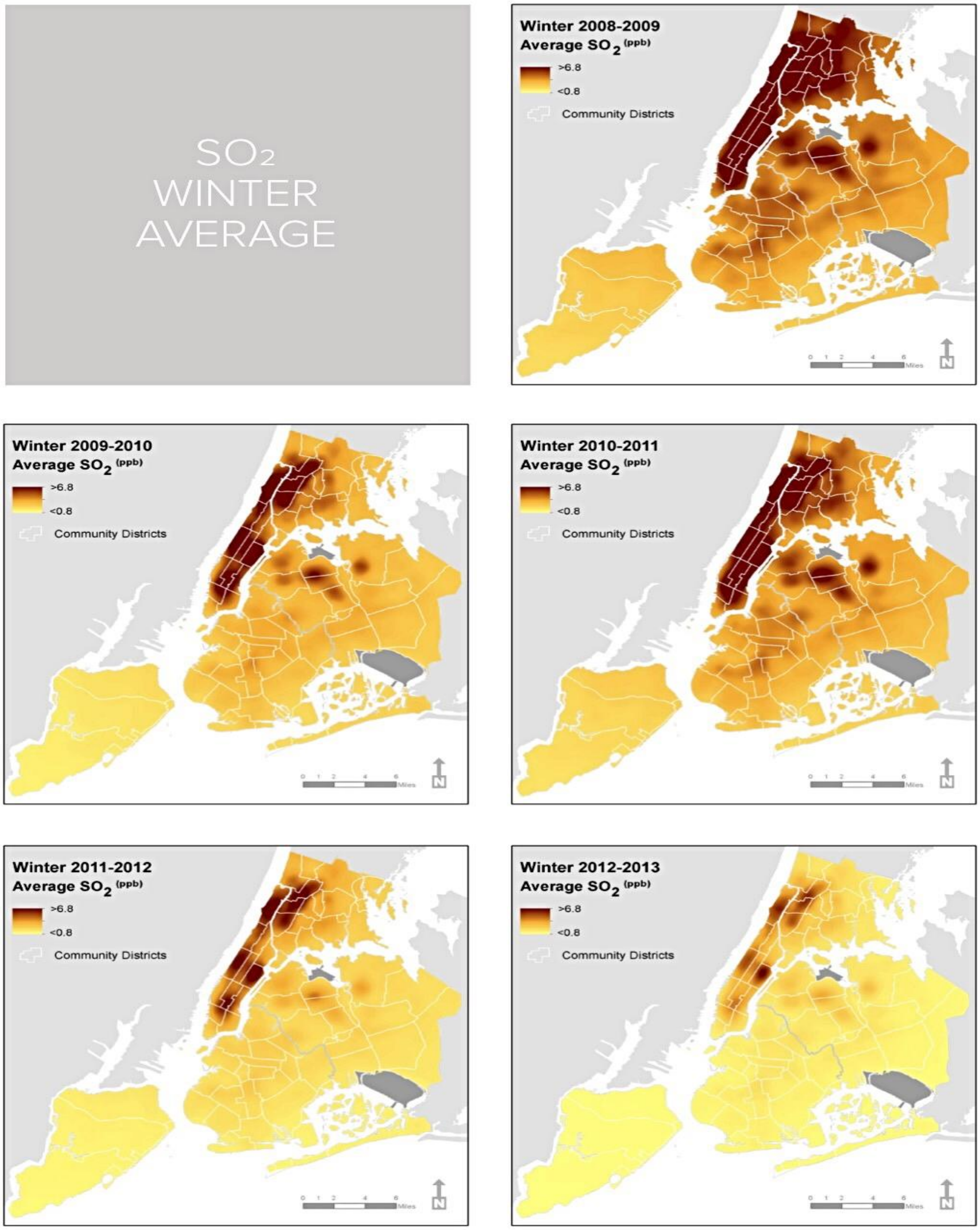


Figure D5

Figure D5: Average Winter SO_2 levels in NYC through five years. Staten Island's averages in parts per billion are low compared to the rest of the city. The North Shore concentration levels are slightly higher than the rest of the borough (greater than 0.8 ppb). Source[332]

Public Health Data: Obesity, Traffic Accidents

Staten Island's walking and cycling data can be correlated to its Obesity data. Obesity according to the National Institute of Health (NIH) is a Body Mass Index (BMI) above 29. Thirty six percent, and 34.8% of Staten Island residents between the ages of 25 and 44, and 45 and 64[333] respectively are Obese, as shown in figure 3 below, which is 232,000 overweight or obese adults.[334] Based on 2013 data, 242,000 adults in Staten Island walk or bike more than 10 blocks for transportation to and from either school, work, or public transportation, this is 4.7% of the city's total walking and biking population.[335] The corresponding effects of Obesity are heart disease and diabetes, and the North Shore is a "hot-spot" for diabetes, with the highest rates in Staten Island.[336]

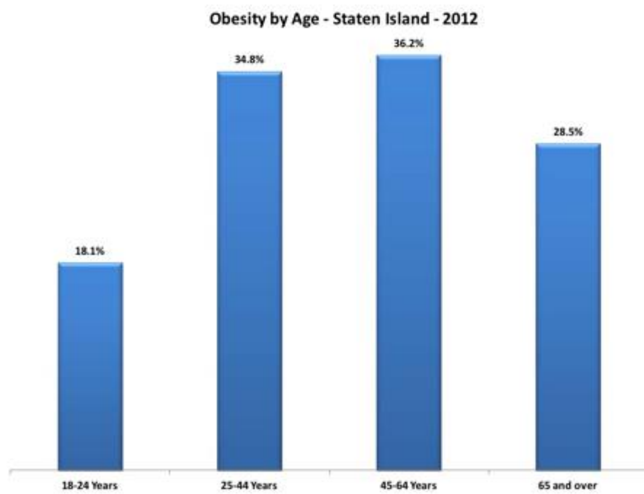


Figure D6: Staten Island Obesity distribution by age. Source[337]

Indore, India BRT Case-Study

The case-study of BRT in the city of Indore in India, further proves the public health benefits of BRT's and support its recommendation. The benefits from the study in Indore were estimated using a health impact assessment methodology that was based upon modal shift, and the vehicle kilometers travelled. The results from the study show that 14 lives could be saved annually with the implementation of a BRT system, from the increase in walking and cycling, and a decrease in driving that leads to reduced air pollution exposure. [338] "Also, more than 96 deaths could be prevented from 2013 to 2017 along the BRT corridor when compared with current trends in motorization with no BRT system investment. The reduction in emissions between a business-as-usual scenario and post-BRT scenario was 11%. The mortality risk from exposure to particulate matter of up to 2.5 μm in size could be reduced by 1.1%. Even given the limitations with respect to the data and the assumptions made in the study, the results were significant enough to recommend that public health aspects be considered in the formulation of transport policy and in the maximization of benefits."[339]

Orange Line, Los Angeles accident mitigation Case-Study

Within two years of the commencement of operations for the Orange Line, Los Angeles, the line had experienced 58 crash accidents from collisions with motorists that ran red lights at intersections, and once from the BRT driver. Due to the series of incidents, the metro authority reduced the BRT speed to 10mph at intersections, improved the signage and other warning signals, and added red light photo-enforcement cameras at intersections and educational outreach training for the public on how to approach BRT's. These changes reduced traffic accidents and near-collisions in the BRT, subsequently making it the safest line in the whole LA metro system.[340]

Staten Island Traffic accident, Pedestrian, and Bicycle Injury Statistics

Pedestrian Injury Emergency Department Visits

Geography	Number	Age-Adjusted Rate, per 100,000 residents
⊟ 2010		
⊟ Citywide		
New York City	9,185	111.1
⊟ Borough		
Bronx	1,492	106.3
Brooklyn	3,161	122.9
Manhattan	1,383	86.6
Queens	2,299	103.1
Staten Island	349	75.8

Figure D7: Pedestrian Injury in all five boroughs, 2010 data.[341]

Bicycle Injury Emergency Department Visits

Geography	Number	Age-Adjusted Rate, per 100,000 residents
⊟ 2010		
⊟ Citywide		
New York City	7,280	89.8
⊟ Borough		
Bronx	989	68.8
Brooklyn	2,669	103.6
Manhattan	1,411	89.2
Queens	1,662	78.9
Staten Island	219	49.3

Figure D8: Bicycle Injury in all five boroughs, 2010 data.[342]

There have been 389 traffic accidents at highways, bridges, tunnels in Staten Island between January and February 2017[343]. In 2016, Staten Island had 9,499 motor vehicle collisions at intersections, and 2,688 accidents at highways, bridges, and tunnels[344]. The accident figure at intersections is alarming, and caution and care should be applied to the design at intersections. The two charts above show the number of emergency department visits for both bicycle and pedestrian traffic-based injuries in 2010, and Staten Island has the lowest number of pedestrian and bicycle emergency department visits, amongst the five boroughs. In addition, the NYC department of health further shows that were are 42 bicycle injury hospitalizations, and 146 pedestrian hospitalizations in 2010.

Designing Stations to be Weather Resilient

The APTA Standards Development Program provides a series of recommendations for Bus Rapid Transit Stations. These best practices are meant to inform transit agencies, local governments, and developers.[345] The listed suggestions for stations, including the requirements for resilient design, are listed in the table below titled "Design Considerations for Amenities in Stations and Stops".

Design Considerations for Amenities in Stations and Stops

Shelter	
Configuration	• Free-standing shelter with vertical wall panels and roof. • Canopy attached to adjacent privately owned building.
Modularity	• Comprised of standard components that can be modified to suit ridership levels. • Standard components can be oriented to site conditions.
Design considerations	• Provide consistency among all stations, distinction from other system bus stops and connection to the BRT brand. Use shelter design to enhance visibility of the service. • Explore concepts for integrating existing shelters, facilities and public amenities along each corridor while creating an overall design that can be read as an integrated whole. • Provide consistency (in materials, colors and design) with other site elements, including lighting, railings, signage, litter receptacles, bike racks, etc. • Materials and components must be easy to maintain, repair and refurbish; be proven vandal-resistant; be transportable; and have a proven and dependable performance history.
Area	• Minimum allowable shelter or canopy lengths and widths should be based on 10-square-foot coverage area per passenger served. • Provide maximum visibility of and access to adjacent development.
Furnishings within the shelter	• Benches or leaning rails may be considered inside all shelters. (See seating requirements below.) • Hardwired internal shelter lighting preferred. (See lighting requirements below.) Minimum 4-foot-candle illumination (average within the shelter) is recommended.
Vertical panels	• Shelter structure should accommodate the placement of advertising, art or information panels within or in place of some vertical panels. • Orientation of vertical panels to protect from prevailing winds and wind-driven rain is preferred. • Vertical panels should be sized to enable portability by one person for purposes of installation and maintenance. • Transparent vertical panels on the side of the approaching vehicle are required.
Roof	• Translucent roof panels should be considered for ambient light. • Avoid placing drip lines over pedestrian travel paths. • Cover over the boarding area is not required.

Table D2: Design considerations for Weather resilient BRT Stations. Source[346]

Appendix D-1: Environmental Benefits Calculation

Excel File

Appendix: D-2: Time Savings Calculation

Excel File

Appendix E-1: Supporting Information – Envision Credit List

QUALITY OF LIFE
13 Credits

1 PURPOSE

- QL1.1 Improve Community Quality of Life
- QL1.2 Stimulate Sustainable Growth & Development
- QL1.3 Develop Local Skills & Capabilities

2 WELLBEING

- QL2.1 Enhance Public Health & Safety
- QL2.2 Minimize Noise and Vibration
- QL2.3 Minimize Light Pollution
- QL2.4 Improve Community Mobility & Access
- QL2.5 Encourage Alternative Modes of Transportation
- QL2.6 Improve Site Accessibility, Safety & Wayfinding

3 COMMUNITY

- QL3.1 Preserve Historic & Cultural Resources
- QL3.2 Preserve Views & Local Character
- QL3.3 Enhance Public Space

QL0.0 Innovate or Exceed Credit Requirements

LEADERSHIP
10 Credits

1 COLLABORATION

- LD1.1 Provide Effective Leadership & Commitment
- LD1.2 Establish A Sustainability Management System
- LD1.3 Foster Collaboration & Teamwork
- LD1.4 Provide for Stakeholder Involvement

2 MANAGEMENT

- LD2.1 Pursue By-Product Synergy Opportunities
- LD2.2 Improve Infrastructure Integration

3 PLANNING

- LD3.1 Plan For Long-Term Monitoring & Maintenance
- LD3.2 Address Conflicting Regulations & Policies
- LD3.3 Extend Useful Life

LD0.0 Innovate or Exceed Credit Requirements

RESOURCE ALLOCATION
14 Credits

1 MATERIALS

- RA1.1 Reduce Net Embodied Energy
- RA1.2 Support Sustainable Procurement Practices
- RA1.3 Use Recycled Materials
- RA1.4 Use Regional Materials
- RA1.5 Divert Waste From Landfills
- RA1.6 Reduce Excavated Materials Taken Off Site
- RA1.7 Provide For Deconstruction & Recycling

2 ENERGY

- RA2.1 Reduce Energy Consumption
- RA2.2 Use Renewable Energy
- RA2.3 Commission & Monitor Energy Systems

3 WATER

- RA3.1 Protect Fresh Water Availability
- RA3.2 Reduce Potable Water Consumption
- RA3.3 Monitor Water Systems

RA0.0 Innovate or Exceed Credit Requirements

NATURAL WORLD
15 Credits

1 SITING

- NW1.1 Preserve Prime Habitat
- NW1.2 Protect Wetlands & Surface Water
- NW1.3 Preserve Prime Farmland
- NW1.4 Avoid Adverse Geology
- NW1.5 Preserve Floodplain Functions
- NW1.6 Avoid Unsuitable Development on Steep Slopes
- NW1.7 Preserve Greenfields

2 LAND + WATER

- NW2.1 Manage Stormwater
- NW2.2 Reduce Pesticide & Fertilizer Impacts
- NW2.3 Prevent Surface & Groundwater Contamination

3 BIODIVERSITY

- NW3.1 Preserve Species Biodiversity
- NW3.2 Control Invasive Species
- NW3.3 Restore Disturbed Soils
- NW3.4 Maintain Wetland & Surface Water Functions

NW0.0 Innovate or Exceed Credit Requirements

CLIMATE AND RISK
8 Credits

1 EMISSIONS

- CR1.1 Reduce Greenhouse Gas Emissions
- CR1.2 Reduce Air Pollutant Emissions

2 RESILIENCE

- CR2.1 Assess Climate Threat
- CR2.2 Avoid Traps & Vulnerabilities
- CR2.3 Prepare For Long-Term Adaptability
- CR2.4 Prepare For Short-Term Hazards
- CR2.5 Manage Heat Island Effects

CR0.0 Innovate or Exceed Credit Requirements

www.sustainableinfrastructure.org

Institute For Sustainable Infrastructure
1275 K Street, NW, Suite 750
Washington, DC 20005

Appendix E-2: Supporting Information – Envision Credits Overview

ENVISION™

HDR

Envision® Sustainable Infrastructure Rating System

Designed as a project assessment tool and to offer **guidance for sustainable infrastructure design**, Envision®'s objective framework of criteria helps identify ways in which sustainable approaches can be used to plan, design, construct and operate infrastructure projects.

Envision® Benefits

Economic
- Consideration of future expansion
- Extend useful life of project
- Lower heating bills
- Lower O&M costs
- Process in place to manage the project and achieve the project's objectives and targets
- Reduce energy and water costs
- Reduce wastewater fees
- Return on investment

Societal
- Create more livable communities
- Durable long-lasting infrastructure, with less maintenance
- Improve business environment
- Improve community – i.e. safety, mobility, recreational opportunities
- Improve/increase local job market
- Increase community/stakeholder involvement in process
- Integrate into the local environment
- Preserve community culture/ history
- Reduce noise
- Reduce construction impacts
- Reduce environmental impact of development

Environmental
- Conserve energy and water
- Optimize resource efficiency
- Preserve greenfields/redevelop brownfields
- Reduce greenhouse gas emissions
- Reduce light pollution
- Reduced air pollution
- Reduce stormwater runoff
- Reduce waste sent to landfills
- Source local materials
- Use materials more efficiently
- Use recycled materials

Other
- Demonstrate commitment to environmental stewardship and social responsibility
- Demonstrate leadership
- Improve public perception

February 2016

PURPOSE OF ENVISION®

To foster a dramatic and necessary improvement in the performance and resiliency of our physical infrastructure across the full dimensions of sustainability. Envision® provides the framework and incentives needed to initiate this systemic change. As a planning and design guidance tool, Envision® is meant to provide industry-wide sustainability metrics for all infrastructure types—an approach similar to its vertical facility counterpart, LEED®.

ENVISION® BACKGROUND

Envision® was created by a strategic alliance of the Zofnass Program for Sustainable Infrastructure at the Harvard University Graduate School of Design and the Institute for Sustainable Infrastructure (ISI). ISI is a not-for-profit education and research organization, dedicated to developing and maintaining a civil infrastructure rating system, and was formed by the American Council of Engineering Companies, the American Public Works Association and the American Society of Civil Engineers.

WHERE DOES ENVISION® APPLY?

- Covers power generation, roads, bridges, pipelines, railways, airports, dams, levees, landfills, water treatment systems and other civil infrastructure
- Does not include buildings or facilities, except process-focused, industrial-type facilities
- Primarily focused on the U.S. and Canada, Envision® benefits and criteria could be adapted to other locations
- Used by infrastructure owners, design teams, community groups, environmental organizations, constructors, regulators and policy makers

STRUCTURE

Credit Categories & Subcategories

1 | Quality of Life – Purpose, Wellbeing, Community

2 | Leadership – Collaboration, Management, Planning

3 | Resource Allocation – Materials, Energy, Water

4 | Natural World – Siting, Land & Water, Biodiversity

5 | Climate and Risk – Emissions, Resilience

Credit Levels of Achievement

1 | Improved – Performance that is above conventional

2 | Enhanced – Sustainable performance that adheres to Envision® principles

3 | Superior – Sustainable performance that is noteworthy

4 | Conserving – Performance that has achieved essentially zero impact

5 | Restorative – Performance that restores natural or social systems

Innovation Points

Possible points awarded in each category for both exceptional performance and application of methods that push innovation in sustainable infrastructure.

Project Award Levels

To qualify for an award, projects must achieve a minimum percentage of the total applicable Envision® points. Projects can be recognized at four award levels.

Recognition Level	Total Applicable Points (%)
Bronze Award	20
Silver Award	30
Gold Award	40
Platinum Award	50

Registration and Certification Fees

Registration Fee: $1,000

Certification Fees:

Project Size ($)	Non-Member Fee	ISI Member Fee
Up to 2M	$3,000	$2,400
2-5 M	$8,500	$7,000
5-25M	$17,000	$14,000
25-100M	$25,000	$21,000
100-250M	$33,000	$28,000
Over 250M	Contact IS for large or multi-phase projects	

Note: HDR is a member of ISI and will be able to negotiate a fair certification fee.

Use as a **decision-making checklist** or to document processes, decisions and design to apply for a third-party verified Envision® award.

ENVISION® POINTS TABLE

HDR

				Improved	Enhanced	Superior	Conserving	Restorative
QUALITY OF LIFE	PURPOSE	QL 1.1	Improve Community Quality of Life	2	5	10	20	**25**
		QL 1.2	Stimulate sustainable growth and development	1	2	5	13	**16**
		QL 1.3	Develop local skills and capabilities	1	2	5	12	**15**
	WELLBEING	QL 2.1	Enhance public health and safety	2	-	-	**16**	
		QL 2.2	Minimize noise and vibration	1	-	-	8	**11**
		QL 2.3	Minimize light pollution	1	2	4	8	**11**
		QL 2.4	Improve community mobility and access	1	4	7	**14**	
		QL 2.5	Encourage alternative modes of transportation	1	3	6	12	**15**
		QL 2.6	Improve site accessibility, safety and wayfinding	-	3	6	12	**15**
	COMMUNITY	QL 3.1	Preserve historic and cultural resources	1	-	7	13	**16**
		QL 3.2	Preserve views and local character	1	3	6	11	**14**
		QL 3.3	Enhance public space	1	3	6	11	**13**
			Maximum QL Points				181*	
LEADERSHIP	COLLABORATION	LD 1.1	Provide effective leadership and commitment	2	4	9	**17**	
		LD 1.2	Establish a sustainability management system	1	4	7	**14**	
		LD 1.3	Foster collaboration and teamwork	1	4	8	**15**	
		LD 1.4	Provide for stakeholder involvement	1	5	9	**14**	
	MANAGEMENT	LD 2.1	Pursue by-product synergy opportunities	1	3	6	12	**15**
		LD 2.2	Improve infrastructure integration	1	3	7	13	**16**
	PLANNING	LD 3.1	Plan for long-term monitoring and maintenance	1	3	-	**10**	
		LD 3.2	Address conflicting regulations and policies	1	2	4	**8**	
		LD 3.3	Extend useful life	1	3	6	**12**	
			Maximum LD Points				121*	
RESOURCE ALLOCATION	MATERIALS	RA 1.1	Reduce net embodied energy	2	6	12	**18**	
		RA 1.2	Support sustainable procurement practices	2	3	6	**9**	
		RA 1.3	Use recycled materials	2	5	11	**14**	
		RA 1.4	Use regional materials	3	6	9	**10**	
		RA 1.5	Divert waste from landfills	3	6	8	**11**	
		RA 1.6	Reduce excavated materials taken off site	2	4	5	**6**	
		RA 1.7	Provide for deconstruction and recycling	1	4	8	**12**	
	ENERGY	RA 2.1	Reduce energy consumption	3	7	12	**18**	
		RA 2.2	Use renewable energy	4	6	13	16	**20**
		RA 2.3	Commission and monitor energy systems	-	3	-	**11**	
	WATER	RA 3.1	Protect fresh water availability	2	4	9	17	**21**
		RA 3.2	Reduce potable water consumption	4	9	13	17	**21**
		RA 3.3	Monitor water systems	1	3	6	**11**	
			Maximum RA Points				182*	
NATURAL WORLD	SITING	NW 1.1	Preserve prime habitat	-	-	9	14	**18**
		NW 1.2	Protect wetlands and surface water	1	4	9	14	**18**
		NW 1.3	Preserve prime farmland	-	-	6	12	**15**
		NW 1.4	Avoid adverse geology	1	2	3	**5**	
		NW 1.5	Preserve floodplain functions	2	5	8	**14**	
		NW 1.6	Avoid unsuitable development on steep slopes	1	-	4	**6**	
		NW 1.7	Preserve greenfields	3	6	10	15	**23**
	LAND & WATER	NW 2.1	Manage stormwater	-	4	9	17	**21**
		NW 2.2	Reduce pesticide and fertilizer impacts	1	2	5	**9**	
		NW 2.3	Prevent surface and groundwater contamination	1	4	9	14	**18**
	BIODIVERSITY	NW 3.1	Preserve species biodiversity	2	-	-	13	**16**
		NW 3.2	Control invasive species	-	-	5	9	**11**
		NW 3.3	Restore disturbed soils	-	-	-	8	**10**
		NW 3.4	Maintain wetland and surface water functions	3	6	9	15	**19**
			Maximum NW Points				203*	
CLIMATE & RISK	EMISSIONS	CR 1.1	Reduce greenhouse gas emissions	4	7	13	18	**25**
		CR 1.2	Reduce air pollutant emissions	2	6	-	12	**15**
	RESILIENCE	CR 2.1	Assess climate threat	-	-	-	**15**	
		CR 2.2	Avoid traps and vulnerabilities	2	6	12	16	**20**
		CR 2.3	Prepare for long-term adaptability	-	-	-	16	**20**
		CR 2.4	Prepare for short-terms hazards	3	-	10	17	**21**
		CR 2.5	Manage heat island effects	1	2	4	**6**	
			Maximum CR Points				122*	

Maximum TOTAL Points **809***

* Not every credit has a restorative level. Therefore totals include the maximum possible points for each credit whether conserving or restorative.

Endnotes

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Name of System	Rea Vaya Bus System	Greenline	MetroPlús	Orange Line	Guangzhou Bus Rapid Transit	Metropolitano	Martin Luther King Jr. East Busway	TransMilenio	HealthLine	Emerald Express (EmX) The GreenLine
System Location	Johannesburg, Republic of South Africa [1]	Curtiba, Brazil [1]	Medellin, Colombia [1]	Los Angeles, California [1]	Guangzhou, China [1]	Lima, Peru [1]	Pittsburgh, Pennsylvania [1]	Bogota, Colombia [1]	Cleveland, Ohio [1]	Eugene, Oregon [1]
ITDP Rating	Silver [2]	Gold [2]	Gold [2]	Silver [2]	Gold [2]	Gold [2]	Bronze [2]	Gold [2]	Silver [2]	Bronze [2]
	[3]	3	[3]	3	6 million in city; 13 million in metropolitan [3]	[3]	[3]	[3]	[3]	[3]
City Population	957,441	1,879,355	2.2 million	3.8 million	area	8,482,619	306,211	7,760,500	396,815	156,185
	[4]	[4]	[4]	[4]	[4]	[4]	[4]	[4]	[4]	[4]
Managing Entity	Transport Department	City	The Metro Authority: "Empresa de Transporte Masivo del Valle de Aburrá Ltda"	Los Angeles Metropolitan Transportation Authority	Bus Rapid Transit Operation and Management Co., Ltd	The Metro Authority: "Instituto Metropolitano PROTRANSPORTE de Lima"	Port Authority of Allegheny County	TransMilenio S.A, Institute of Urban Development (IDU), Private Corporations	Grater Cleveland Region Transit Authority(RTA)	Lane Transit District (LTD)
Year Opened	2009 [5]	2009 [5]	2011 [5]	2005 [5]	2010 [5]	2010 [5]	1983, extension 2003 [5]	2000 [5]	2008 [5]	2007 [5]
System Statistics										
Daily Ridership	42,000 [6]	31,000 [6]	60,000 [6]	33,000 [6]	850,000 [6]	350,000 [6]	24,000 [6]	2,213,236 [6]	15,800 weekday [6]	10,000 [6]
System Length (miles)	27 [7]	4.34 [7]	11.18 [7]	14.5 [7]	14 [7]	16.2 miles [7]	6.8 miles (1983), 2.3 mile extension (2003) [7]	53 miles [7]	9.2 [7]	4 miles [7]
# of buses	277 [8]	16 buses/hour [8]	67 [8]	30 [8]	130 [8]	300 [8]	200 [8]	312 (peak) [8]	21 [8]	6 [8]
Average Bus Speed (miles/hour)	NA 9	17-30 miles/hour [9]	9.9 mph [9]	11.2 [9]	11 [9]	Peak hour:15mph ; at Intersections: n/a [9]	30 [9]	9.3-16.6 mph [9]	12.5 mph [9]	15 mph [9]
	[10]	10	[10]	[10]	[10]	[10]	[10]	[10]	[10]	[10]
Type of fuel	Sulphur Diesel	Biodiesel	Euro IV CNG	CNG	LPG	CNG	Diesel; only 5 buses are CNG (compressed natural gas)	Diesel	Diesel - electric hybrid buses	Diesel - electric hybrid buses
# of stations	33 [11]	5 [11]	29 [11]	14 [11]	26 [11]	36 [11]	9 [11]	116 [11]	36 [11]	10 [11]
BRT Features										
Dedicated Right-of-Way (ROW)	Have ROW [12]	Have ROW [12]	Have ROW [12]	Yes [12]	Yes [12]	Yes [12]	Yes [12]	Have ROW [12]	Yes [12]	Yes [12]
Busway Alignment (Bus-Only Corridor)	Truck lines with feeder routes [13]	Truck lines with feeder routes [13]	Yes [13]	Yes [13]	Yes [13]	-	Yes [13]	Yes [13]	Yes [13]	Partial [13]
Off board fare collection	Pre-board fare collection [14]	Pre-board fare collection [14]	Yes (partial pre-board ticketing) [14]	Yes [14]	Yes [14]	Partial [13]	No [14]	Yes [14]	Yes [14]	Yes [14]
Platform Level Boarding	Low Level Platform [15]	High level platform [15]	Mixed Use (platform & on-street levels) [15]	Yes [15]	Yes [15]	No (high level boarding) [14]	Partial [15]	Pre-board fare collecation [15]	Yes [15]	Yes [15]
	[16]	[16]		At intersections. Loop detectors give signal [16]		[15]	[16]	[16]	[16]	[16]
Intersection Treatments/Traffic signal coord	Give priority at junctions	Dynamic signal priority	-	priority	N/A	Yes	Yes	Yes	Yes	Yes
Service Planning										
	[17]	[17]		[17]			[17]	[17]	[17]	[17]
Frequency	3-4 minutes at peak, 20 minutes off-peak	90 seconds at peak	-	5-6 mins at peaks, 10-20 mins off peak	-	-	4-5 min rush hour; 10-12 min mid-day; 18 min evening	2 minutes at peak, 10minutes at off-peak	2.1 minutes peak	10 minutes at weekday, 20minutes at weekend
Hours of Operation	Weekdays 5AM-9PM [18]	7 AM - 7PM [18]	-	22 hours a day, 7 days a week. [18]	5:30 am - 11 pm [16]	-	5 a.m - midnight daily [18]	4:30 am - 1:50 am [18]	24/7 [18]	4 am - midnight daily [18]
Feeder routes	Integrated into stations and terminals [19]	Integrated into stations and terminals [19]	25 [16]	Yes (informal) [19]	44 including short & express route variations [17]	23 [16]	Yes, 36 bus routes run along corridor [19]	235 feeders [19]	multiple bus routes use BRT route [19]	Integrated with feeder buses [19]
	[20]	[20]	Well integrated with other modes of public [17]	[20]	[18]	[17]	[20]			
Timing with other systems	Planned separately	Integrated within public transport system	transport	Well integrated with other systems	Integrared with feeder buses	Integrated with feeder buses	ntegrated with feeder buses	-	-	-
Time savings	$331 Million from opening [21]	40% faster [21]	-	22% time savings [21]	7.2 minutes average per trip [19]	-	21-24 minutes [21]	16 minutes [20]	12 minutes [20]	2 minutes [20]
Infrastructure										
No. of Corridors/Lanes	2 [22]	1 main corridor [22]	2 [18]	2 [22]	1 [20]	1 [18]	1 [22]	11 [21]	2 [21]	3 [21]
Center Stations	Median [23]	Median busways and tube stations [23]	No [19]	No 23	Yes [21]	-	N/A	4 [22]	-	No [22]
Passing Lanes	Partial [24]	Yes [24]	Partial passing lanes [20]	Yes, wide passing lanes [24]	Yes, at every station [22]	Yes [19]	N/A	Yes [23]	-	-
Built on rail road	N/A	N/A	No [21]	Yes [25]	No, but it connects to metro [23]	No [20]	Parts of the route are on a railroad [23]	Yes [24]	No [22]	No [23]
Park and ride	N/A	Near buildings with parking access [25]	No [22]	Yes [26]	No [24]	N/A	Yes [24]	-	-	Yes [24]
Costs										
	[25]	[26]	$350 million financed by UTP, $250 million [23]	[27]	[25]	[21]	[25]	Phase I – 240 million USD; Phase II – 545 [25]	[23]	[25]
Construction Costs (million)	$8.3/km	~$0.8/km	World bank	Capital cost: $304.6 million (2004 dollars)	US $140.5 in 2010	US$133.5 million	USD 115 (1983), USD 68 (2003)	million USD	US $200 million	US $25 million
Operating Costs (million)	248 M [26]	-	-	$226.40 per annual hour of revenue service [28]	US $13.3 in 2010 [26]	-	-	-	-	-
	[27]	27	World Bank and National Urban Transporation [24]	State and Local funding. Federal Funding for [29]		World Bank, Inter-American Development Bank (IDB), [22]	[26]	[26]	[24]	[26]
Funding Source	National/Dity government	Private	Program	recreation path	-	and the Metropolitan Municipality of Lima	Local, State, and Federal Sources	National government, Local fuel surcharges	FTA New Starts, State and Local sources	FTA Small Starts, State, and LTD general fund
User cost	$.85 (subsidized) [28]	$0.40 28	$0.71, $0.65 prepaid [25]	$1.75 [30]	$0.30 [27]	$0.74 [23]	$1.75 [27]	$0.70 [27]	$2.25 [25]	$1.75 [27]
Benefits	$143 M (12% IRR) [29]	-	$8.98 mil(based on fare and annual demand) [26]	-	47% reduction in per trip bus cost [28]	-	USD 903 million Transit Oriented Development [28]	-	-	-
Sustainability/Resilience										
Emission Savings (US Dollars)	$18 million CO2 reduction savings since opening [30]	-	-	-	-	-	N/A		-	-
Emissions Avoided	40,095 tCO2e reduced until date [31]	30% less CO2 than standard buses [29]	[illegible] tCO2eq (between 2011 and 2018, estimated) [27]	-	[illegible] total CO2 direct emissions reduction estimated 2010-2019 [29]	-	N/A	2006 94,567 tonnes of CO2eq2007 134,011 ton [28]	Reduction in overall traffic cut particulate emissions in the corridor by 95% [26]	Hybrid-electric buses had a 27% higher fuel economy on average when compared to the [28]
Bike lanes	N/A	Integrated [30]	Yes [28]	Integrated, metro built adjacent bike lanes [31]	Yes [30]	No [24]	Bike racks [29]	Yes [29]	Yes [27]	Yes [29]
Charging stations P&R	N/A	N/A	N/A	N/A	N/A	N/A	N/A		-	-
Parks/greenway	N/A	Enhanced alongside stations [31]	Present [29]	Present [32]	N/A	-	Linear park being build adjancent to busway [30]		-	Yes [30]

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Scores using 2013 version of BRT Standard						
	Country	Colombia	USA	USA	USA	USA
	City	Medellin	Cleveland, OH	Eugene, OR	Los Angeles, CA	Pittsburgh, PA
	System	Metroplús	(no BRT system name)	Emerald Express (EmX)	(no BRT system name)	(no BRT system name)
	Corridor	(no corridor name)	Healthline	Green Line	Orange line	Martin Luther King Jr. East
	Corridor Length (km)	12.5	15	12.5	23	14.6
BRT Basics - Minimum score of 4 points needed	**33**	32	29	20	25	20
Busway alignment	7	7	7	4	7	7
Dedicated right-of-way	7	7	7	4	7	7
Off-board fare collection	7	7	6	6	6	0
Intersection treatments	6	5	3	0	5	6
Platform-level boarding	6	6	6	6	0	0
Service Planning	**24**	17	16	11	13	13
Multiple routes	4	0	4	0	0	4
Peak frequency	3	3	1	0	3	2
Off-peak frequency	2	2	0	2	2	0
Express, limited, and local services	3	0	0	0	0	2
Control center	3	3	3	3	3	0
Located In top ten corridors	2	2	2	2	0	2
Demand Profile	3	3	3	3	3	0
Hours of operations	2	2	2	1	2	2
Multi-corridor network	2	2	1	0	0	1
Infrastructure	**14**	13	8	5	9	11
Passing lanes at stations	4	3	2	0	4	4
Minimizing bus emissions	3	3	2	2	3	2
Stations set back from intersections	3	3	1	1	0	3
Center stations	2	2	1	0	0	0
Pavement quality	2	2	2	2	2	2
Station Design and Station-bus Interface	**10**	10	9	7	5	5
Distances between stations	2	2	2	2	0	0
Safe and comfortable stations	3	3	3	2	1	1
Number of doors on bus	3	3	3	3	3	3
Docking bays and sub-stops	1	1	1	0	1	1
Sliding doors in BRT stations	1	1	0	0	0	0
Quality of Service & Passenger Information Systems	**5**	5	5	5	5	0
Branding	3	3	3	3	3	0
Passenger information	2	2	2	2	2	0
Integration and Access	**14**	8	9	10	8	7
Universal access	3	3	3	3	3	2
Integration with other public transport	3	3	1	3	0	2
Pedestrian access	3	2	3	2	1	2
Secure bicycle parking	2	0	1	1	2	1
Bicycle lanes	2	0	1	1	2	0
Bicycle-sharing integration	1	0	0	0	0	0
TOTAL 100	**100**	**85**	**76**	**58**	**65**	**56**
BRT BASICS (MINIMUM NEEDED 18)	**33**	**32**	**29**	**20**	**25**	**20**
Point Deductions	**-36**	**0**	**0**	**-3**	**0**	**0**
Commercial Speeds	-10	0	0	-3	0	0
Peak passengers per hour per direction (pphpd) below 1,000	-5	0	0	0	0	0
Lack of enforcement of right-of-way	-5	0	0	0	0	0
Significant gap between bus floor and station platform	-5	0	0	0	0	0
Overcrowding	-3	0	0	0	0	0
Poorly-maintained Busway, Buses, Stations and Technology Systems	-8	0	0	0	0	0
Total Score:		**85**	**76**	**55**	**65**	**56**
Rank:		**Gold**	**Silver**	**Bronze**	**Bronze**	**Bronze**

Source: https://www.itdp.org/library/standards-and-guides/the-bus-rapid-transit-standard/the-scorecard/

Emissions Impact of Personal Vehicle Trips Avoided by BRT

A. Emissions Avoided by Work Trips

Emissions Factors	Private Vehicle	GWP
CO_2 (g CO_2/mi)	411	1
CO (g CO/mi)	8.73	
NOx (g NOx/mi)	0.56	
PM2.5 (g/mi)	0.087	
North Shore Data		
Population	175,756	
Population using buses (19.8%)	34,800	
Working Age Population (61.3%)	107,738	
Total Number of Travel Market Residents	53,216	

North Shore Residents Commuting to Work on Single Occupancy Vehicles

Work Destination	% Total Work Trips by Destination	Number of Single Occupancy Vehicles (SOV)	Distance (mi)	Vehicle Miles Travel Annually (VMT)	CO_2 (tonnes) Annually	CO (tonnes) Annually	NOx (tonnes) Annually
Within North Shore	26.50%	14,119	6	44,051,280	18,105.08	384.57	24.67
New York County	28.80%	15,316	24.9	198,311,568	81,506.05	1,731.26	111.05
Brooklyn County	11.90%	6,337	13.5	44,485,740	18,283.64	388.36	24.91
Queens County	2.10%	1,114	21.5	12,454,520	5,118.81	108.73	6.97
Staten Island outside North Shore	23.40%	12,466	6.8	44,079,776	18,116.79	384.82	24.68
Bronx County	0.60%	299	35.1	5,457,348	2,242.97	47.64	3.06
Hudson County, NJ	1.30%	666	18.9	6,545,448	2,690.18	57.14	3.67
Middlesex County, NJ	1.20%	645	26.4	8,854,560	3,639.22	77.30	4.96
All Other Counties	3.90%	2,095	30	32,682,000	13,432.30	285.31	18.30

Possibility of Commuters switching to BRT	CO_2 Emissions Avoided (tonnes) Annually	CO Emissions Avoided (tons) Annually	NOx Emissions Avoided (tons) Annually	VMT Avoided Annually	Number of Cars off the Road Daily	PM2.5 Emissions Avoided (tons) Annually
HIGH	99,611.13	2,115.83	135.72	242,362,848	29,435	21
MEDIUM	23,402.45	497.09	31.89	56,940,260	7,451	5
LOW	40,121.46	852.22	54.67	49,537,124	12,765	4

Table 9: Work Destinations for Travel Market Residents

Work Destination	Number of Travel Market Residents	% Total Work Trips by Destination
Richmond County (Staten Island) Total	26,585	50.0%
Richmond County Within Travel Market Area	*14,119*	*26.5%*
Richmond County Outside Travel Market Area	*12,466*	*23.4%*
New York County (Manhattan) Total	15,316	28.8%
Lower Manhattan	*7,607*	*14.3%*
Midtown Manhattan	*6,595*	*12.4%*
Upper Manhattan	*1,114*	*2.1%*
Kings County (Brooklyn)	6,337	11.9%
Queens County	1,144	2.1%
Bronx County	299	0.6%
Hudson County, NJ	666	1.3%
Middlesex County, NJ	645	1.2%
All Other Counties	2,095	3.9%
Total	**53,216**	**100.0%**

Source: 2000 Census Transportation Planning Package Part 3.

Bus types	Diesel	Stoich. CNG	Lean Burn CNG
Fuel cons. (l/100km)	62.8	73.5	83.2
CO2 (g/km)	1633	1475	1634
CO (g/km)	3.5	0.7	0.8
THC (g/km)	1.7	0.2	7.5
NOx (g/km)	15.2	1.8	25.1

ROW (km)	8	Km

Total GHG emissions per bus trip

Bus types	Diesel	Stoich. CNG	Lean Burn CNG
Fuel cons. (l)	5.024	5.88	6.656
CO2 (g)	13064	11800	13072
CO (g)	28	5.6	6.4
THC (g)	13.6	1.6	60
NOx (g)	121.6	14.4	200.8

General Data and Statistics on North Shore Travel	Value	Sources
Staten Island Population	476,015	https://www.census.gov/quickfacts/table/PST045
North Shore Population	175756	http://prattcenter.net/sites/default/files/pratt_rock
Percentage that relies on bus for transportation	12.5%	http://www.nycedc.com/system/files/files/project
Estimated no. of people relying on bus in Staten Island	59501.875	
Estimated no. of people relying on bus in North Shore	21969.5	
Percentage of SI that relies on car for transportation	67.0%	http://web.mta.info/mta/planning/nsaa/pdfs/nsaa.
Estimated minimum no. of people using BRT	35,000	
Estimated maximum no. of people using BRT	70,000	no. of people that use the ferry
Weekly wage (Q1 of 2016)	$ 865.00	https://www.bls.gov/regions/new-york-new-
Median household income	$ 71,121.00	https://www.nycedc.com/sites/default/files/filem
Average per capita income	$ 31,611.00	
Average wage/hour	$ 21.63	
Total Staten Island Travel Population (2009)	141,958	AA Report
Port Richmond Travel Population	50295	AA Report
Elm Park Travel Population	45412	AA Report
New Brighton Travel Population	27,892	AA Report
Northwest SI Travel Population	4,049	AA Report

Time Values of Travel Time (Staten Island)			
Bus & BRT Users	**Percent of gross hourly wage**	**Per hour**	**Per minute**
In vehicle non-work trip (local)	50%	$ 10.81	$ 0.18
In-vehicle non-work (internally)	70%	$ 15.14	$ 0.25
Invehicle work trip	100%	$ 21.63	$ 0.36
Excess for work-trip (walking, waiting, transfer)	100%	$ 21.63	$ 0.36
Excess for non-work trip (walking, waiting, transfer)	100%	$ 21.63	$ 0.36
Automobile Users	**Percent of gross hourly wage**	**Per hour**	**Per minute**
In vehicle non-work trip (local)	50%	$ 10.81	$ 0.18
In-vehicle non-work (internally)	70%	$ 15.14	$ 0.25
Invehicle work trip	100%	$ 21.63	$ 0.36
Carpool driver	60%	$ 12.98	$ 0.22
Carpool passenger	40%	$ 8.65	$ 0.14
Excess for work-trip (walking, waiting, transfer)	100%	$ 21.63	$ 0.36
Excess for non-work trip (walking, waiting, transfer)	100%	$ 21.63	$ 0.36

Average wage/hour for a Staten Island Resident:	$ 21.63

Value of Travel Time Saved per Capita						
Trip Origins (to St. George)	Current Bus Travel Time (min)	BRT Travel Time (min)	Savings Comparison (min)	Value per capita (work trip)	Value for estimated minimum users of BRT	Value for estimated maximum users of BRT
Arlington Station	39	14	25	$ 9.01	$ 197,954.35	$ 630,729.17
WSP Station	56	23	33	$ 11.89	$ 261,299.74	$ 832,562.50
Port Richmond Station	16	9	7	$ 2.52	$ 55,427.22	$ 176,604.17
Manor Road/Forest Ave	25	13	12	$ 4.33	$ 95,018.09	$ 302,750.00