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Metropolitan Transportation Authority
State of New York

The Transit Effect Multiplier of is a cumulative total of the Landuse Factor, Congestion Relief Factor and Mode Shift Factor. In the case of the MTA it is a weighted average of these factors from various points in the service region. The factor was initially computed to be 7.9 (in the attached report) and subsequently updated to 8.24 (in the powerpoint slides). Future calculations incorporated a greater weight to the Landuse Factor in the denser parts of the territory, from where more trips originate and terminate.

MTA BLUE RIBBON COMMISSION ON SUSTAINABILITY

IMPACT OF PUBLIC TRANSPORTATION ON GHG IN THE MTA AREA

MAY 28, 2009

PREPARED FOR:

METROPOLITAN TRANSPORTATION AUTHORITY (MTA)

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Impact of Public Transportation on GHG in the NY MTA Area

Executive Summary

A. Purpose

This study describes the results of an analysis conducted by Booz Allen Hamilton (Booz Allen) for the New York Metropolitan Transportation Authority (MTA) on the impact of MTA operations on anthropogenic greenhouse gas (GHG) emissions. The report evaluates GHG emissions from MTA operations and GHG emissions not generated in the region because MTA provides an efficient transportation network that results in less emissions than if riders used personal vehicles for their trips.

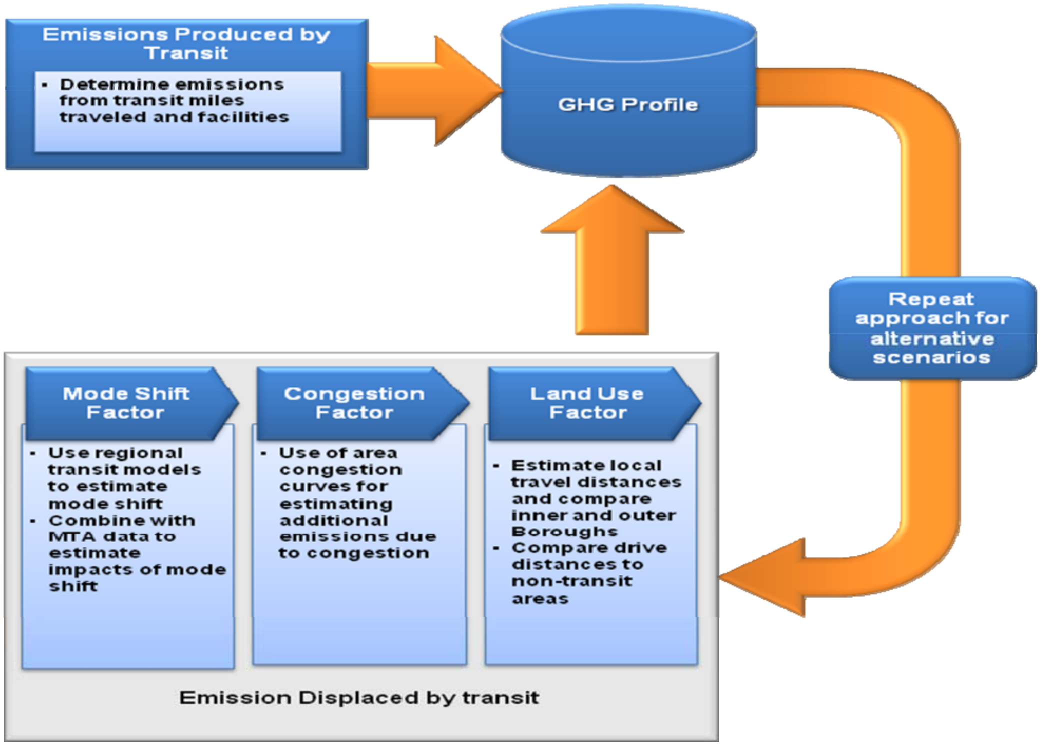
B. Background

Transportation is a major source of GHG emissions. The most recent data from the Energy Information Administration (EIA) estimates that transportation accounts for 28 percent of GHG emissions in the U.S. Public transportation plays a key role in reducing regional GHG emissions, because public transportation is more carbon efficient than private vehicles. There is a growing recognition of this fact. For example, a number of federal, state, and local legislative proposals would incentivize state and local governments to invest in public transit programs to reduce regional GHG emissions. If these proposals are to be workable, they must be founded on a clear understanding of the GHG emissions saved or avoided from public transport. Currently, the exact magnitude of these savings is unknown and there is no consensus on how to calculate such savings. In an effort to develop a common approach, American Public Transportation Association (APTA) has developed a draft methodology to estimate the impact of public transit on GHG. Given these developments, MTA asked Booz Allen to use the APTA methodology to determine the impacts of MTA operations on regional GHG emissions. This report presents the findings of this effort and provides recommendations for improvements to the approach, including necessary studies to improve data availability.

C. Approach

Booz Allen adapted the APTA approach for estimating GHG emissions in the MTA Region. The approach evaluates the total emissions produced by transit and the emissions not generated because of the benefits provided by transit. The benefits take the form of mode shift from personal vehicles to more efficient transit, reduction in congestion resulting from mode shift, and land use patterns that historically develop around plentiful supply of mass transit. The approach is diagramed below and discussed in further detail in the report.

Figure 1: High-Level Overview of Approach



D. Findings

Based on our analysis, we have identified the following key points:

- **Without MTA, the MTA operating region's transportation-related GHG emissions would be approximately 30 percent greater.** MTA reduces congestion, allows individuals to use public transportation rather than private vehicles, and permits the New York region to maintain a compact, dense land use pattern. Without the MTA, we estimate that GHG emissions from the entire MTA Region could be approximately 30 percent greater (and possible as high as 70 percent greater depending on the assumptions on how land use would change in response to the absence of the MTA). These percentages do not account for co-benefits – such as physically smaller households that result in smaller energy consumption.
- **Without MTA, the total GHG generated by individuals currently using MTA would be approximately eight times greater.** We estimate that the entire MTA system currently generates approximately 2.3 million tons of GHG per year - compared to private motor vehicles which produce 53 million tons per year in the MTA region or more than 24 times as much GHG. Without the MTA, we estimate that the impact of changing

land use to accommodate more cars and increased congestion, would increase from current MTA passengers by approximately eight times (i.e., mode shift factor of 2.31, congestion factor of 0.73, and land use factor of 4.85). This means that MTA passengers would go from generating approximately 2.3 million tons of GHG to more than 18 million tons per year. This assumes that without MTA, New York would come to resemble the average US city. That is, without MTA, the New York area would sprawl and become more dependent on the car. Average trips would be longer, people would have to use their cars more, and congestion would increase. This is not an extreme case. Under some assumptions (for instance, if the MTA Region sprawled to look like a Sunbelt City), emissions from current MTA passengers could be as much as 19 times greater than the approximate 2.3 million tons of GHG currently generated. Thus, a cautious, middle-of-the-road estimate shows that MTA demonstrates dramatic GHG reduction benefits.

- **MTA saves 18 million tons of GHG:** Without MTA, GHG emissions could be more than 18 million tons per year – equivalent to removing more than 3 million cars per year – or more than 25 percent greater than current GHG emissions. This is as conservative estimate that assumes that, without MTA, the region could have sprawled to look like the average U.S. land use. If the MTA Region became even more like low public transport, car-based cities, savings could be as high as 44 million tons per year.
- **The land use factor makes a critical contribution to GHG savings:** MTA allows more dense land use to develop. This is a key contribution to achieving GHG savings. Booz Allen estimated that more dense land use contributes approximately 62 percent of the direct impact on GHG emissions.
- **Status quo scenario:** If MTA maintains a state of good repair but does not expand the system to account for population growth, the region will generate an additional 11 million metric tons (MT) of GHG emissions in 2030 or a total of approximately 133 million MT between 2010 and 2030.
- **Increased investment scenario:** This scenario evaluates an even distribution of additional investment to expand the system. This would result in a small reduction in GHG emissions; however, if investment was concentrated in the areas where it could make a major difference (e.g., in low transit land use area), greater GHG impacts are likely to be produced.

I. Introduction

The purpose of this document is to describe the results of an analysis conducted by Booz Allen Hamilton (Booz Allen) for the New York Metropolitan Transportation Authority (MTA) on the impact of MTA operations on anthropogenic greenhouse gas (GHG) emissions.[1] For purposes of this document, these gases are measured as carbon dioxide equivalents (CO2e)[2] and are referred to both as "CO2e" and "GHG" (for purposes of this report, these terms are synonymous).

The remainder of this document is divided into four sections:

- The background to the report;
- Our approach and methodology for estimating GHG/CO2e impacts;
- The results of our analysis; and
- Our main conclusions and findings.

Appendix 1 describes in detail the calculations conducted to estimate the impacts of New York public transit on GHG emissions.

A. Background

Transportation is a major source of GHG emissions. The most recent data from the Energy Information Administration (EIA) estimates that transportation accounts for 28 percent of GHG emissions (Figure 2). Since 1990 transportation GHG emissions have grown an average of 1.9 percent per year. As shown in Figure 3, in terms of CO_2 alone, transportation has risen since 1949 to become the most important source of CO_2 (34 percent).[3]

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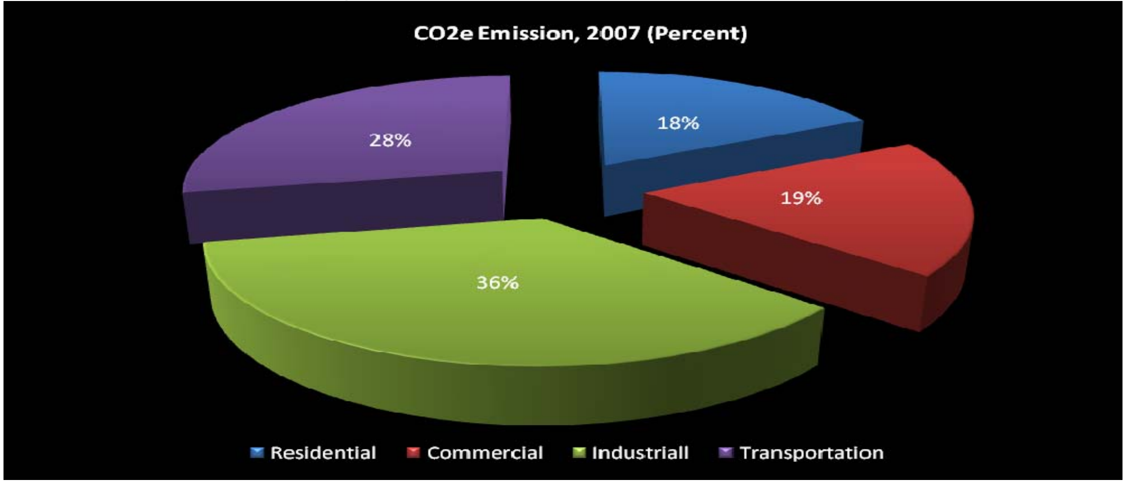
[1] The principal GHGs are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and three types of synthetic gases (sulfur hexafluoride, hydrofluorocarbons, and perfluorocarbons).

[2] CO2e is a measure that allows comparison of the total cumulative warming effects of different greenhouse gases. It is determined by multiplying the emissions of the gas by its associated global warming potential (GWP) -- a measure of gas heat-trapping ability relative to that of carbon dioxide. For example, GWP for methane is 24.5 (i.e., emissions of one million metric tons of methane is equivalent to emissions of 24.5 million metric tons of carbon dioxide).

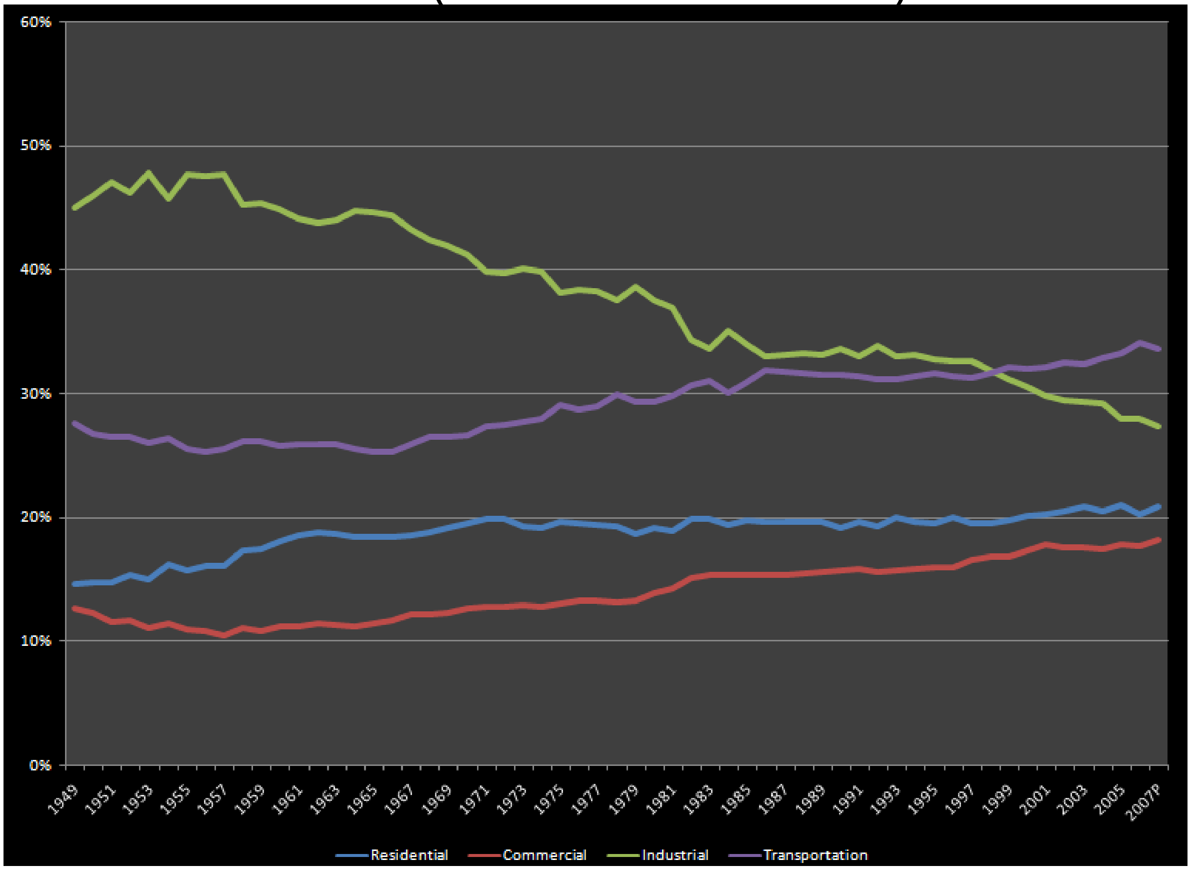
[3] However, EIA and our analysis do not account for the energy savings that occur as a result of the greater efficiency in buildings in high density areas.

Figure 2: U.S. GHG Emissions, 2007



Source: Emissions of Greenhouse Gases Report, 2007. Energy Information Administration, 2008

Figure 3: Percent Contribution of Major Economic Sectors to U.S. CO2 Emissions, 1949-2007 (Percent of millions of MT of CO2)



Source: Emissions of Greenhouse Gases Report, 2007. Energy Information Administration, 2008

The single largest source of GHG emissions within the transportation sector is road and highway use (i.e., cars, trucks and other on-road motor vehicles). As shown in Table 1, between 1990 and 2004 (latest available data), on-road vehicles accounted for approximately 80 percent of US Mobile Source GHG emissions.

Table 1: U.S. GHG Emissions from Mobile Sources, 1990-2004 (Tg of Co2e)

	1990	1995	2000	2001	2002	2003	2004
Car, Trucks and Other Vehicles	80%	78%	80%	81%	81%	81%	81%
Aircraft	12%	11%	10%	10%	9%	9%	9%
Marine	3%	3%	3%	3%	3%	3%	3%
Locomotives	3%	2%	2%	2%	2%	2%	3%
Mobile Air Conditioners & Refrigerated Transport	0%	1%	2%	2%	2%	2%	2%
Other	3%	6%	3%	2%	3%	3%	2%

Source: *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004, U.S. Environmental Protection Agency, 2006 and U.S. Department of Transportation Center for Climate Change and Environmental Forecasting*

One way to reduce GHG emissions from transportation is to shift drivers from personal vehicles to public transit. Public transport is much more carbon efficient than personal vehicles. In recognition of this fact, a number of federal, state, and local legislative proposals incentivize state and local governments to invest in public transit programs. For example, Senators Tom Carper (D-DE) and Arlen Specter (R-PA) recently introduced “The Clean, Low-Emission, Affordable, New Transportation Efficiency Act (CLEAN-TEA)”. The bill proposes to take 10 percent of the revenue from a future cap-and-trade climate program and use it to fund a Low Greenhouse Gas Transportation Fund. The fund would provide money to state, regional, and local governments, favoring investments in programs that produce higher per capita GHG emission reductions. Potential projects include public transit, passenger and freight rail, biking and pedestrian improvements, vanpools, smart traffic management and congestion pricing, and land use changes to make communities more walkable. Other proposals have suggested compensating state and local governments for public transit investments and even monetizing GHG savings from past investments.

If these proposals are to be workable, they must be founded on a clear understanding of the GHG emissions saved by public transport. However, the magnitude of these savings is unknown and there is no consensus on how to calculate such savings. Table 2 identifies the main studies that have been conducted to estimate reductions in GHG emissions due to public transit.

Table 2: Summary of Recent U.S. Studies on the Impact of Public Transportation on GHG Emissions

Study	Author	Year of Publication	Impact
Public Transportation and Petroleum Savings in the U.S.: Reducing Dependence on Oil	ICF (for APTA)	2007	This study shows that a solo commuter of a household, switching daily driving to public transportation, can reduce household carbon footprint by 10 percent. If a household also gives up the second car and switches to public transit, they can reduce their GHG emissions up to 30 percent.

The Broader Connection between Public Transportation, Energy Conservation and Greenhouse Gas Reduction	ICF	2008	This study found a significant correlation between transit availability and reduced automobile travel, independent of transit use. Transit reduces U.S. travel by an estimated 102.2 billion vehicle miles traveled (VMT) each year. This is equal to 3.4 percent of the annual VMT in the U.S. in 2007. By reducing VMT, public transportation reduces energy use and emissions in the transportation sector. The total effects reduce greenhouse gas emissions from automobile travel by 37 million MT.
Public Transportation's Contribution to U.S. Greenhouse Gas Reduction	SAIC (for APTA)	2008	This study found that public transportation is a net CO2 reducer; saving 6.9 million MT in 2005. A solo commuter switching to existing public transportation in a single day can reduce CO2 emissions by 20 pounds or more than 4,800 pounds in a year.

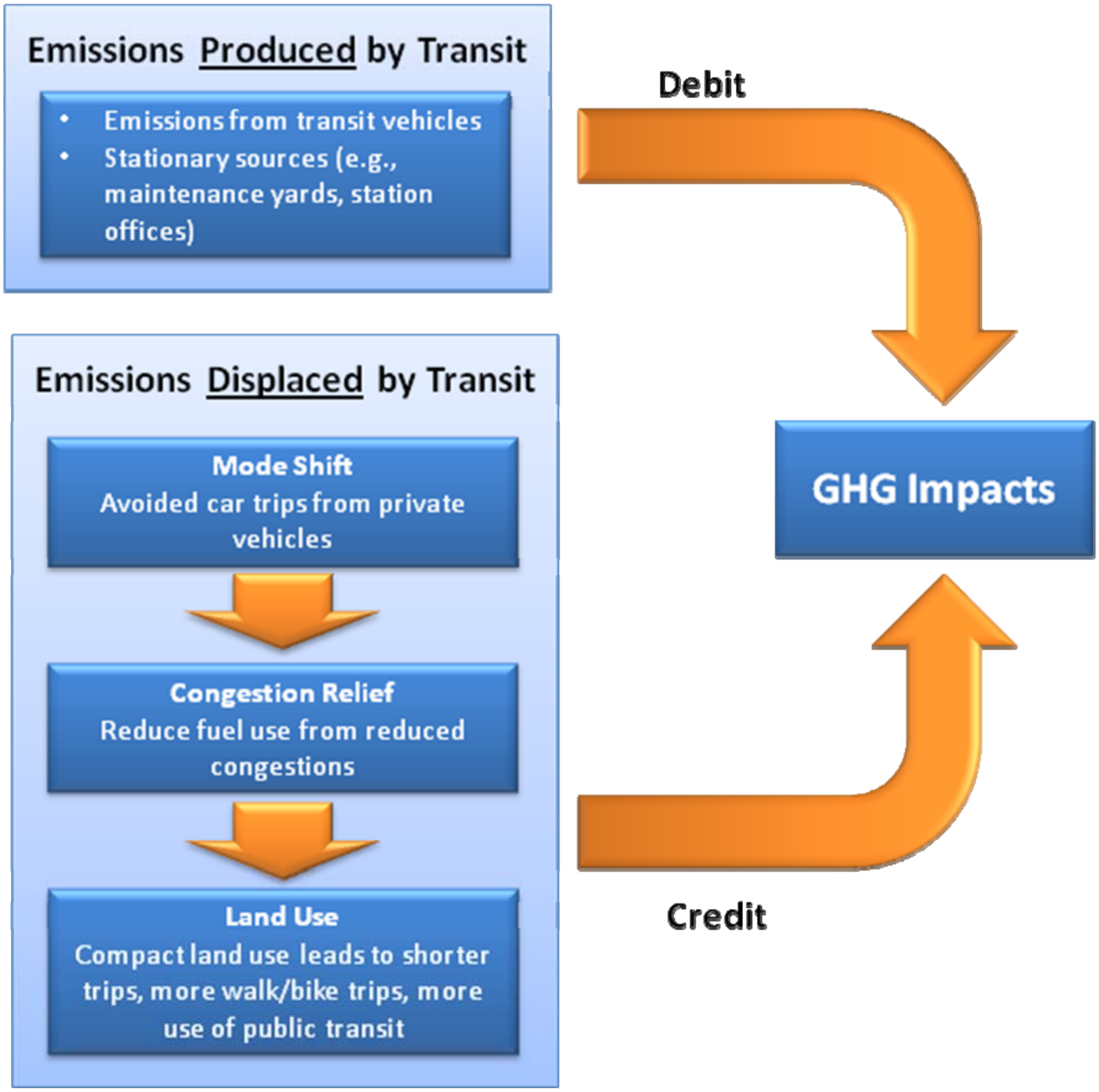
As depicted in Table 2, while there is a general consensus that public transport produces considerable GHG savings, there is uncertainty over the size of these savings. For example, the ICF study referenced in Table 2 estimated GHG savings using a complex statistical technique known as Structural Equation Modeling (SEM). SEM uses a combination of statistical data and qualitative, theory-based assumptions. SEM can estimate the impact of interactions between multiple inter-connected variables, nonlinear relationships, and conditional relationships (e.g., "X caused Y, but only when Z is present"). However, it has a number of problems (e.g., it confirms rather than tests assumptions, it is difficult to interpret, it has no single significance test for variables, and it is very sensitive to sample sizes and outliers). Thus, while the study provides perspective at a national level, the methodology is too complex for local and state governments to replicate on a regular basis and does not produce easily generalizable or comprehensible results.

Furthermore, in the ICF study, the amount of variation explained by the model was approximately 20 percent. This is a very low level for statistical models and means that 80 percent of the variation in the data is being caused by other, unnamed variables. This is especially a problem when one considers that more than 20 variables were used in the study. Normally, including a large number of variables (e.g., more than ten) should explain a higher proportion of the variance. Furthermore, the tests of significance shown in the ICF report seem to indicate that none of the variables were significant within the terms of the model. As a result, despite its impressive statistical sophistication, the ICF model neither explains the complex patterns and associations between public transit and VMT or yields useful results.

In an effort to develop a common approach, APTA is developing a methodology to estimate the impact of public transit on GHG. Figure 4 summarizes this approach. As can be seen, savings from public transit are produced by:

- **Mode shift:** shifting from private vehicles to public transit or non-motorized transport
- **Congestion:** reducing congestion by removing private vehicles from the road when drivers shift to public transportation
- **Land Use:** creating denser, mixed-use land use patterns as a result of the availability of public transit.

Figure 4: High-Level Overview of APTA Approach to Estimating the GHG Impacts of Public Transit



Given these developments, MTA wished to use the APTA methodology to determine the impacts of MTA operations on GHG emissions regionally. Specifically, MTA requested Booz Allen to apply the APTA methodology to the MTA Region[4] to evaluate GHG benefits provided by the MTAs' operations and evaluate three different scenarios: (1) reduced operations (evaluated here as the "No MTA" scenario; (2) state of good repair (e.g., status quo investment over time while population grows; and (3) increased investment

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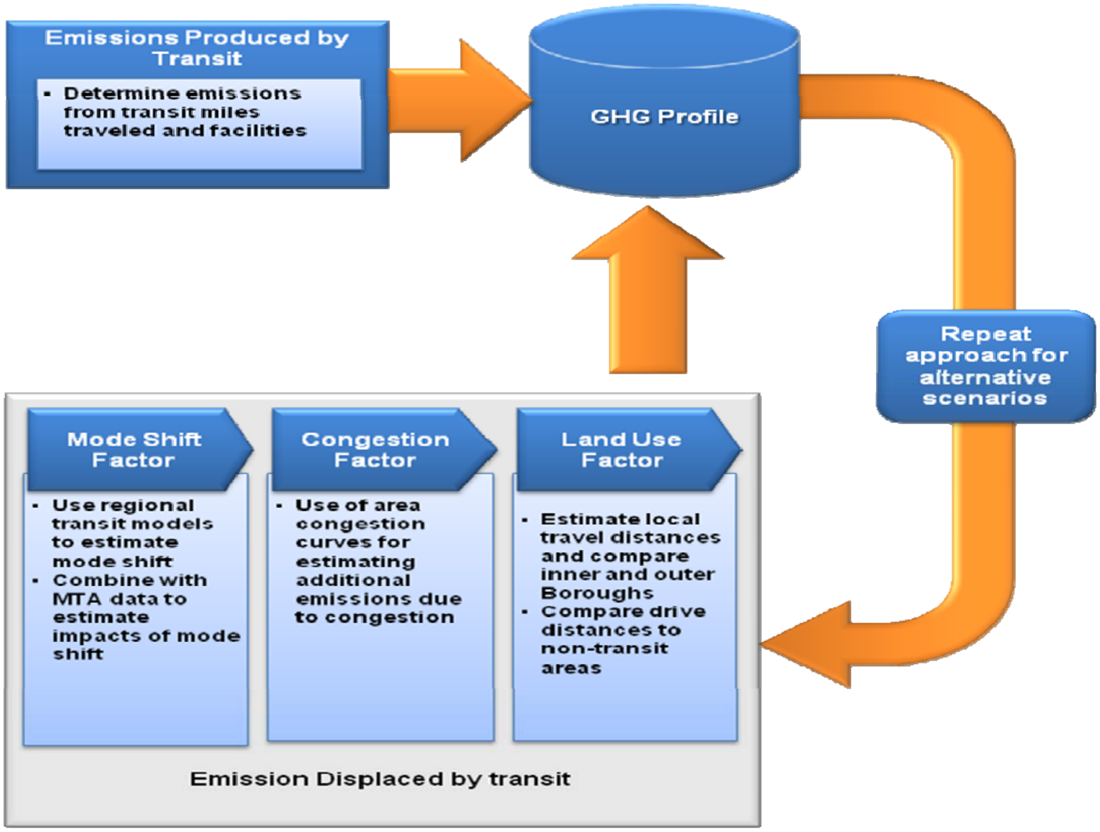
[4] The New York MTA Region is defined as the five boroughs of New York City and the suburban counties of Dutchess, Nassau, Orange, Putnam, Rockland, Suffolk and Westchester.

This document reports on the results of these analyses. In the following sections we describe how APTA's methodology was applied to the MTA Region and what it shows about GHG savings from public transit in the MTA Region.

B. Approach to Estimating GHG Savings from Public Transit in the MTA Area

This section provides a description of the approach Booz Allen used to estimate the impact of MTA on GHG emissions. As shown in Figure 5, Booz Allen adapted the APTA approach for estimating GHG emissions. Below, we describe the methodology used to estimate each factor.

Figure 5: High-Level Overview of Approach



1. Emissions Produced by Transit

While public transit reduces overall GHG emissions, it also produces GHG as part of its everyday operations. Thus, Booz Allen developed a baseline estimate of the direct and indirect GHG emissions generated by MTA facilities, rail, buses, and equipment using the methodology described in The Climate Registry (TCR). [5]

Of the six principal GHGs, emissions were estimated for CO_2, N_2O, and CH_4 for calendar years 2000 through 2007 and converted into CO2e. Booz Allen did not estimate hydrofluorocarbons,

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[5] All figures cited in this report related to MTA operations are net. That is, any additional GHG emissions produced by MTA operations have been subtracted from potential savings.

perfluorocarbons, or sulfur hexafluoride emissions because data were not available and adding these gases were not expected to significantly change results.

MTA provided Booz Allen with electricity and fuel consumption data for all MTA agencies for calendar years 2000 through 2007. This information, obtained from MTA's audit department, included the following complete list:

- Purchased electricity for use in facilities and traction;
- Fuel for use in vehicles and equipment, including gasoline, diesel, biodiesel (B5 and B20), ethanol (E85), kerosene and compressed natural gas (CNG);
- Fuel for use in non-revenue vehicles and equipment including gasoline and diesel;
- Fuel for heating, including #2, #4, and #6 oil and natural gas; and
- Purchased steam.

MTA also provided the number of passenger miles traveled for the MTA system for calendar years 2000 through 2007.

Additional details on the methodologies Booz Allen used to calculate GHG emissions from MTA operations are described below. In general, Booz Allen calculated emissions by multiplying an energy consumption rate by an emission factor using appropriate unit conversion factors. The emission factors are on a mass per volume, mass per energy, or mass per vehicle miles traveled basis. To convert the fuel combusted for vehicles when using an emission factor based on vehicle miles traveled, Booz Allen assumed the miles per gallon to be 20.3 MPG for vehicles and 2.69 MPG for buses. The vehicle miles per gallon figure was obtained from the U.S. Environmental Protection Agency and the bus miles per gallon figure was obtained by dividing the total fuel consumed by the bus fleet for MTA by the total vehicle-miles for buses in the MTA region.

- **Purchased Electricity:** Booz Allen used TCR methodology to calculate purchased electricity emissions. MTA provided the emission factors from the electricity generators. MTA purchases electricity from a variety of sources including Con Edison, Long Island Power Authority (LIPA), New York Power Authority (NYPA) as well as suppliers in Upstate New York, Connecticut, and Westchester, NY.
- **Fuel Purchased for Vehicles and Equipment:** Booz Allen used the TCR methodology to calculate fuel purchased for vehicles and equipment. MTA purchases fuel such as gasoline, diesel, biodiesel, and CNG that is combusted in vehicles and equipment. Booz Allen estimated emissions from combustion of these fuels using emission factors from TCR. Booz Allen derived the E85 emission factor for automobiles by summing 85 percent of the E100 value and 15 percent of the gasoline emission factor from TCR since no factor for E85 is available. For E85 buses, Booz Allen used the E85 emission factor found in the Transport Canada Urban Transportation Emissions Calculator; and for CNG buses,. Booz Allen used an emission factor from the American Petroleum Institute since no factor was available from the TCR protocol for this emissions source..
- **Fuel Used in Non-Revenue Vehicles and Equipment:** The fuels burned in non-revenue vehicles and equipment include gasoline and diesel. Booz Allen used the TCR methodology to calculate fuel used for non-revenue vehicles and equipment. However, we used an emission factor from the American Petroleum Institute for light duty trucks since no factor was available from the TCR protocol for this emissions source**Fuel Used for Heating:** Some MTA facilities combust various grades of fuel oil and natural gas for

comfort heating. Booz Allen used the TCR methodology to calculate fuel used for heating.

Booz Allen converted the estimated emissions of N_2O and CH_4 to units of CO_2e by multiplying the emissions by the GWP_shown in Table 3, and then added these emissions to the CO_2 emissions to obtain the total CO_2e.

Table 3: GWP for Greenhouse Gases

GHG	GWP[1]
N_2O	310
CH_4	21

The total CO_2e emissions in MT estimated for MTA operations from calendar years 2000 through 2007 are shown in Table 4 below.[6]

Table 4: CO_2e Emissions for MTA Operations 2000-07

Year	NYCT (MT)	MNR (MT)	B&T (MT)	MTA Bus (MT)	LIRR (MT)	LIB (MT)	HQ (MT)	Total (MT)
2000	848,965	270,500	29,710	0	298,927	12,151	23,325	1,483,579
2001	879,416	273,984	28,957	0	314,815	21,297	20,832	1,539,302
2002	920,799	269,990	29,460	0	321,003	20,310	20,006	1,581,569
2003	916,529	270,124	30,029	0	326,254	18,637	25,424	1,586,997
2004	765,965	256,711	27,410	0	345,045	32,616	24,375	1,452,121
2005	1,551,043	309,026	34,231	25,035	372,949	16,545	30,586	2,339,414
2006	1,481,744	311,024	30,513	100,927	366,143	15,901	25,351	2,331,602
2007	1,605,637	335,064	31,050	111,687	365,428	15,685	29,699	2,494,249

Booz Allen also converted the GHG emissions to a mass per passenger mile traveled (PMT) basis as shown in Figure 5 by dividing the CO2e by the PMT provided by MTA for each calendar year. PMT is the total distance traveled by all passengers and is calculated as the product of the occupancy rate in vehicles and the vehicle miles traveled. It is different from VMT, which is a unit to measure vehicle travel made by a private vehicles, such as automobiles, vans, or motorcycles and is independent of the number of persons in the vehicle.

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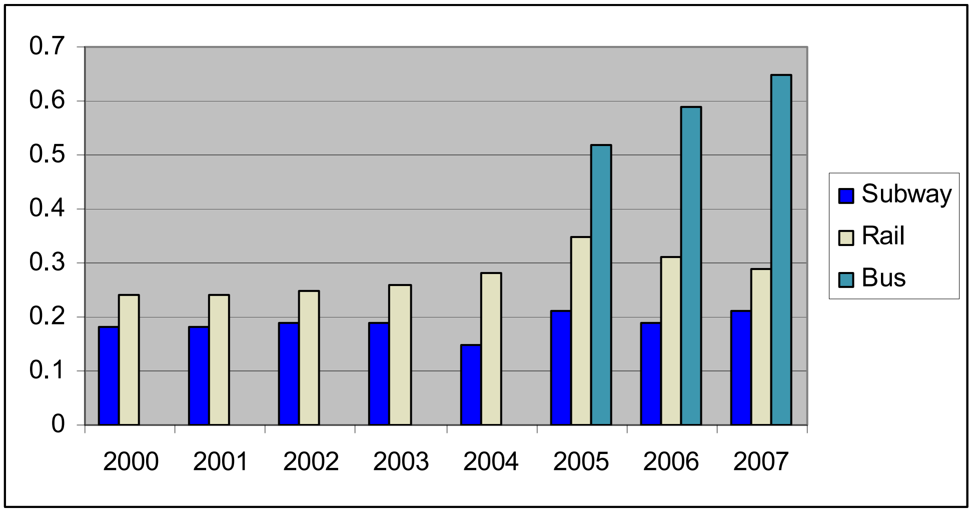
[6] Booz Allen did not calculate emissions for the operation of MTA Buses during 2000 through 2004. Private bus fleets were consolidated during that timeframe and accurate fuel consumption data were not available.

Figure 5: CO_2e Emissions for MTA Operations for 2000-07 on a Mass per PMT Basis[7]



2. Emissions Reduction from Mode Shift Factors

Mode Shift measures the impact of individuals changing travel behavior from one mode of transport to another. For this study, Booz Allen examined a number of scenarios that posited shifts of different magnitude between public transit (e.g., subways, commuter rail (CR), and buses), personal vehicles (e.g., cars and trucks), and non-motorized transport (e.g., walking and biking). For each scenario Booz Allen used MTA's Regional Transit Forecasting Model (RTFM) to estimate the impact of changes to individuals' transport choices and behaviors.

The RTFM evaluates the attributes of a particular travel mode (time and costs) in combination with individual socio-economic characteristics to estimate mode shares for every origin-destination combination in the MTA Region (about 12,000,000). MTA uses the mode choice model to evaluate how changes in MTA policies and services shift trips between modes (i.e. private automobile-to-transit or transit-to-private automobile). MTA uses these shifts or modal diversions to estimate the resulting impacts on automobile and transit trips. The modeled mode choices in the mode choice model are:

- Single-occupancy vehicle (SOV)
- High-occupancy vehicle (HOV)
- Walk-to-commuter rail
- Drive-to-commuter rail
- Walk-to-transit
- Drive-to-transit
- Taxi
- Non-motorized (walk/bike).

The model also accounts for multimode trips. For example, a trip that utilizes commuter rail, followed by a bus ride and a walk to the final destination is calculated as a walk-to-commuter rail trip. The model uses data from 2006 (the most recent year for which data are available) on

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[7] Booz Allen did not calculate emissions for the operation of MTA Buses during 2000 through 2004. Private bus fleets were consolidated during that timeframe and accurate fuel consumption data were not available

regional origin-to-destination flows, throughout the five boroughs of New York City and the surrounding counties.

For each scenario, Booz Allen used the RTFM to estimate changes in the use of different modes of transportation given the assumptions of the scenario. For example, for the "No-MTA" scenario, Booz Allen assumed that MTA would cease to function. Under this assumption, the RTFM provided the number of individuals that would drive and the distance they would drive, as well as the number of individuals that would use non-motorized transport.

Booz Allen obtained baseline VMT from the Highway Performance Monitoring System (HPMS) for the MTA Region[8]. The HPMS is a national level highway information system that includes data on the extent, condition, performance, use, and operating characteristics of the Nation's highways.[9] The HPMS data set is used throughout the transportation profession and has become an integral part of the policy planning process and guides how federal funding is apportioned and allocated. Thus, Booz Allen used the HPMS because it provided the most accurate and up-to-date data on New York VMT.

Booz Allen used the VMT data to estimate the GHG impacts of this change using the following equation:

Equation 1: Approach Used to Estimate GHG Impacts of VMT Shift

$$\Delta GHG = \Delta V / \Phi C \times G$$

Where:

ΔGHG = Change in GHG emissions from mode shift
ΔV = Change in VMT predicted by RTFM
ΦC = Average consumption per vehicle as estimated by EPA[10]
G = Estimated GWP[11]

Similarly, when the RTFM predicted an increase in the number of passengers using public transit, Booz Allen used the following equation to estimate the increase in passengers:

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[8] Non-public transit data taken from HPMS included all private motor vehicles (e.g., cars, trucks, commercial vehicles).

[9] HPMS provided VMT data for 2006 and 2010 for the New York City boroughs. Booz Allen projected these data to 2020 and 2030 using a simple regression model. For the remainder of the MTA Region, Booz Allen increased VMT using the RTFM.

[10] See "Emission Facts: Average Annual Emissions and Fuel Consumption for Passenger Cars and Light Trucks" U.S. EPA at http://www.epa.gov/oms/consumer/f00013.htm.

[11] See section 4.1 for GWP estimation methodology.

Equation 2: Approach Used to Estimate Increase in Number of Public Transit Passengers from VMT Shift

$$\Delta P = \Delta V / \Phi R$$

Where:

ΔP= Change in passengers using public transit
ΔV = Change in VMT predicted by RTFM
ΦR = Average riders per vehicle (e.g., train or bus) as reported by MTA RTFM

The outputs of this equation (i.e., the increase in ridership) translated into increased GHG emissions using the methodology described in Section 4.1.

When a scenario suggested a shift from public transit, Booz Allen estimated increased emissions using the approach shown in Equation 3:

Equation 3: Approach to Estimating GHG from Mode Shift from MTA to Personal Vehicles

Total potential GHG impact of mode shift from public transit to personal vehicles

$$\Delta GHG = (((\sum Pc, Ps, Pb)/Pcr) \text{ x } \Phi C \text{ x } Gcr) - (Vc \text{ x } Gc) + (Vs \text{ x } Gs) + (Vb \text{ x } Gs)$$

Where:

ΔGHG = Change in GHG emissions from mode shift
Pc= PMT for CR (provided by MTA)
Ps = PMT for subway (provided by MTA)
Pb= PMT for buses (provided by MTA)
Vc = VMT for CR from RTFM
Vs = VMT for subway RTFM
Vb = VMT for buses RTF M
Mc = Average miles traveled by car in area under study from RTFM
Gc = GHG emissions for CR per mile (see “Emissions Produced by Transit” above)
Gs = GHG emissions for subway/mile (see Section 4.1)
Gb = GHG emissions for buses per mile (See Section 4.1)
Gcr = GHG emissions per gallon of gasoline (See Section 4.1)
Pcr = Average passengers per car (1.7)[12]
ΦC = Average Consumption per Vehicle as estimated by EPA[13]

3. Methodology to Estimate Congestion Factors

This section describes the approach Booz Allen used to estimate the reduction in emissions due to congestion relief. GHG emissions from congestion derive from the excess fuel consumed due to traffic on the road network. Booz Allen calculated the excess fuel consumed from congestion using the approach recommended by APTA. Specifically, Booz Allen took data from the Urban Mobility Study from the Texas Transportation Institute (TTI) on VMT/lane and excess

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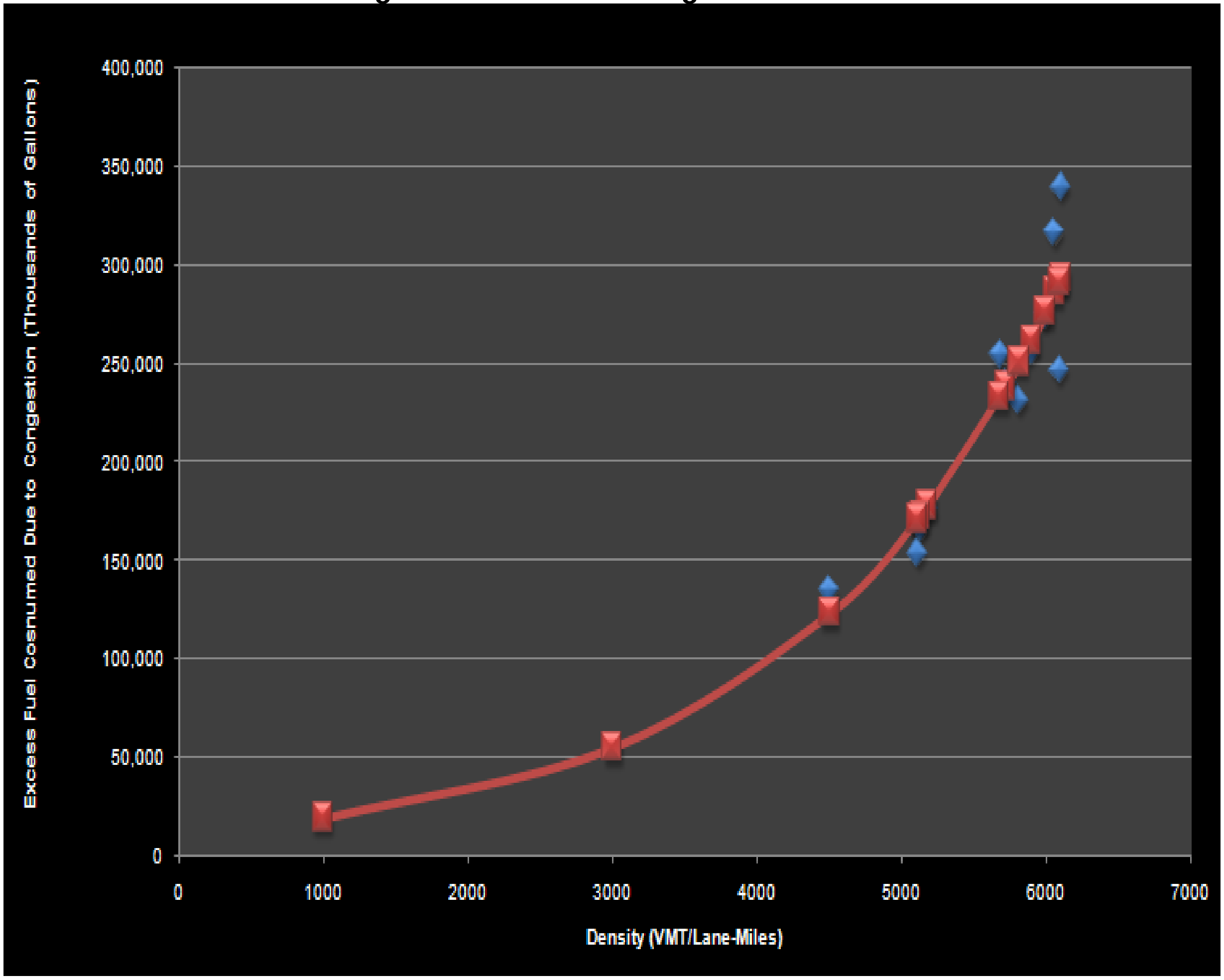
[12] "Transportation Energy Data Book". U.S. Department of Energy at http://cta.ornl.gov/data/download27.shtml.

[13] See “Emission Facts: Average Annual Emissions and Fuel Consumption for Passenger Cars and Light Trucks” U.S. EPA at http://www.epa.gov/oms/consumer/f00013.htm.

fuel consumption due to travel in congested conditions rather than free-flow conditions for the MTA Region. We then ran a series of regression analyses to determine the relationship between increase in VMT and excess fuel consumption in the MTA Region. Based on this analysis, Booz Allen developed a curve that showed the relationship between congestion and excess fuel (see Figure 6).

When a scenario showed increased VMT (as predicted by the RTFM), Booz Allen consulted the congestion curve and identified the appropriate increase in excess fuel due to congestion and converted this to GHG emissions using the methodology describes in “Emissions Produced by Transit” above. Booz Allen then added these calculations to mode shift to obtain the impact of these two factors.

Figure 6: MTA Area Congestion Curve



4. Methodology to Estimate Land Use Factors

In areas with high density population and mixed land use, residents are much less likely to drive than individuals that live in areas with low population density. However, without public transport it is extremely difficult to maintain high density populations. Typically in the absence of public transportation, urban areas sprawl and/or become car dominated with significantly expanded road networks. The result of either outcome is that GHG emissions increase. Thus, apart from the effects associated with mode shift and congestion, there is a separate effect on GHG emissions caused by permitting a more dense land use pattern to be developed and maintained. It should be noted that the land use methodology does not account for the energy savings from the more efficient building construction that results in high density areas. For example, multi-family dwellings use less heat and cooling per capita as compared to large single family homes. The land-use component captures only the GHG savings from travel.

Booz Allen estimated land use impacts using two methods:

- A method that relies on geospatial analysis of proximity to public transit
- A method using a series of comparisons between land use and VMT in areas with different land use.

Each method is described in detail below.

a) GIS-Based Estimates of the Impacts of Land Use

One approach in the APTA guidance is to estimate GHG emission reductions using Equation 4:

Equation 4: APTA Land Use (LU) Equation[14]

Emission reductions from LU multiplier =

(5.185 x Average Rail Availability + (MT/yr) + 0.764 x Average Bus Availability) x Number of households x 365 x Emissions per vehicle mile (default 0.436kg) / 1000[15]

The Average Rail Availability and Average Bus Availability included in Equation 4 are estimated using either geocoded address locations or census blocks for a representative sample of households in the region. APTA recommends identifying a random sample of 1,000 addresses or census blocks for use in Equations 5 and 6 below.

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[14] "Quantifying Greenhouse Gas Emissions from Transit Draft Guidance". APTA.2008.

[15] The coefficients of 5.185 and 0.764 were from a study conducted by ICF based on all U.S transit (see section 3).

Equation 5: Average Rail and Bus Availability for Census Block Data Geocoded Addresses

$$\text{Av. Rail Availability} = \frac{1}{N}\sum_i \frac{1.223}{1+e^{2(d_i^r-0.75)}}$$

$$\text{Av. Bus Availability} = \frac{1}{N}\sum_i \frac{1.135}{1+e^{8(d_i^b-0.25)}}$$

Where:

N is the number of households in the sample

d_i^r and d_i^b are the distances to a rail station and bus line respectively for each household i in the sample

Equation 6: Average Rail and Bus Availability for Census Blocks

$$\text{Av. Rail Availability} = \frac{1}{N}\sum_i \frac{1.223\cdot p_i}{1+e^{2(d_i^r-0.75)}}$$

$$\text{Av. Bus Availability} = \frac{1}{N}\sum_i \frac{1.135\cdot p_i}{1+e^{8(d_i^b-0.25)}}$$

Where:

N is the number of census blocks in the region

p_i is the population of census block i

d_i^r and d_i^b are the distances to a rail station and bus line respectively from the centroid of census block i in the sample

Booz Allen calculated emissions reductions using both geocoded addresses and census blocks to investigate the differences in each method and the ease of estimating the average rail and bus availability. MTA provided 2,000 addresses of MTA patrons from a sampling of 14,000 that were included in a transit survey conducted for New York City. Booz Allen reviewed the data for errors and then geocoded these addresses using a combination of ESRI's ArcInfo and Streetmap (provided by MTA). Once the addresses were geocoded and mapped, Booz Allen randomly selected 1,000 addresses, as suggested by the APTA guidance.

According to the APTA guidance, at a distance of 0.25 miles from a bus stop and 0.75 miles from a rail station, there is a declining propensity for riders to use transit as distance increases. In the next step of the analysis, Booz Allen calculated the distances to bus stops and rail stations using geospatial analysis for both network and straight line paths of travel. A network distance is based on real life paths from the address to either the bus line or rail station (i.e., a pedestrian walking around buildings to a rail station or bus stop via sidewalks). A straight line distance is "as the crow flies" from the address to a bus stop or rail station (See Figure 7). Once the distances were calculated for both the network and straight line, Booz Allen then analyzed the results using ESRI's Network Analyst extension to determine which bus line and rail station were closest to an address based on the assumption that the rider will use the closest bus line or rail station. The distance for any address that met both criteria of being within 0.25 miles of a bus stop or 0.75 miles from a rail station, and was the shortest was carried forward in the analysis.

The difference between the network and straight line distance for any given bus line or rail station was not significant; however, the cumulative difference over the 1,000 sample population set resulted in the networked distance being about 25 percent greater than the straight-lined distance.

Figure 7: Straight Line Distance to Bus Stop or Rail Station

Booz Allen also calculated the network and straight line distances using a random sample of 1,000 census blocks within the MTA Region. The results show the network distance is approximately 25 percent higher than the distance calculated for using the straight line method.

Booz Allen used the total distance obtained for both the geocoded addresses and the census block data in equations 5 and 6 above to calculate the average rail and bus availability. Booz Allen then entered the results from those equations into Equation 4 to estimate the total GHG avoided due to the land-use multiplier; and scaled the emissions calculated for the random sample of 1,000 addresses or census blocks by the number of addresses in the sample (14,000) and the number of census blocks in the MTA Region (32,021) to obtain the total emissions for the land use multiplier. The results from the analysis are shown in Table 6.

Table 6: Emissions Avoided Due to Land-Use Multiplier

Source	Emissions Avoided 1000 Random Sample		Sample Size	Emissions Avoided Scaled to Sample Population	
	Networked (MT/yr)	Straight-line (MT/yr)		Networked (MT/yr)	Straight-line (MT/yr)
Geocoded	809	840	14,000	11,326	11,760
Census Block	158	167	32,021	5,059	5,348

Based on this analysis, Booz Allen determined:

- **The equation used to calculate emission reductions from land use contains coefficients that may not be appropriate for use in the MTA Region**. The coefficients used in Equation 4 (5.185 and 0.764) were derived as part of a national study. The study was based on nation-wide transit and may not accurately represent transit found in the MTA Region.
- **The methodology for calculating distances used in the Rail/Bus Availability equations is data/labor intensive.** Calculating straight-line and/or network distance for a sample of 1,000 households (or more) can be time consuming and costly, depending on the level of expertise available to a transit agency. Conducting the analysis to calculate the network and straight line distance used in the average rail and bus availability equations requires someone experienced in geospatial analysis and the necessary software.
- **Using a sample set of 1,000 census blocks or geocoded addresses may not accurately represent the transit region.** If high or low-density areas are not equally represented in the sample set, the land use results may be skewed. In addition, the sample size impacts total emissions when scaling from the random sample of 1,000 and also skew the results. For example, distances and average rail and bus availability would not change if the sample size were doubled. However, doubling the sample size would have a significant impact on the total emissions (i.e., 28,000/1,000) as compared to a sample size of 14,000 (i.e., 14,000/1,000).

Based on these conclusions, Booz Allen and MTA determined that the GIS method does not provide results that can be assessed with any level of certainty. Thus, Booz Allen discontinued use of this method and used the land-use comparison based approach to estimate the impact of land use.

b) Land Use Comparison Based Estimates

Under this approach Booz Allen estimated the impact of land use on GHG by comparing land use and travel behavior in areas with different land use patterns. Booz Allen implemented this methodology by taking a series of high density, high transit areas and comparing their travel behavior to low density, low transit areas. Specifically, for each region Booz Allen estimated the total number of unlinked transit trips and the average length of non-transit car and truck trips. We then estimated the GHG impacts using the approach shown in Equation 7. This equation produced a factor known as the transit efficiency multiplier. Booz Allen multiplies this factor by the overall mode shift in a scenario to estimate the impact of land use on total GHG.

Equation 7: Impact of Land Use on GHG Emissions

$$\Delta GHG = (\Phi D_L - \Phi D_H) \times N_D/Pcr \times \Phi C + (\Phi D_{ML} - \Phi D_{MH}) \times P_H / Pcr \times \Phi C + (\Phi D_L - \Phi D_T) \times N_T / Pcr \times \Phi C$$

Where:

ΔGHG = Change in GHG emissions

ΦD_L = Average distance per driver traveled by personal vehicle in low density/transit area (based on the RTFM or HMPS depending on the scenario)

ΦD_H = Average distance per driver traveled by personal vehicle in high density/transit area (based on the RTFM or HMPS depending on the scenario)

N_D: Number of Drivers

Pcr = Average passengers per car (1.17)[16]

ΦC = Average consumption per vehicle as estimated by EPA[17]

ΦD_{ML} : Average per capita non-motorized distance in a high density/transit area

ΦD_{ML} : Average per capita non-motorized distance in a low density/transit area

P_H : Total population of the high density/transit area

ΦD_T : Average trip distance in transit

N_T : Total number of transit trips

Initial estimates using this approach showed that radically different results could be obtained depending on the areas compared. Specifically, when Booz Allen compared very high density areas (e.g., Manhattan) to extremely low density areas (e.g., Long Island), we obtained very different results. Thus, Booz Allen made a series of different comparisons, which allowed us to explore a range of potential impacts and examine how land use and VMT varied. These included:

- The five boroughs of New York City to the suburban counties of Dutchess, Nassau, Orange, Putnam, Rockland, Suffolk and Westchester
- MTA Region to the U.S.
- NYC to the U.S.
- Manhattan to the suburban counties of Dutchess, Nassau, Orange, Putnam, Rockland, Suffolk and Westchester
- Manhattan to an average city in the U.S.
- Manhattan to an emerging southern transit city (e.g., Atlanta).

C. Results of Scenario Analyses

1. "No-MTA" Scenario

Under this scenario, Booz Allen assumed that MTA ceases service (or never developed) and all the transit riders utilize personal vehicles to complete their trip. This scenario was developed as a counter-factual to attempt to answer the question, "What is the impact of MTA on GHG in the region?" Without MTA, Booz Allen assumed that the MTA region would either sprawl to resemble a western city or increase the density of inner MTA road networks to become a high-density car transport city. In either case, the impact of not having MTA would be an increase in the number of cars and trucks and an increase in VMT. While neither of these two scenarios is realistic, by considering them, Booz Allen was able to estimate the overall contribution that MTA

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[16] "Transportation Energy Data Book". U.S. Department of Energy at http://cta.ornl.gov/data/download27.shtml.

[17] See "Emission Facts: Average Annual Emissions and Fuel Consumption for Passenger Cars and Light Trucks" U.S. EPA at http://www.epa.gov/oms/consumer/f00013.htm.

makes to reducing GHG (i.e., without MTA, what would GHG emissions be if people drove rather than used public transit?).

As noted above, the impact of public transit on GHG emissions depends on the assumptions that are made concerning how land use would change in the absence of public transit. Thus, in order to capture the range of potential impacts, Booz Allen calculated the impacts using a variety of different methods.[18] Specifically:

- **Method 1, MTA-wide analysis:** Compared the entire MTA Region to areas with different land use
- **Method 2, New York City analysis:** Compared New York City only to areas with different land use
- **Method 3, Manhattan-only analysis:** Compared the densely-develop Manhattan area to less dense areas.

For each method, Booz Allen took the number of public transit trips and assumed that these individuals would shift to motorized and non-motorized trips (in proportions generated by the RTFM). Booz Allen then assumed that in the absence of MTA, land use would change to resemble less dense areas (e.g., suburban New York and New Jersey). Thus, we assumed that the average length of trips would be equivalent to trips in that area. That is, without MTA, not only would the number of trips increase, but the length of those trips would increase as dense development would no longer be possible.[19] In addition, the impact of congestion was also considered for these new hypothetical areas.

For each of the three methods Booz Allen estimated impacts for three different approaches:

- **Approach 1:** Assumes that the most dense parts of the MTA region (Manhattan, Kings, Queens and Bronx counties) resemble suburban New York and New Jersey, if MTA never existed. Thus, Booz Allen calculated multipliers using suburban land use patterns.
- **Approach 2:** Assumes that the entire MTA region resembles the average county or city in the United States. Thus, Booz Allen calculated multipliers using typical U.S. land use patterns.
- **Approach 3:** Assume the entire MTA region comes to resemble the land use patterns of an emerging Southern transit city (i.e., Atlanta).

As can be seen, these approaches differed in terms of land use. By pairing them with the original land use, Booz Allen was able to estimate what would happen if, for example, the whole MTA (Method 1) came to have land use like Suburban New York and New Jersey (Approach 1) or Manhattan (Method 3) came to resemble an emerging transit city (Approach 3). Figure 8 shows an example of this logic.

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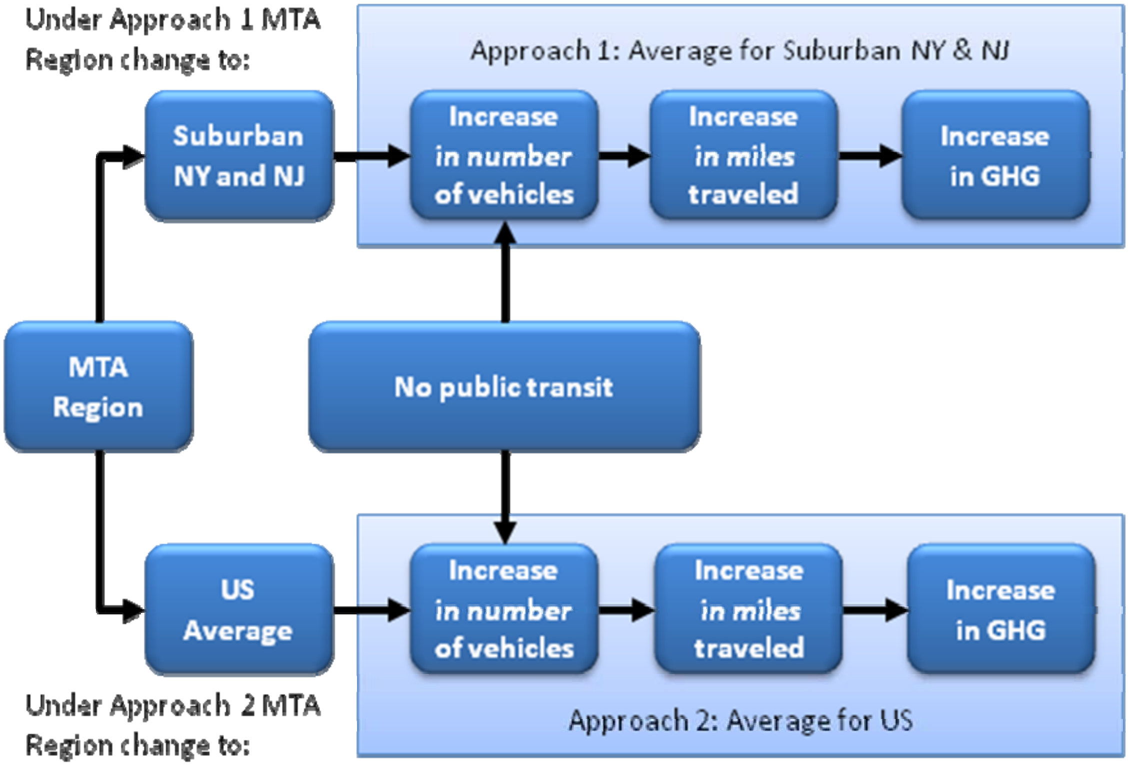
[18] Appendix 1 shows the assumptions for each analysis and provides our detailed calculations.

[19] The average length of private vehicle trips was also expanded to match the length in the less dense area.

Figure 8: Sample Land Use Calculation



Tables 7 and 8 below show the result of this analysis. The impact of land use varies from 1.24 to 6.40 depending on the assumptions made. The total multipliers (including land use, mode shift and congestion) vary from 5.93 to 19.44. However, the effects of mode choice and congestion cannot be obtained from the difference of Tables 7 and 8, as the two factors have different denominators. This analysis illustrates the sensitivity of the analysis to different land use assumptions. For example, if we assume that in the absence of MTA, the entire MTA area would come to look like the suburban counties of Dutchess, Nassau, Orange, Putnam, Rockland, Suffolk and Westchester, then the multiplier will be 5.93 (i.e., 2.88 (land use) plus 3.05 (mode shift and congestion)). In contrast, if we assume that in the absence of MTA, Manhattan would come to look like an emerging transit city like Atlanta then the multiplier would be 19.44 (i.e., 16.32 (land use) plus 3.09 (mode shift and congestion)). As we are dealing with counter-factuals (i.e., what would happen if MTA did not exist), it is extremely difficult to determine what is the most credible alternative. However, based on these analyses it seems that the land use multiplier is between 1.24 and 6.40.

Table 7: Estimated Impacts of "No MTA" Scenario (Compared to Suburban New York and New Jersey)

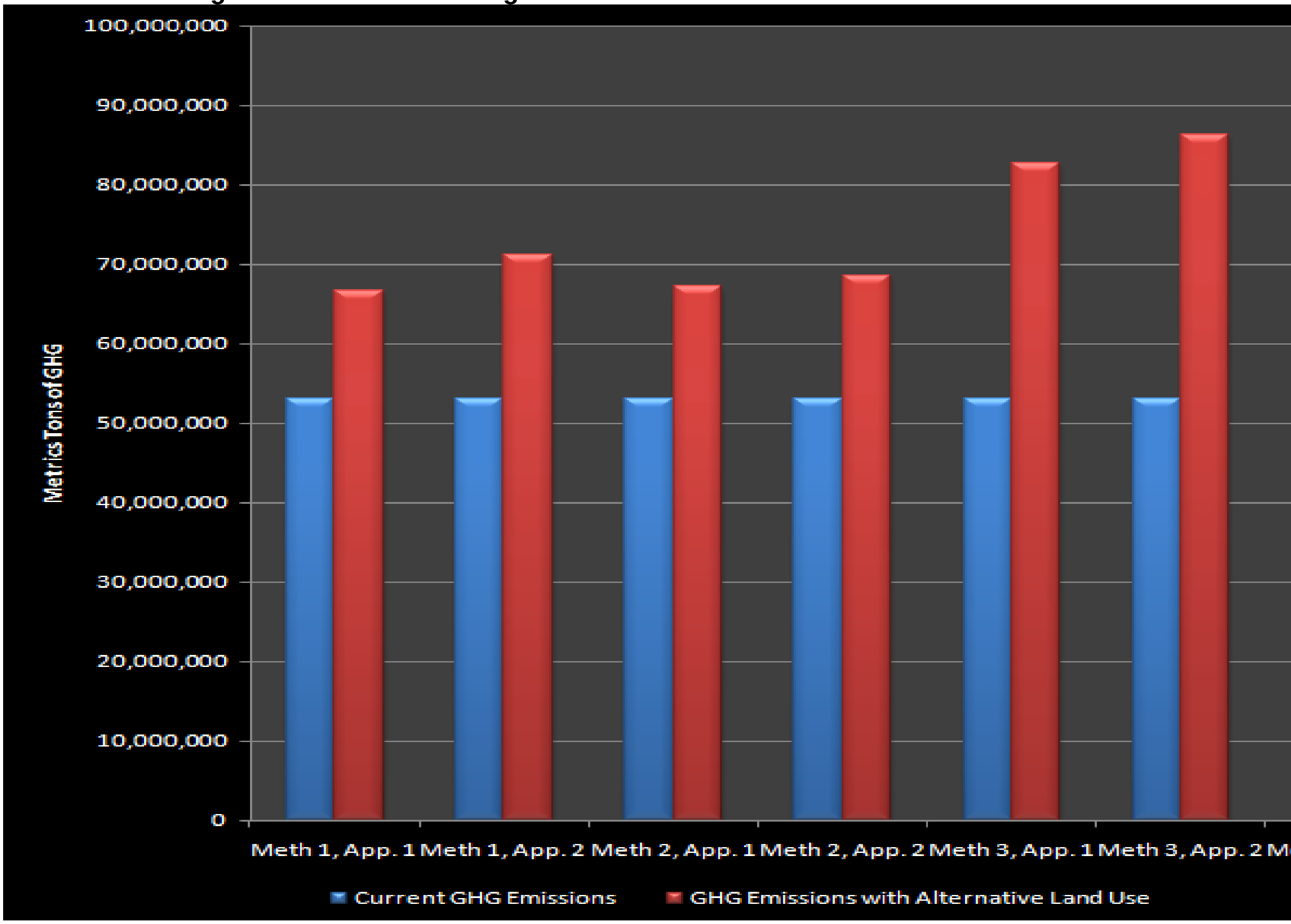
	Method 1		Method 2		Method 3		
	App. 1	App. 2	App. 1	App. 2	App. 1	App. 2	App. 3
Transit Eff. Multiplier	5.93	7.90	6.60	7.22	13.74	15.37	19.44

Table 8: Estimated Land Use Multiplier of "No MTA" Scenario (Compared to US Average)

	Method 1		Method 2		Method 3		
	App. 1	App. 2	App. 1	App. 2	App. 1	App. 2	App. 3
Transit Eff. Multiplier	1.24	2.09	1.41	1.65	4.13	4.76	6.40

Figure 9 below applies these factors to 2010 estimated GHG emissions. As can be seen, GHG emissions would increase by between 13 million and 41 million MT of GHG. This would amount to an increase of between 20 and 44 percent.

Figure 9: Estimated Change in GHG Emissions with No MTA

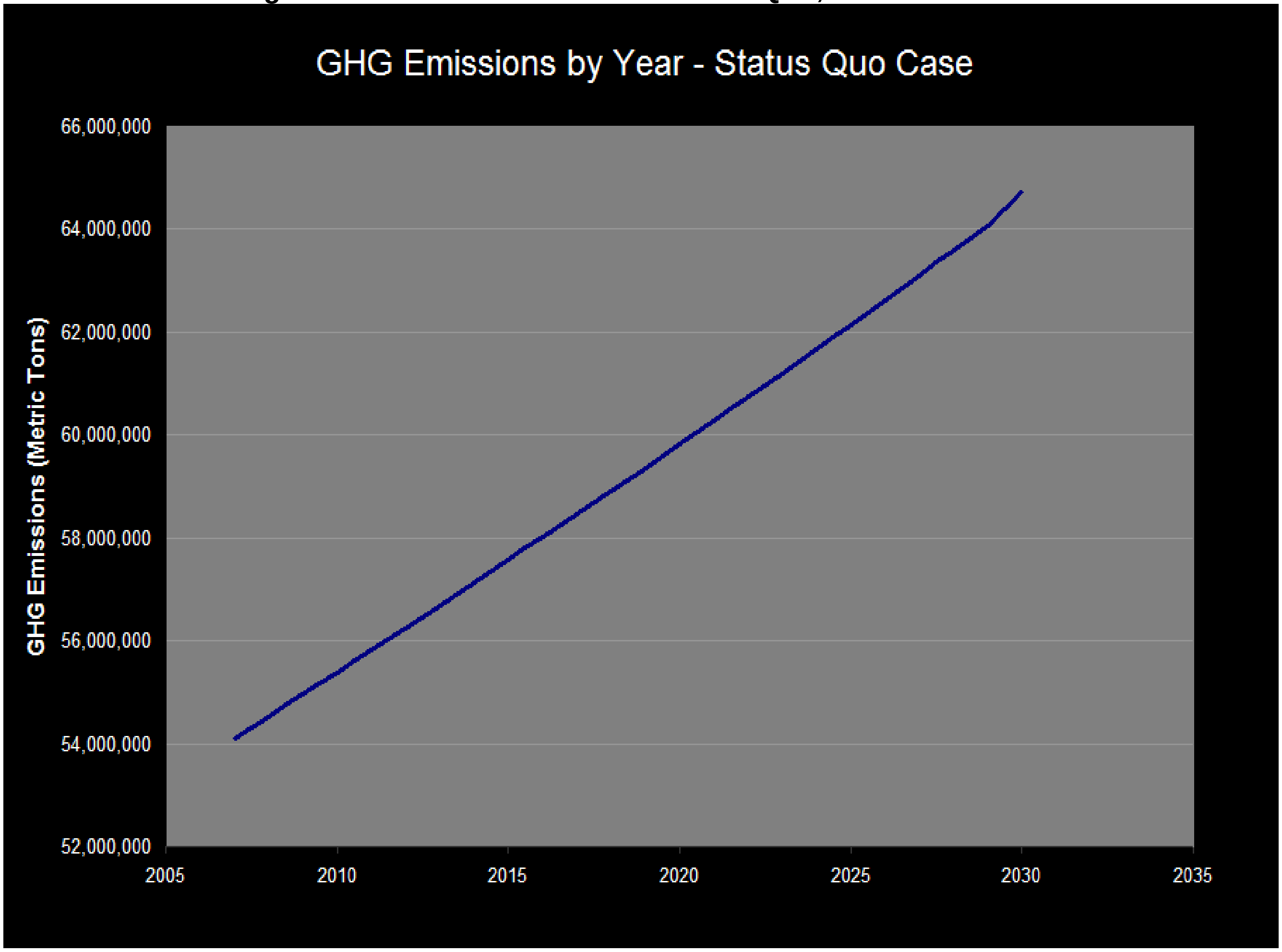


a) Status Quo Investment Case

Figure 10 shows the “Status-Quo” investment scenario. In this scenario, Booz Allen assumed that MTA invests in transit only enough to maintain current levels of service. The status quo investment is executed for the year 2030 by assuming that every new resident in the MTA region from 2006 to 2030 uses an automobile to complete his or her trip. Booz Allen derived the 2030 trip tables from the population and Journey to Work forecasts prepared by the New York Metropolitan Transportation Council (NYMTC). Booz Allen calculated the automobile vehicle miles traveled in the year 2030 from the mode choice module of the RTFM.

It can be concluded that no expansion of service results in an additional 11 million MT of GHG emissions per year in 2030. It should be noted that this is the additional annual greenhouse gas emissions per year in 2030 due to no expansion of service and not the cumulative increase in emissions from 2006 to 2030. The cumulative increase in emissions from 2006 to 2030 is the sum of the annual increase in emissions every year from 2006 to 2030. By repeating the method outlined above every year, the total cumulative emissions from 2006 to 2030 due to no expansion of service is approximately 133 million MT .

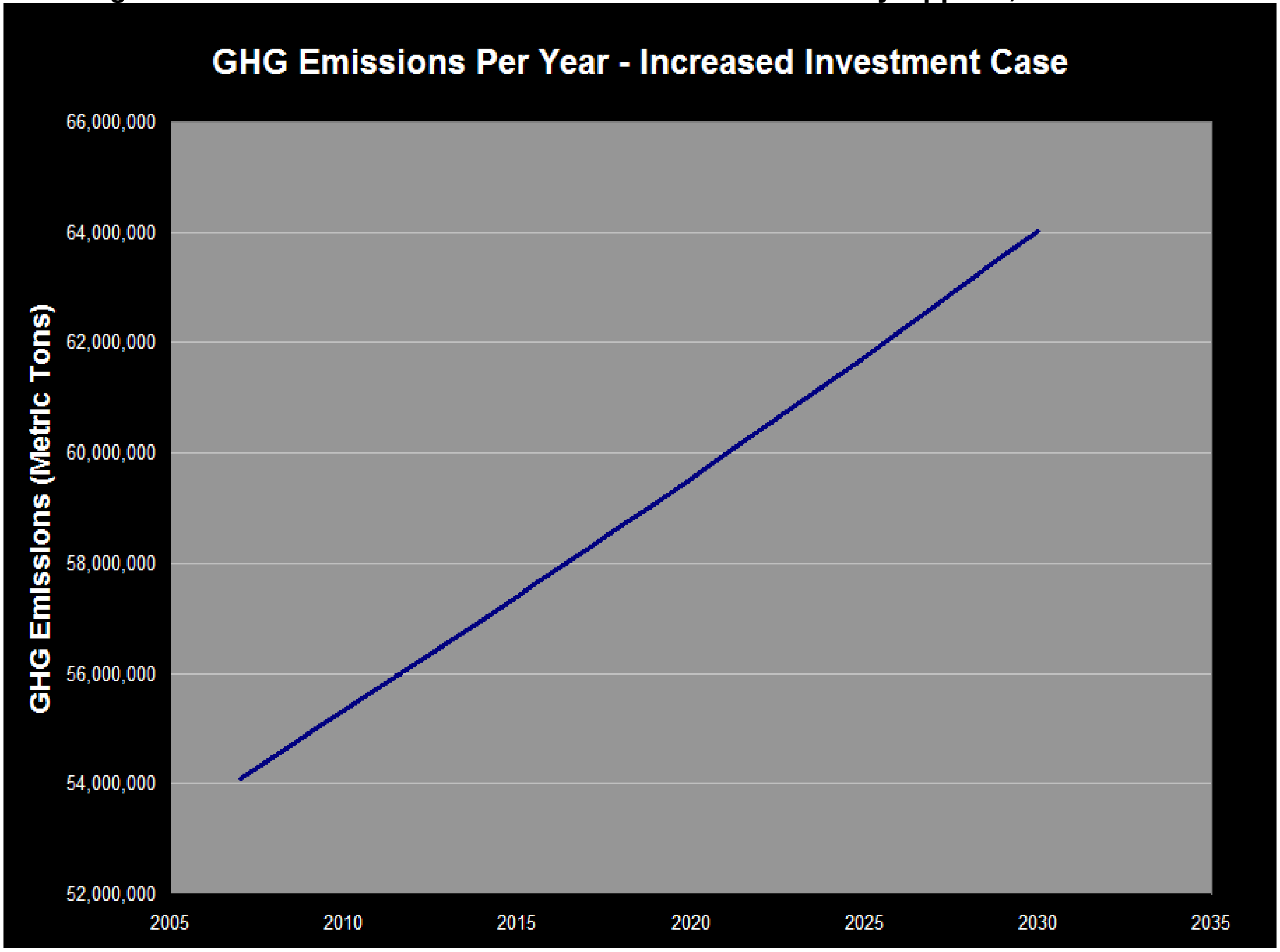
Figure 10: GHG Emissions with Status Quo, 2010-2030



b) Increased Investment Scenario (Uniformly Applied)

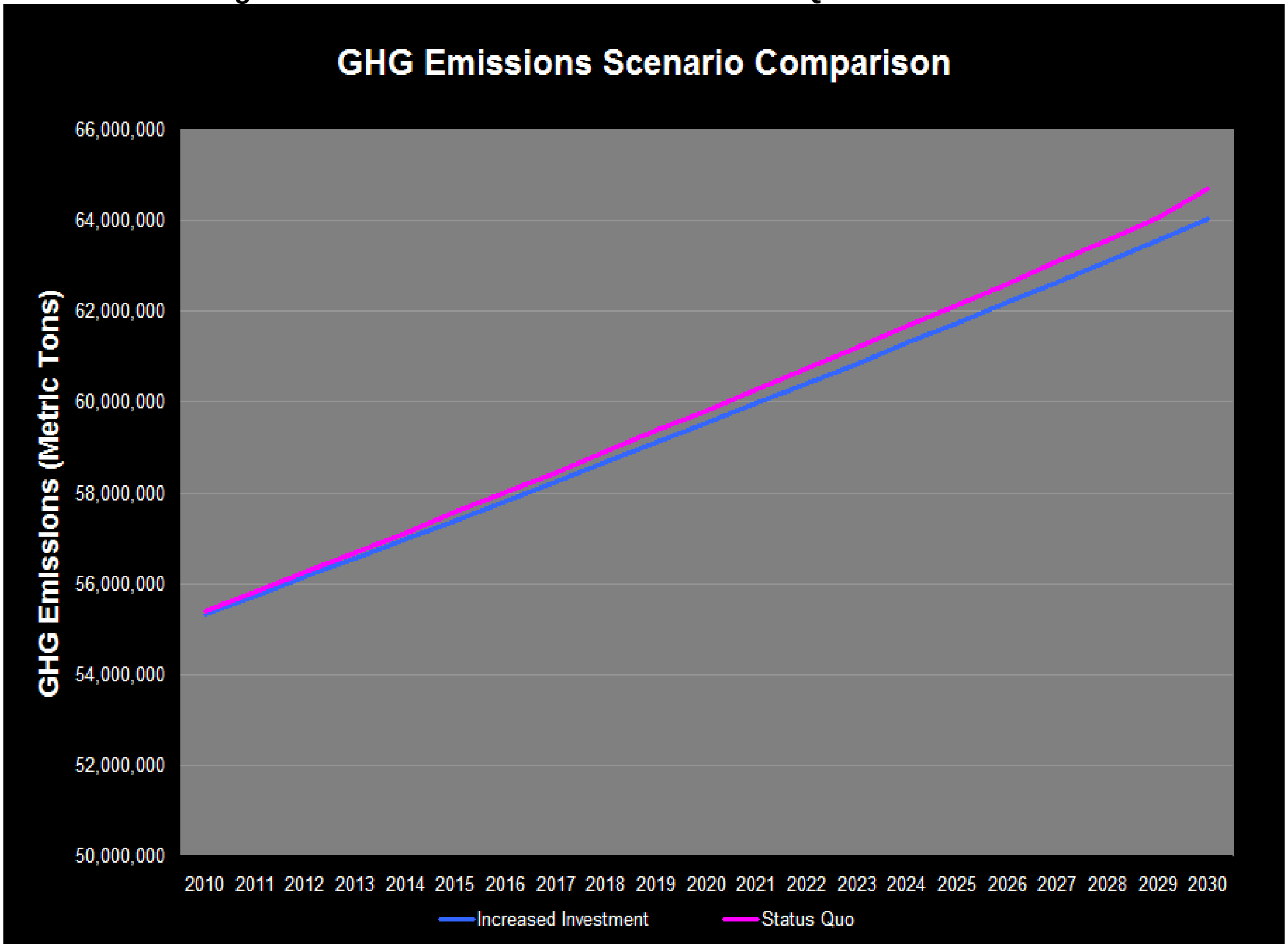
Figure 11 shows the increased investment scenario. In this case, Booz Allen assumed that the investment is uniform over the entire MTA operating area. The investment would be a capacity increase of the existing system. Scenarios that evaluated specific new stations or lines were not evaluated because these types of scenarios would require a re-execution of the network building module of the RTFM.

Figure 11: Emissions with Increased Investment Uniformly Applied, 2010-2030



When compared to the Status Quo Scenario, we see that there are minimal impacts from a uniform investment in MTA (Figure 12). This is not unexpected since a uniform investment does not address the areas of greatest potential ridership growth. A better scenario would be the evaluation of a specific improvement to the system, such as a new rail line or bus rapid transit in the areas of the system with very little current service but high potential growth. If investments were concentrated in the areas where it could make a major difference (e.g., in low transit land use area), research would tell us that we would expect it to produce major impacts on GHG. However, by spreading the investment around the whole system (including areas that are already well served by transit and where there is little opportunity to mode shift), the overall impact of the investment is diluted. More detailed analyses that focuses on where and how increased investment was to be used would show a much larger effect on GHG emissions.

Figure 12: Increased Investment and Status Quo Scenarios



D. Conclusions and Findings

Based on the analyses presented in this study, Booz Allen has concluded the following:

- **Without MTA, the MTA operating region's GHG emissions would be approximately 30 percent greater.** MTA reduces congestion, allows individuals to use public transportation rather than private vehicles, and permits the New York region to maintain a compact, dense land use pattern. Without the MTA, we estimate that GHG emissions from the entire MTA Region could be approximately 30 percent greater (and possible as high as 70 percent greater depending on the assumptions on how land use would change in response to the absence of the MTA).
- **Without MTA, the total GHG generated by individuals currently using MTA would be approximately eight times greater.** We estimate that the entire MTA system currently generates approximately 2.3 million tons of GHG per year - compared to private motor vehicles which produce 53 million tons per year in the MTA region or more than 24 times as much GHG. Without the MTA, we estimate that the impact of changing land use to accommodate more cars and increased congestion, would increase from current MTA passengers by approximately eight times (i.e., mode shift factor of 2.31, congestion factor of 0.73, and land use factor of 4.85). This means that MTA

passengers would go from generating 2.3 million tons of GHG to more than 18 million tons per year. This is a conservative case and assumes that without MTA New York would come to resemble the average US city. Under some assumptions (e.g., if the MTA Region sprawled to look like a Sunbelt City), emissions from current MTA passengers could be as much as 19 times greater than the current 2 million tons of GHG.

- **MTA saves 18 million tons of GHG:** Without MTA, GHG emissions could be more than 18 million tons per year – equivalent to removing more than 3 million cars per year – or more than 25 percent greater than current GHG emissions. This is as conservative estimate that assumes that, without MTA, the region could have sprawled to look like the average U.S. land use. If the MTA Region became even more like low public transport, car-based cities, savings could be as high as 44 million tons per year.
- **The land use factor makes a critical contribution to GHG savings:** MTA allows more dense land use to develop. This is a key contribution to achieving GHG savings. Booz Allen estimated that more dense land use contributes approximately 62 percent of the direct impact on GHG emissions.
- **Status quo scenario:** If MTA maintains a state of good repair but does not expand the system to account for population growth, the region will generate an additional 11 million MT of GHG emissions in 2030 or a total of approximately 138 million MT between 2010 and 2030.
- **The APTA approach is a good basis for estimating GHG emissions, but additional work is needed to define key parameters:** APTA's approach to estimating GHG impacts provide a solid foundation for estimating GHG impacts. However, Booz Allen's analysis shows that there is ambiguity in how key parameters (e.g., land use characterization, boundaries for high density and low density areas) should be estimated, primarily resulting from the lack of available data at levels that would allow a more accurate analysis. Additional work could be done to develop a standard method for estimating these parameters, and more guidance needs to be provided on how to define data inputs.
- **Land use multipliers are highly sensitive to assumption:** Booz Allen's analyses showed that land use impacts are highly sensitive to assumption. Guidance needs to be developed to define a standard approach to defining areas and identifying comparison groups.
- **Land use analysis is more applicable to small areas than large areas:** Land use varies greatly within large areas. For example, land use multipliers could vary between ~1.24 and ~6.40. Because of this, it is difficult to make generalizations about land use within a large area. Booz Allen recommends that future analyses attempt to conduct a more micro-scale analysis of land use in order to better capture its impacts on public transit.

Table 8: Impact of Land Use, Mode Shift, and Congestion Factors

	Minimum	Average	Maximum
Total Annual GHG Savings from Mode Choice (1,000 kg)	285,891	1,466,703	2,986,941
Total Annual GHG Savings from Congestion (1,000 kg)	101,137	614,286	1,634,794
Total Annual GHG Savings from Land Use (1,000 kg)	1,957,959	5,289,823	11,313,761

Appendix 1: Detailed Calculations

No MTA Case

In this scenario, the benefits from operating MTA are computed for entire MTA operating region. The benefits from mode choice and congestion are computed by assuming that all the passengers that currently use transit start to utilize their automobile upon cessation of transit service. However, the benefits from land use can be computed using two different methodologies. In the first method, it is assumed that the most dense part of the MTA region (Manhattan, Kings, Queens and Bronx counties) resemble suburban New York and New Jersey upon cessation of transit service. In the second method, the assumption is that the entire MTA region resembles the average county or city in the United States. Therefore, two land use multipliers and two transit efficiency multipliers are computed for Scenario 1.

Calculations:

1. Total Automobile Vehicle Miles (VMT) for the entire MTA region (2006) = 302,579,350.
2. Total Transit Passenger Miles (PMT) for the entire MTA region (2006) = 39,918,550.
3. Average Auto Occupancy in the entire MTA region = 1.17
4. Total Automobile Vehicle Miles for the entire MTA region in the absence of transit (2006) = 302,579,350 + 39,918,550/1.17 = 336,697,769
5. Excess fuel wasted from Congestion for the MTA Region (2006,Gallons) = 388,960,000
6. Excess fuel wasted from Congestion for the MTA Region for the no MTA case (2006, Gallons) = 584,007,000.
7. Total CO2e Emissions avoided due to Mode Choice (2006, Tons) = (Automobile CO2e , no MTA case – Automobile CO2e (2006)) = 5,404,576
8. Total CO2e Emissions avoided due to Congestion Relief = (584,007,000- 388,960,000) * 8.81 / 1,000 = 1,718,368 Tons

The land use benefits can be computed by either assuming that the dense regions of MTA would resemble the suburbia or that the entire MTA region would resemble an average town or city in the US, that lacks good transit service.

The land use benefits is derived from 1) Auto travelers driving less on account of denser development 2) Increased use of non-motorized modes of transport 3) Reduced trip lengths for transit riders.

Land Use Benefits from Method 1

1. Average Daily Driving Distance in the dense regions of MTA : 20.2 miles
2. Average Daily Driving Distance in the suburban regions of MTA : 36.7 miles
3. Total Drivers in the dense regions of MTA = 1,503,349.
4. Total Daily VMTs saved from reduced automobile driving distance = 24,805,258
5. Total Annual CO2e avoided from reduced automobile driving distance (2006,Tons) = 3,929,911
6. Average Per Capita Non-Motorized passenger miles in the dense regions of MTA = 0.53 miles
7. Average Per Capita Non-Motorized passenger miles in the suburban regions of MTA = 0.008 miles
8. Daily VMTs saved due to increase use of non-motorized modes of transport = 3,362,022

9. Total Annual CO2e avoided from increase use of non-motorized modes of transport (2006, Tons) = 532,565.
10. Total Daily Linked Transit Trips in MTA Region = 6,628,750
11. Average Transit Trip Length = 5.78 miles
12. Average Auto Trip length in the suburban regions = 8.3 miles
13. Auto Daily VMTs saved from transit ridership (in addition to the mode choice benefits) = 14,277,307
14. Total Annual CO2e avoided from transit (In addition to mode choice) (2006, Tons) = 2,261,616
15. Total CO2e avoided due to land use benefits = 3,929,911+ 532,565 + 2,261,616 = 6,723,495 MT.
16. Land Use Multiplier = Total CO2e avoided due to land use benefits / Total CO2e avoided due to mode choice benefits = 6,723,495 / 5,404,576 = 1.24
17. Transit Emissions Efficiency Multiplier = Total CO2e benefits from transit / Total CO2e emitted by transit = 5.93
18. Transit Emissions Efficiency Multiplier from Mode Choice = Total CO2e Emissions avoided due to Mode Choice / Total CO2e emitted by transit = 2.31
19. Transit Emissions Efficiency Multiplier from Congestion = Total CO2e Emissions avoided due to Congestion Relief / Total CO2e emitted by transit = 0.73
20. Transit Emissions Efficiency Multiplier from Land Use = Total CO2e avoided due to land use benefits / Total CO2e emitted by transit = 2.88

Land Use Benefits from Method 2

1. Average Daily Driving Distance in MTA region : 33 miles
2. Average Daily Driving Distance United States (except MTA region) : 40 miles
3. Total Drivers in MTA region = 7,683,292
4. Total Daily VMTs saved from reduced automobile driving distance = 7,683,292 * 7 = 53,783,044.
5. Total Annual CO2e avoided from reduced automobile driving distance (2006,Tons) = 8,519,578
6. The total annual CO2e saved from the two other two components remain the same
7. Total CO2e avoided due to land use benefits = 8,519,578 + 532,565 + 2,261,616 = 11,313,759 MT
8. Land Use Multiplier = Total CO2e avoided due to land use benefits / Total Automobile CO2e avoided due to mode choice benefits = 11,313,759 / 5,404,576 = 2.09
9. Transit Emissions Efficiency Multiplier = Total CO2e benefits from transit / Total CO2e emitted by transit = 7.90
10. Transit Emissions Efficiency Multiplier from Mode Choice = Total CO2e Emissions avoided due to Mode Choice / Total CO2e emitted by transit = 2.31
11. Transit Emissions Efficiency Multiplier from Congestion = Total CO2e Emissions avoided due to Congestion Relief / Total CO2e emitted by transit = 0.73
12. Transit Emissions Efficiency Multiplier from Land Use = Total CO2e avoided due to land use benefits / Total CO2e emitted by transit = 4.85

No MTA Case – Scenario 2

In this scenario, the benefits from operating MTA are computed for New York City only. The benefits from mode choice and congestion are computed by assuming that all the passengers that currently use transit start to utilize their automobile upon cessation of transit service. However, the benefits from land use can be computed using two different methodologies. In the first method, it is assumed that the most dense part of New York City (Manhattan, Kings, Queens and Bronx counties) resemble suburban New York and New Jersey upon cessation of transit service. In the second method, the assumption is that New York City resembles the average county or city in the United States. Therefore, two land use multipliers and two transit efficiency multipliers are computed for Scenario 1.

1. Total Automobile Vehicle Miles (VMT) for New York City (2006) = 41,028,947.
2. Total Transit Passenger Miles (PMT) for New York City (2006) = 28,365,108.
3. Average Auto Occupancy in the entire MTA region = 1.17
4. Total Automobile Vehicle Miles for the entire MTA region in the absence of transit (2006) = 41,028,947 + 28,365,108/1.17 = 65,272,629.
5. Excess fuel wasted from Congestion for the MTA Region (2006,Gallons) = 38,840,000.
6. Excess fuel wasted from Congestion for the MTA Region for the no MTA case (2006, Gallons) = 109,223,000.
7. Total CO2e Emissions avoided due to Mode Choice (2006, Tons) = (Automobile CO2e , no MTA case – Automobile CO2e (2006)) = 3,840,355
8. Total CO2e Emissions avoided due to Congestion Relief = (109,223,000- 38,840,000) * 8.81 / 1,000 = 620,074 Tons

A.1.2.1 Land Use Benefits from Method 1

1. Average Daily Driving Distance in the dense regions of New York City : 20.2 miles
2. Average Daily Driving Distance in the suburban regions: 36.7 miles
3. Total Drivers in the dense regions of New York City = 1,503,349.
4. Total Daily VMTs saved from reduced automobile driving distance = 24,805,258
5. Total Annual CO2e avoided from reduced automobile driving distance (2006,Tons) = 3,929,911
6. Average Per Capita Non-Motorized passenger miles in the dense regions of New York City = 0.53 miles
7. Average Per Capita Non-Motorized passenger miles in the suburban regions of MTA = 0.008 miles
8. Daily VMTs saved due to increase use of non-motorized modes of transport = 3,362,022
9. Total Annual CO2e avoided from increase use of non-motorized modes of transport (2006, Tons) = 532,565.
10. Total Daily Linked Transit Trips in New York City = 2,810,652
11. Average Transit Trip Length = 5.78 miles
12. Average Auto Trip length in the suburban regions = 8.3 miles
13. Auto Daily VMTs saved from transit ridership (in addition to the mode choice benefits) = 7,082,843
14. Total Annual CO2e avoided from transit (In addition to mode choice) (2006, Tons) = 958,946
15. Total CO2e avoided due to land use benefits = 3,929,911+ 532,565 + 958,946 = 5,420,823 MT.
16. Land Use Multiplier = Total CO2e avoided due to land use benefits / Total CO2e avoided due to mode choice benefits = 5,420,823 / 3,840,855 = 1.41
17. Transit Emissions Efficiency Multiplier = Total CO2e benefits from transit / Total CO2e emitted by transit = 6.60
18. Transit Emissions Efficiency Multiplier from Mode Choice = Total CO2e Emissions avoided due to Mode Choice / Total CO2e emitted by transit = 2.56
19. Transit Emissions Efficiency Multiplier from Congestion = Total CO2e Emissions avoided due to Congestion Relief / Total CO2e emitted by transit = 0.41

20. Transit Emissions Efficiency Multiplier from Land Use = Total CO2e avoided due to land use benefits / Total CO2e emitted by transit = 3.62

Land Use Benefits from Method 2

1. Average Daily Driving Distance in New York City : 20 miles
2. Average Daily Driving Distance United States (except the MTA region) : 40 miles
3. Total Drivers in the MTA region = 1,503,360
4. Total Daily VMTs saved from reduced automobile driving distance = 1,503,360 * 20 = 30,067,200.
5. Total Annual CO2e avoided from reduced automobile driving distance (2006,Tons) = 4,762,837
6. The total annual CO2e saved from the two other two components remain the same
7. Total CO2e avoided due to land use benefits = 4,762,837+ 523,565 + 958,946 = 6,254,350 MT
8. Land Use Multiplier = Total CO2e avoided due to land use benefits / Total Automobile CO2e avoided due to mode choice benefits = 6,254,350 / 3,840,355 = 1.65
9. Transit Emissions Efficiency Multiplier = Total CO2e benefits from transit / Total CO2e emitted by transit = 7.22
10. Transit Emissions Efficiency Multiplier from Mode Choice = Total CO2e Emissions avoided due to Mode Choice / Total CO2e emitted by transit = 2.56
11. Transit Emissions Efficiency Multiplier from Congestion = Total CO2e Emissions avoided due to Congestion Relief / Total CO2e emitted by transit = 0.41
12. Transit Emissions Efficiency Multiplier from Land Use = Total CO2e avoided due to land use benefits / Total CO2e emitted by transit = 4.24

No MTA Case – Scenario 3

In this scenario, the benefits from operating MTA are computed for Manhattan only. The benefits from mode choice and congestion are computed by assuming that all the passengers that currently use transit start to utilize their automobile upon cessation of transit service. However, the benefits from land use can be computed using two different methodologies. In the first method, it is assumed that Manhattan would resemble suburban New York and New Jersey upon cessation of transit service. In the second method, the assumption is that Manhattan resembles the average county or city in the United States. Therefore, two land use multipliers and two transit efficiency multipliers are computed for Scenario 1.

1. Total Automobile Vehicle Miles (VMT) for Manhattan (2006) = 7,785,718.
2. Total Transit Passenger Miles (PMT) for Manhattan (2006) = 9,109,290.
3. Average Auto Occupancy in the entire MTA region = 1.17
4. Total Automobile Vehicle Miles for Manhattan in the absence of transit (2006) = 7,785,718 + 3,502,700/1.17 = 10,779,479.
5. Excess fuel wasted from Congestion for Manhattan (2006,Gallons) =8,951,000.
6. Excess fuel wasted from Congestion for Manhattan for the no MTA case (2006, Gallons) = 20,431,000.
7. Total CO2e Emissions avoided due to Mode Choice (2006, Tons) = (Automobile CO2e , no MTA case – Automobile CO2e (2006)) = 474,231 Tons
8. Total CO2e Emissions avoided due to Congestion Relief = (20,431,000- 8,951,000) * 8.81 / 1,000 = 101,137 Tons

Land Use Benefits from Method 1

1. Average Daily Driving Distance in the Manhattan: 20.2 miles
2. Average Daily Driving Distance in the suburban regions of MTA : 36.7 miles
3. Total Drivers in Manhattan= 474,139.
4. Total Daily VMTs saved from reduced automobile driving distance = 7,586,224
5. Total Annual CO2e avoided from reduced automobile driving distance (2006,Tons) = 1,201,706
6. Average Per Capita Non-Motorized passenger miles in Manhattan = 0.53 miles
7. Average Per Capita Non-Motorized passenger miles in the dense regions of MTA = 0.008 miles
8. Daily VMTs saved due to increase use of non-motorized modes of transport = 683,197
9. Total Annual CO2e avoided from increase use of non-motorized modes of transport (2006, Tons) = 126,620
10. Total Daily Linked Transit Trips in Manhattan = 1,845,438
11. Average Transit Trip Length = 5.78 miles
12. Average Auto Trip length in the suburban regions = 8.3 miles
13. Auto Daily VMTs saved from transit ridership (in addition to the mode choice benefits) = 3,974,789
14. Total Annual CO2e avoided from transit (In addition to mode choice) (2006, Tons) = 629,632
15. Total CO2e avoided due to land use benefits = 1,201,706+ 126,620+ 629,632 = 1,957,959 MT.
16. Land Use Multiplier = Total CO2e avoided due to land use benefits / Total CO2e avoided due to mode choice benefits = 1,957,959 / 474,231 = 4.13
17. Transit Emissions Efficiency Multiplier = Total CO2e benefits from transit / Total CO2e emitted by transit = 13.74
18. Transit Emissions Efficiency Multiplier from Mode Choice = Total CO2e Emissions avoided due to Mode Choice / Total CO2e emitted by transit = 2.57
19. Transit Emissions Efficiency Multiplier from Congestion = Total CO2e Emissions avoided due to Congestion Relief / Total CO2e emitted by transit = 0.54
20. Transit Emissions Efficiency Multiplier from Land Use = Total CO2e avoided due to land use benefits / Total CO2e emitted by transit = 10.62

A.1.3.2 Land Use Benefits from Method 2

1. Average Daily Driving Distance in Manhattan : 20 miles
2. Average Daily Driving Distance United States (except the MTA region) : 40 miles
3. Total Drivers in Manhattan = 474,139
4. Total Daily VMTs saved from reduced automobile driving distance = 474,139 * 20 = 9,482,780.
5. Total Annual CO2e avoided from reduced automobile driving distance (2006,Tons) = 1,502,133
6. The total annual CO2e saved from the two other two components remain the same
7. Total CO2e avoided due to land use benefits = 1,502,133+ 126,620+ 629,632 = 2,258,385 MT
8. Land Use Multiplier = Total CO2e avoided due to land use benefits / Total Automobile CO2e avoided due to mode choice benefits = 2,258,385 / 474,231 = 4.76
9. Transit Emissions Efficiency Multiplier = Total CO2e benefits from transit / Total CO2e emitted by transit = 15.37

10. Transit Emissions Efficiency Multiplier from Mode Choice = Total CO2e Emissions avoided due to Mode Choice / Total CO2e emitted by transit = 2.56
11. Transit Emissions Efficiency Multiplier from Congestion = Total CO2e Emissions avoided due to Congestion Relief / Total CO2e emitted by transit = 0.41
12. Transit Emissions Efficiency Multiplier from Land Use = Total CO2e avoided due to land use benefits / Total CO2e emitted by transit = 12.25

Land Use Benefits from Method 3

1. Average Daily Driving Distance in Manhattan: 20 miles
2. Average Daily Driving Distance in Atlanta: 50 miles
3. Total Drivers in Manhattan = 474,139
4. Total Daily VMTs saved from reduced automobile driving distance = 474,139 * 30 = 14,224,170.
5. Total Annual CO2e avoided from reduced automobile driving distance (2006,Tons) = 2,253,199
6. Total CO2e avoided due to land use benefits = 1,502,133+ 126,620+ 629,632 = 3,009,453 MT
7. Land Use Multiplier = Total CO2e avoided due to land use benefits / Total Automobile CO2e avoided due to mode choice benefits = 3,009,453 / 474,231 = 6.34
8. Transit Emissions Efficiency Multiplier = Total CO2e benefits from transit / Total CO2e emitted by transit = 19.44
9. Transit Emissions Efficiency Multiplier from Mode Choice = Total CO2e Emissions avoided due to Mode Choice / Total CO2e emitted by transit = 2.56
10. Transit Emissions Efficiency Multiplier from Congestion = Total CO2e Emissions avoided due to Congestion Relief / Total CO2e emitted by transit = 0.41
11. Transit Emissions Efficiency Multiplier from Land Use = Total CO2e avoided due to land use benefits / Total CO2e emitted by transit = 16.32

Status Quo Investment Case

In this scenario, it is assumed that MTA does not invest in transit, therefore transit capacity does not keep pace with increasing demand and transit is not considered to be a viable travel choice for any new travelers. The status quo investment is executed for the year 2030 by assuming that every new resident in the MTA region from 2006 to 2030 uses an automobile to complete his trip. The 2030 trip tables are derived from the population and Journey to Work forecasts prepared by the New York Metropolitan Transportation Council (NYMTC). The automobile vehicle miles traveled in the year 2030, were calculated from the mode choice module of the Regional Transit Forecasting Model (RTFM).

1. Total Population of the MTA Region in 2030 = 23,643,160.
2. Total Automobile Vehicle Miles Traveled in the MTA Region in 2030 = 353,945,197.
3. Total Automobile Person Miles Traveled in the MTA Region in 2030 = 413,324,096.

4. Greenhouse Gas emissions from automobile trips = 56,067,186 MT
5. Greenhouse Gas emissions due to congestion = 6,318,655 MT
6. Greenhouse Gas emissions from transit = 2,331,609 MT
7. Total Greenhouse Gas emissions in the MTA region in 2030 = 56,067,186 + 6,318,655 + 2,331,609 = 64,717,450 MT.
8. Total Greenhouse Gas emissions in the MTA region in 2006 = 53,688,851 MT.

9. Increase in Greenhouse Gas emissions from 2006 to 2030 due to lack of transit investment = 64,717,450- 53,688,851 = 11,028,599 MT.

LIST OF ACRONYMS

Acronym	Definition
APTA	American Public Transportation Association
B5	5 percent biodiesel
B20	20 percent biodiesel
CH_4	methane
CLEAN-TEA	The Clean, Low-Emission, Affordable, New Transportation Efficiency Act
CNG	compressed natural gas
CO_2	carbon dioxide
CO2e	carbon dioxide equivalents
CR	commuter rail
E85	85 percent ethanol
EIA	Energy Information Administration
GHG	greenhouse gas
GWP	global warming potential
HOV	high-occupancy vehicle
HPMS	Highway Performance Monitoring System
LIPA	Long Island Power Authority
LU	land use
MTA	Metropolitan Transportation Authority
N_2O	nitrous oxide
NYMTC	New York Metropolitan Transportation Council
NYPA	New York Power Authority
PMT	passenger miles traveled
RTFM	Regional Transit Forecasting Model
SEM	structural equation modeling
SOV	single-occupancy vehicle
TCR	The Climate Registry
TTI	Texas Transportation Institute
Tg	teragrams
VMT	vehicle miles traveled

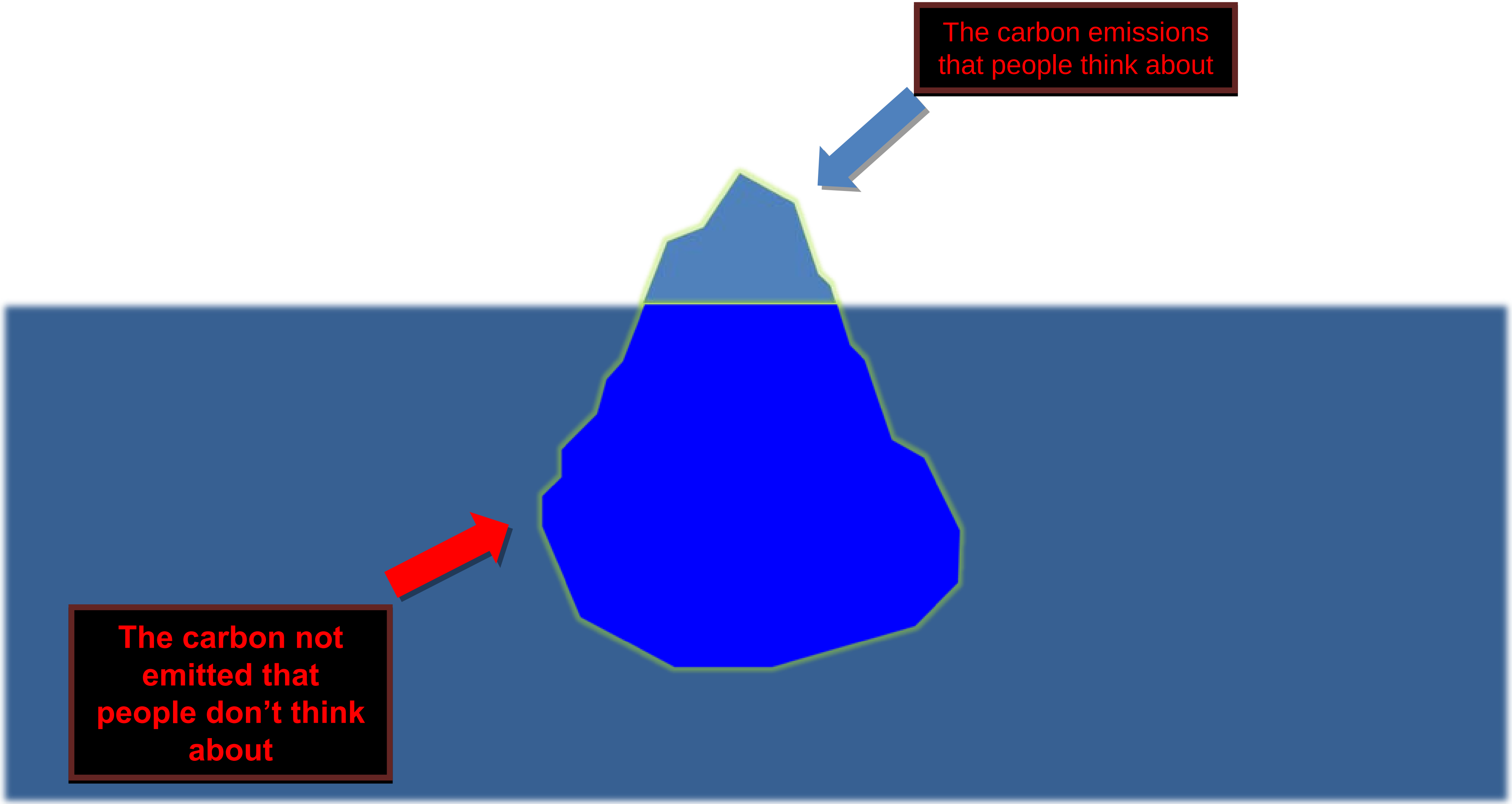
Booz | Allen | Hamilton

Carbon Displacement Modeling for New York Metropolitan Transportation Authority

Application of APTA Approach

December 11, 2009

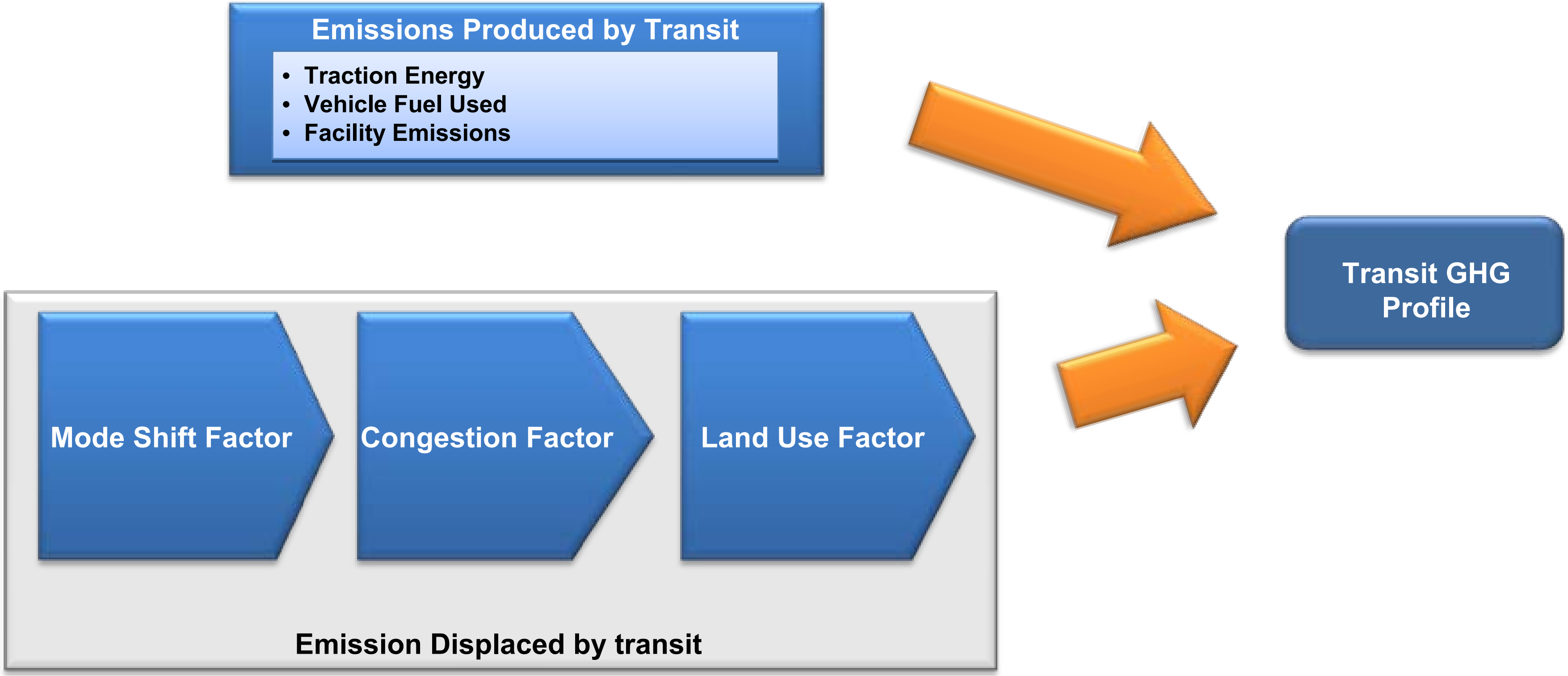
There is little recognition of the true carbon picture for public transit, particularly the benefits that are hidden under the surface



The carbon emissions that people think about

The carbon not emitted that people don't think about

The APTA Climate Change Working Group developed an innovative approach to evaluating the GHG emission from transit as well as the emissions not generated as a result of transit



Emissions Produced by Transit

- Traction Energy
- Vehicle Fuel Used
- Facility Emissions

Mode Shift Factor

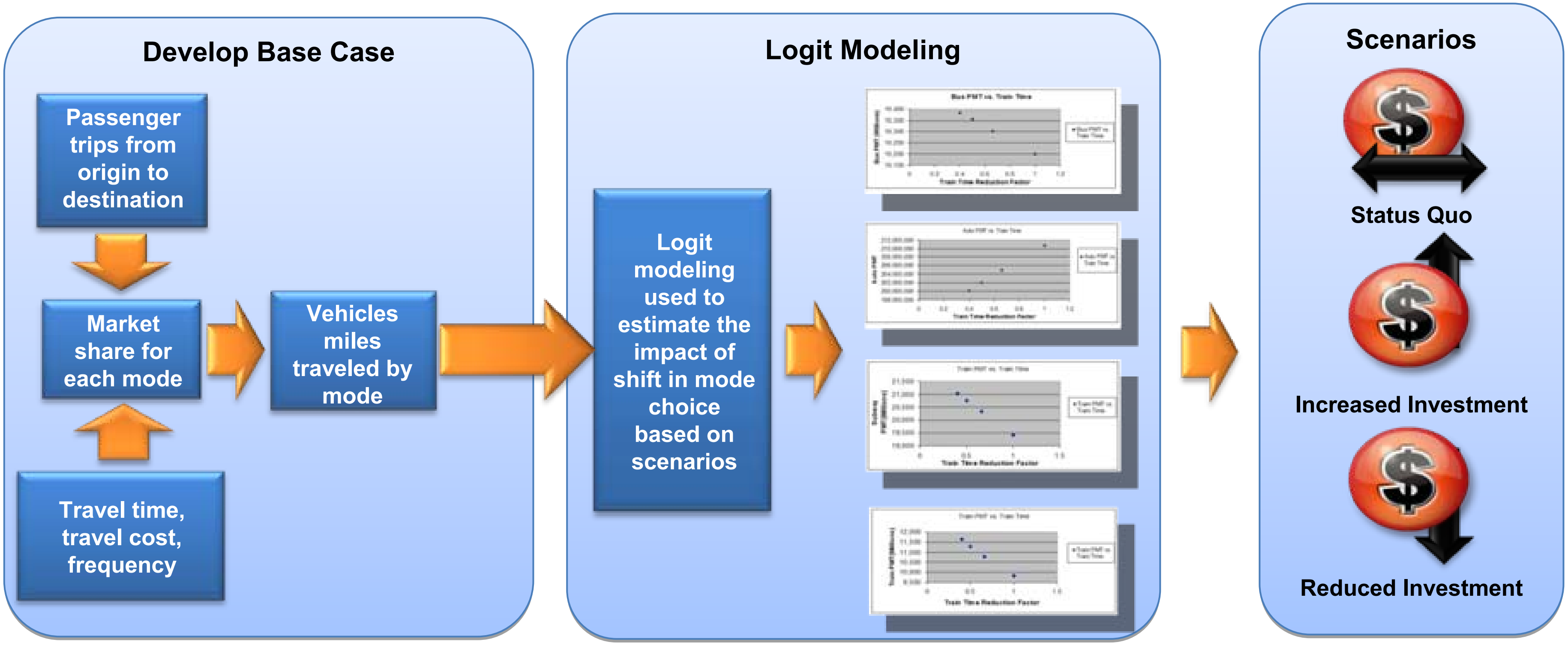
Congestion Factor

Land Use Factor

Emission Displaced by transit

Transit GHG Profile

Mode Shift Factor estimates the impact of moving trips from private auto to transit and the resulting reduction in carbon emissions



Develop Base Case

Passenger trips from origin to destination

Market share for each mode

Travel time, travel cost, frequency

Vehicles miles traveled by mode

Logit Modeling

Logit modeling used to estimate the impact of shift in mode choice based on scenarios

Scenarios

Status Quo

Increased Investment

Reduced Investment

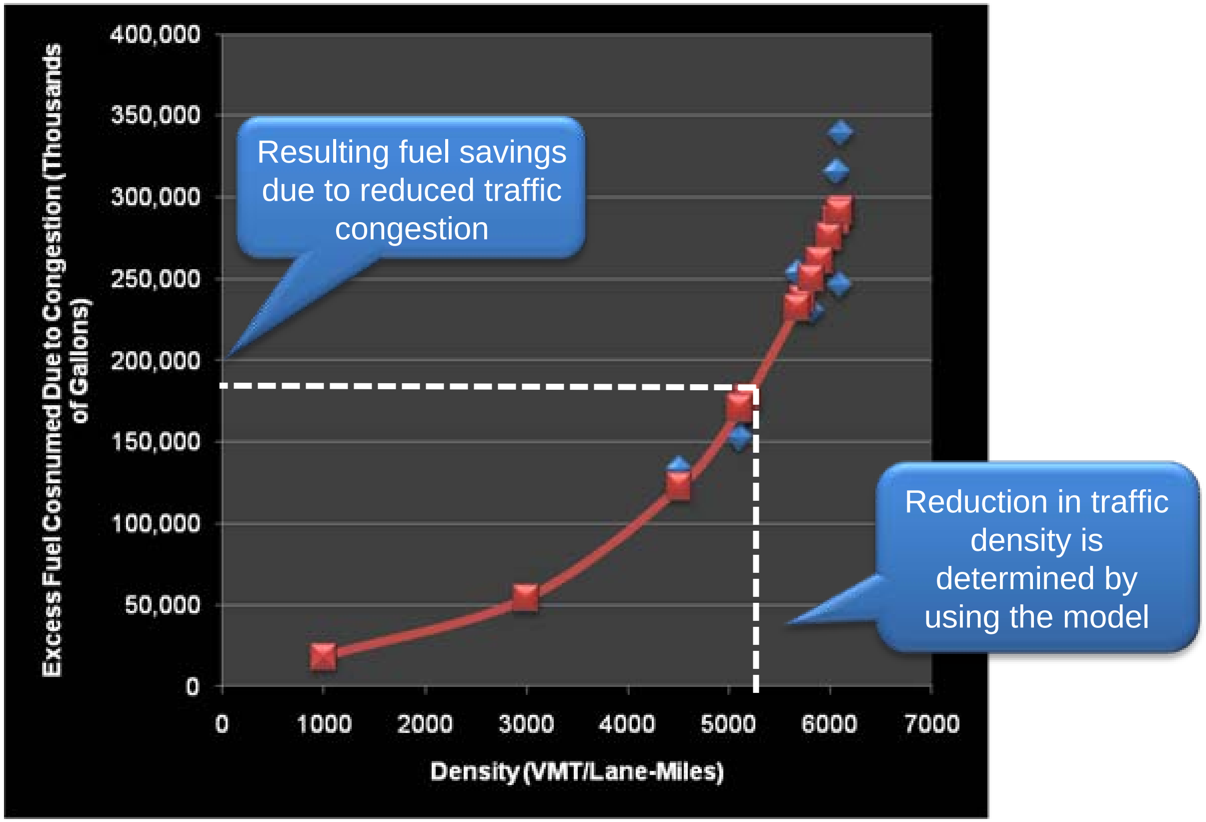
VMT/PMT is calculated using a passenger choice model – the output of the model is VMT/PMT by mode based on changes in demand

Estimates from running the Mode Shift Model show the willingness of automobile travelers to shift to transit. Changes are converted to carbon emission reductions using standard conversion factors.

Mode shift curves can be used to develop different scenarios based on investment priorities

Congestion Factor estimates the impact of transit on reducing overall congestion and associated carbon emissions

Congestion impacts are estimated by using TTI data specific to the region



Resulting fuel savings due to reduced traffic congestion

Reduction in traffic density is determined by using the model

Land Use Factor estimates the benefits that transit creates by allowing more dense development

APTA guidance includes three approaches for estimating the land use impacts on GHG emissions:

Regional Transportation Models & Studies

Regional GIS Study

Average Land Use Impact Multiplier (1.9)

Land use analysis using geospatial analysis

- GIS Spatial Approach:
  - Use a random sample of 1,000 households and 1,000 Census Blocks and evaluate straightline and network distances to transit
  - Apply nonlinear equations from APTA study to calculate a land use multiplier

Based on this analysis, the land use multiplier for the MTA region was around 1.8

Bus

Rail

Land Use analysis using regional models and survey data

- VMT reduction from land use
  - VMT saved from driving less because of dense development
  - VMT saved by non-motorized trips
  - VMT saved by transit riders because of dense development
- The land use multiplier is:

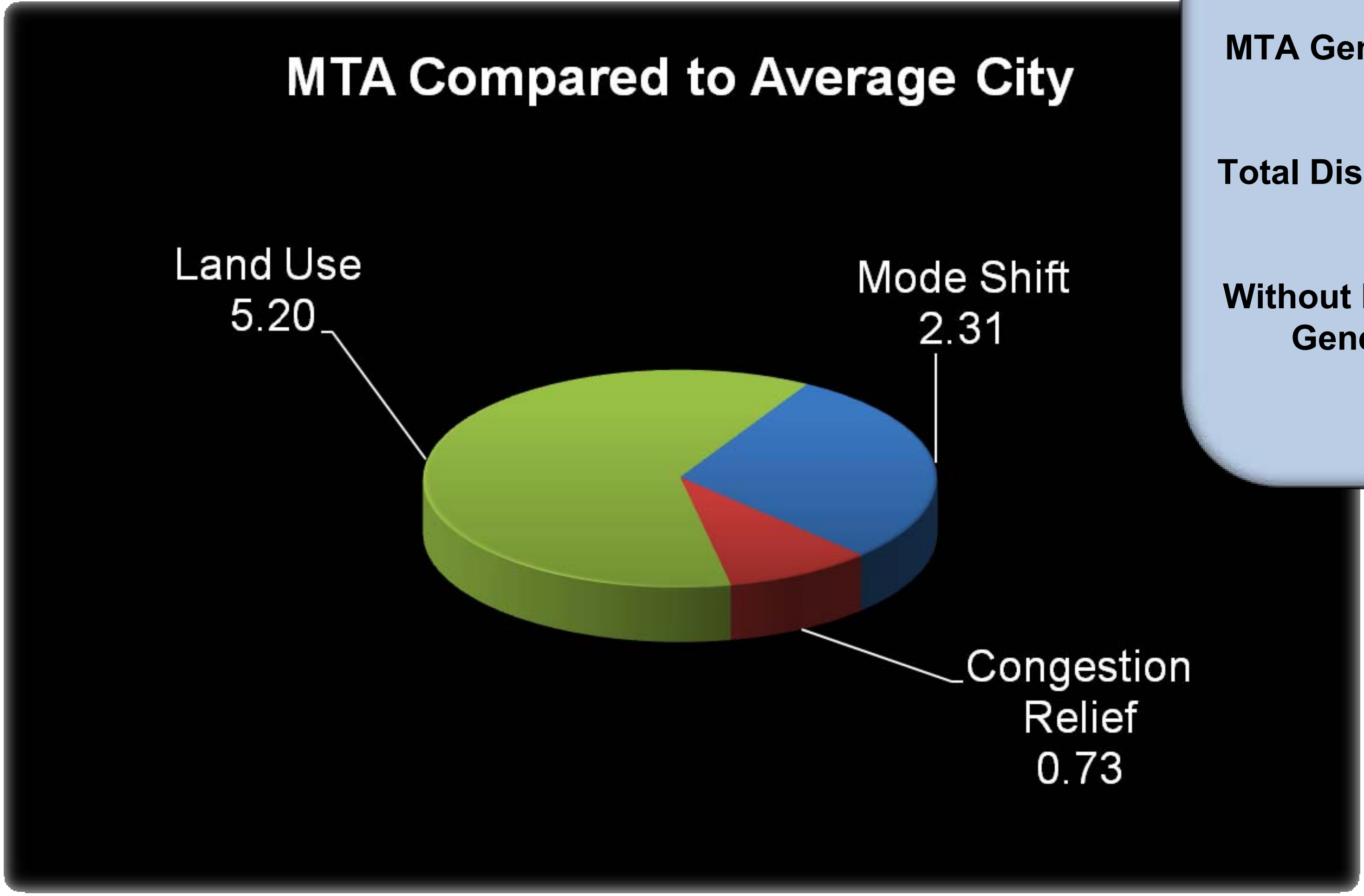
$$\frac{\textit{GHG emissions reduction from land use effects}}{\textit{GHG emissions effects from mode choice}}$$

- Land use multiplier varies depending on the study and reference areas
  - Does not take into account building efficiency

Land Use Multipliers: How do they compare?

Scenario	Approach	Land Use Multiplier
Four dense counties	Resemble suburban NY/NJ	2.88
	Resemble average city*	5.20
NYC	Resemble suburban NY/NJ	3.62
	Resemble average city	4.24
Manhattan	Resemble suburban NY/NJ	10.62
	Resemble average city	12.25
Average Distance	GIS Study	1.8
Default	Multiplier	1.9

What is the impact of MTA on GHG emissions?



MTA Generates ≈ 2.72 M tons/yr

Total Displacement Factor ≈ 8.24

Without MTA, the Region Would Generate ≈ 20 M tons/yr