SOUTH BRONX ENVIRONMENTAL HEALTH AND POLICY STUDY

Public Health and Environmental Policy Analysis

Funded with a Congressional Appropriation sponsored by Congressman José E. Serrano and administered through the U.S. Environmental Protection Agency

Transportation and Traffic Modeling, Air Quality, Waste Transfer Stations, and Environmental Justice Analyses in the South Bronx

Final Report for Phase II & III

December 2004

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Edited by Carlos Restrepo and Rae Zimmerman

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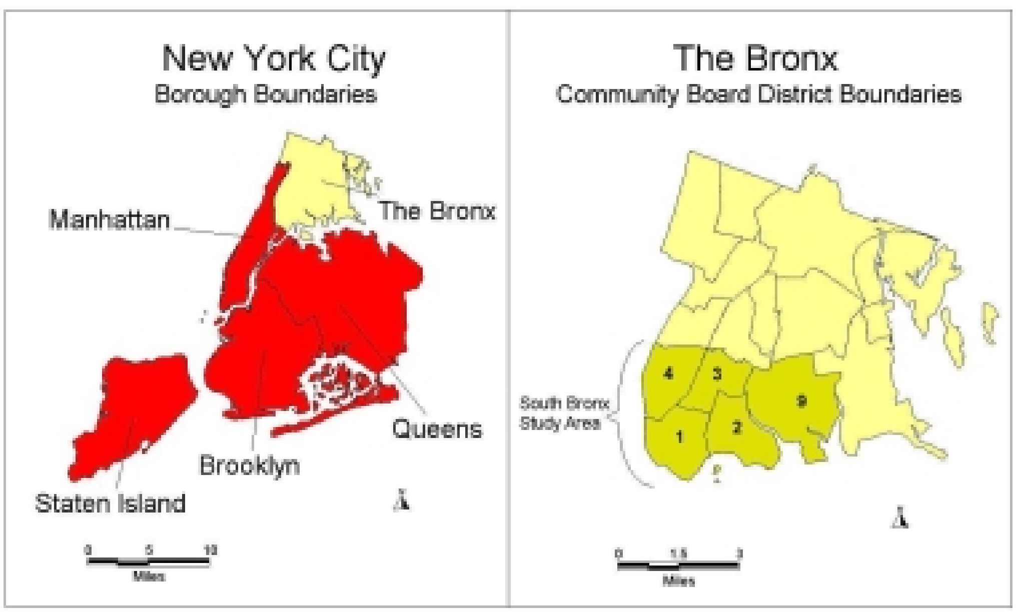
Chapter 1
Introduction

The South Bronx is a low-income, minority community in New York City. It has one of the highest asthma rates in the country, which residents feel is one of the most pressing health issues in their community. The main goal of the South Bronx Environmental Health and Policy Study is to study environmental and health issues affecting that community, with particular emphasis on the relationships between air quality, transportation, waste transfer activity, demographic characteristics, and public health. It is a collaborative research project that involves the NYU School of Medicine's Nelson Institute of Environmental Medicine (NIEM), the NYU Wagner Graduate School of Public Service's Institute for Civil Infrastructure Systems (ICIS), and four community groups: The Point Community Development Corporation, We Stay/Nos Quedamos, Sports Foundation Inc., and Youth Ministries for Peace and Justice Inc.

The study area of the project is shown in Figure 1, and comprises community boards 1,2,3,4 and 9 in Bronx County, New York.

Figure 1. Study Area



During Phase I of the project, the following goals were achieved:

- Identification & acquisition of environmental, demographic and transportation databases & literature

- Assessment of problems associated with these resources' suitability for addressing the relationship between environmental conditions and waste transfer
- The building of a community knowledge base about environmental conditions to support a community training program

This report was preceded by the Phase I Report, which was completed in September, 2002. That report includes a description of data gathered and analyzed on the demographic characteristics of the study area, transportation, waste transfer activities, ambient air quality, and water quality. In addition, the report includes a review of the literature on the association between asthma and air pollution. The report includes chapters on:

- Demographic characteristics of the study area
- Waste transfer stations in the South Bronx
- Transportation and traffic in the study area
- Air quality in the South Bronx
- Asthma and air pollution - literature review
- Water quality in the South Bronx watershed

The full report is available on-line at:
http://www.icisnyu.org/admin/files/PhaseIWagner930.pdf.

The goals of Phases 2 & 3 of the project include:

The objectives of the second and third phases of the Wagner/ICIS portion of the South Bronx Environmental Health and Policy study are:

(1) To characterize selected transportation and associated air quality patterns and trends within the study area using computer models.

(2) To evaluate alternative policies toward the future role of waste transfer stations in the South Bronx, in light of transportation and air quality patterns and trends by evaluating alternative scenarios for the future of these facilities. The air quality modeling focused on traffic-related particulate matter, although the broader description of existing conditions in the area will encompass other air quality parameters.

(3) To build on some of the demographic and environmental information analyzed during Phase 1 to identify issues of equity that may exist with respect to waste transfer and its environmental effects. Equity pertains to disproportionate conditions that may exist in the South Bronx vs. other area in New York City and the city as a whole.

A common theme throughout all the components of the project is to produce a means of designing information that is easy to communicate to the community and easily accessible to them. This work will be used as inputs to Phase 4 of the project which includes the development of decision-tools to help community groups and local policy-makers analyze policy alternatives. A complementary set of environmental justice analyses will be carried out during Phase IV of the study to look at the association between asthma hospitalization rates and the socio-economic variables examined in this report.

Project team

The following people worked in the research components of Phases II & III of the NYU Wagner/ICIS component of this project:

- Rae Zimmerman (co-Principal Investigator), Professor and Director, ICIS
- Carlos Restrepo, Ph.D candidate, Graduate Research Assistant and South Bronx Project Manager, ICIS
- José Holguín-Veras, Ph.D., P.E., Associate Professor, Rensselaer Polytechnic Institute
- Bruce A. Egan, Sc.D, CCM, Egan Environmental Inc.
- Zvia Naphtali, Ph.D., Adjunct Professor, Wagner School, NYU
- Cary Hirschstein, Graduate Research Assistant, NYU-Wagner/ICIS (MUP 2004)
- Nicole Dooskin, Graduate Research Assistant, NYU-Wagner/ICIS (MUP 2005)
- Wendy Remington, Administrative Aide, NYU-Wagner/ICIS

Organization of the report

This report is divided into the following sections:

I. Introduction
II. Air quality in the South Bronx: Comparing ground-level measurements of air pollutants with data from the New York State Department of Environmental Conservation monitoring network
III. Transportation and air quality modeling
   - Transportation and traffic modeling
   - Air quality modeling
IV. Waste transfer scenario analyses using transportation and air quality modeling
   - Transportation scenario analyses results
   - Air quality scenario analyses results
V. Environmental justice analyses
   - Environmental justice literature review
   - Development of effective environmental justice assessment techniques using geographic information systems (GIS)
VI. Policy recommendations and conclusions
   - South Bronx potential environmental improvement strategies
   - Conclusions and policy recommendations of Phases II & III of the project

The rest of this introductory chapter summarizes the goals and main findings of each of these sections.

II. Air quality in the South Bronx: Comparing ground-level measurements of air pollutants with data from the New York State Department of Environmental Conservation (NYSDEC) monitoring network

Air quality is measured in three different ways in the South Bronx Environmental Health and Policy Study. As described in detail in the Phase I report mentioned above, one way to look at air quality in the study area is to look at the data from the network of air quality monitoring stations maintained by the New York State Department of Environmental Conservation (NYSDEC). Another way the project looks at air quality is through computer modeling using traffic count estimates to model the contribution of transportation to pollutant emissions such as particulate matter and nitrogen oxides. This is described in the next section. The third way the project looks at air quality in the study air is to take air samples through the use of mobile laboratory.

The main objective of this chapter is to compare ground-level measurements of nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), carbon monoxide (CO) and fine particulate matter($PM_{2.5}$) made by the project's mobile van station with those provided by New York State Department of Environmental Conservation (NYSDEC) monitoring stations in the South Bronx. The mobile van station was operated by the NYU Nelson Institute of Environmental Medicine.

Information about the equipment used, locations, and data gathered by the van is found at: www.nyu.edu/projects/southbronxhealth/index.htm. This comparison responds to a concern expressed by the participating community groups that the monitoring stations operated by the NYSDEC are located on school roof-tops 15 meters above ground and may not adequately represent the quality of the air that local residents breathe at ground-level. The mobile van samples air at a height of approximately 4 meters above ground and comparison of the two sets of data for days when the van was in the field measuring air quality was carried out.

The main findings of the comparison are:

- For NO_2, CO and SO_2 the ground-level measurements are significantly higher than those provided by NYSDEC monitoring stations.
- For CO and SO_2 both sets of data are well within accepted EPA air quality standards.
- The measurements of NO_2 are higher than expected. The results for one measuring period are shown in Figure 2.
- Concentrations of O_3 appear to be lower at ground-level.
- Concentrations of $PM_{2.5}$ measured by the project's van and NYSDEC are very similar. The results for one measuring period are shown below in Figure 3.

Figure 2. NO_2 data comparison

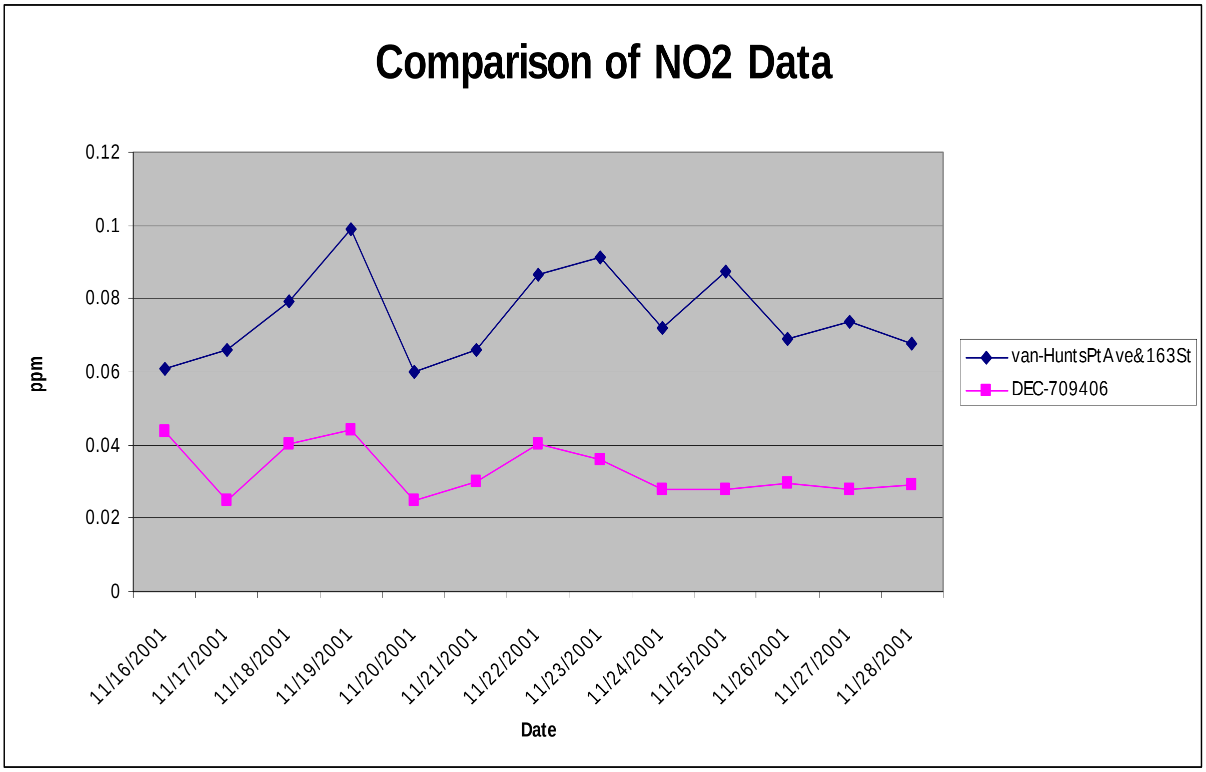
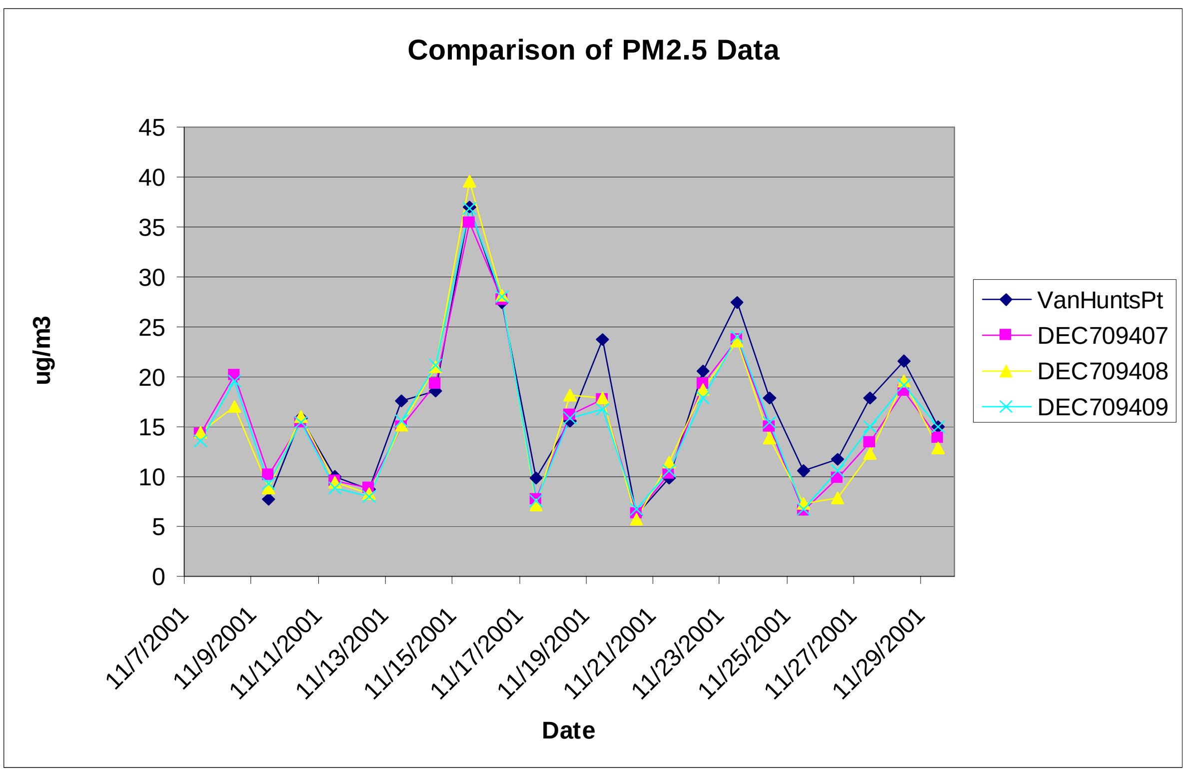


Figure 3. PM2.5 data comparison



III. Transportation and air quality modeling

The transportation air quality modeling component of the project has four main objectives:

(1) Estimation of Traffic Volumes
(2) Estimation of Air Quality for Existing Traffic
(3) Estimation of Traffic and Air Quality Associated with Existing Waste Transfer
(4) Estimation of Traffic and Air Quality Associated with Waste Transfer Scenarios

The models results include vehicular traffic count estimates for the road network in the study area, as well as estimates of air pollutant concentrations for particulate matter associated with pollutant emissions from traffic in the area. As the next section explains, one goal of the models is to produce data that can be used to evaluate potential public policy scenarios such as the air quality and traffic impacts of adding or removing waste transfer stations. Such scenario evaluations could be used as inputs for waste management policy in Bronx County and are described in the next section.

III.a Transportation and traffic modeling

This section summarizes the steps taken in the transportation modeling process and some of the main findings. The main goal of this part of the project is to model part of the South Bronx network and to analyze traffic conditions and their environmental impact during typical workday AM and PM peak conditions.

The preparation and assembly of the traffic data needed for preliminary modeling of traffic and air pollution consisted of obtaining traffic data sets already collected by the local agencies and converting the hard copies into electronic files which were included as part of the GIS system of the project. The process followed consisted of:

- Contacting NYSDOT and NYCDOT to obtain accurate locations of traffic monitoring stations in the South Bronx, including electronic files for traffic data, and updates of the traffic data based on data analyses earlier in the project.
- Converting the traffic data, originally in paper copies, to electronic files for use in modeling.
- Geocoding the traffic data into the project GIS.
- Estimating traffic volumes per hour, both peak and average estimates by vehicle type to provide a baseline against which to ultimately determine the impact of waste transfer scenarios on traffic.
- Geocoding and interpolation of NYS/NYCDOT data where data is inadequate or missing.

The bulk of the traffic data was provided by NYSDOT Region 11. The data included traffic counts from 1999, 2000, and 2001. The data sets corresponding to the different years were analyzed the most complete data set was for 2001. Figure 4 shows the actual

Average Annual Daily Traffic (AADT) for the different highway segments from the 2001 data set. As shown, the available traffic data is relatively limited (approximately 35 traffic stations). The project team proceeded to complement the traffic data for 2001 with estimates of the traffic counts made from the other years for those highway segments with no 2001 data.

Figure 5 shows the traffic data superimposed on the primary network, which also has a significant number of data gaps, though not as severe as in the case shown in Figure 4. The primary network represents the links that were part of the modeling process. Figure 6 provides an illustration of the peak hour traffic in key segments of the network based on 2001 data.

An important piece of information for environmental modeling is related to the key features of the commercial vehicles in the study area. Since obtaining accurate estimates of the characteristics of the truck fleets in the South Bronx was not possible because of project constraints, estimates were produced based on the 1997 Vehicle Inventory and Use Survey (VIUS) which is a study conducted every five years by the US Department of Commerce. The VIUS collects data about truck fleets in the Nation that could be used to produce tabulations at the State level.

These data are presented in the report in several ways, including breakdowns by: type of fuel and model year for both the entire US and the State of New York; engine type and type of fuel; truck size and fuel type; axle type and engine type; model year and vehicle size; miles per gallon and engine type; engine displacement and engine type; and gross vehicle weight and engine type. The classification used to describe truck size is:

- Light - The average vehicle weight is 10,000 lbs. or less.
- Medium - The average vehicle weight is 10,001 to 19,500 lbs.
- Light-heavy - The average vehicle weight is 19,501 to 26,000 lbs.
- Heavy-heavy - The average vehicle weight is 26,001 lbs. or more.

Figure 4: Average Annual Daily Traffic (AADT) for 2001

Figure 5: AADT in primary network

Figure 6: Peak hour traffic in the network

The chapter on transportation and traffic modeling also includes information about waste transfer stations in the study area. This information includes mode and route for New York City household garbage, origins and destination of New York City garbage, location, capacity and output of waste transfer stations in the South Bronx, and market shares for the South Bronx waste transfer stations. Figure 7 is a map of the South Bronx that includes the locations of waste transfer stations. Figure 8 shows their output.

Figure 7: Waste Transfer Stations in the South Bronx

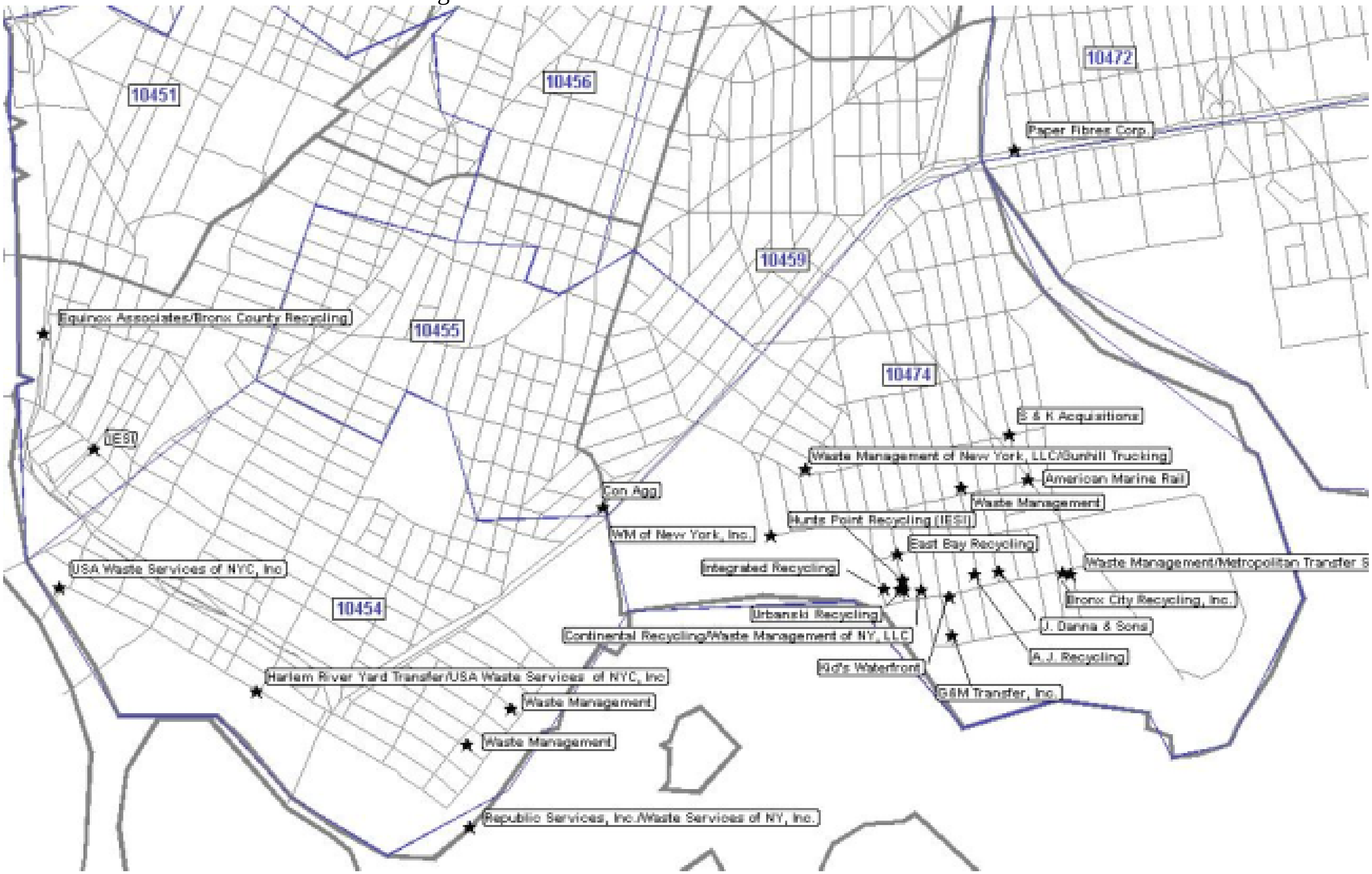


Figure 8: Tons/Day Output at Waste Transfer Stations

As mentioned earlier, the main goal of this part of the project was to model part of the South Bronx network, using state of the art Dynamic Traffic Assignment/Simulation tools, and to analyze the traffic conditions and the environmental impact from traffic during a typical workday AM and PM peak conditions. The model adopted is an extension of Northwestern University's mesoscopic simulation-assignment model called VISTA (Visual Interactive System for Transportation Algorithms), modified to include multiple vehicle classes (i.e., truck and passenger car movements) as well as traffic signal control in the simulation. Vehicle emissions on any road network (total emissions on the network or/and emissions on a particular link) in VISTA can be obtained by supplying pertinent road network details to any standard emission-modeling package.

The main agencies/entities that maintain data on the South Bronx networks are the New York Metropolitan Transportation Council (NYMTC), the New York City Metropolitan Planning Organization, the City Department of Transportation (NYCDOT), the City College of New York (CCNY) and consultants (Urbitran). Engineers and Planners from these agencies were contacted and the following data sets were obtained:

- Network Infrastructure Data: The network selected consists of 1365 intersections (interchanges) and 2672 arterial and freeway segments.
- Network Demand Data: The zoning system of NYMTC was used and the Origin-Destination data as supplied by Urbitran were mapped on the same network. The total number of ODs used was 10984; the PM and AM peak total demand are as follows:
    - AM Peak Total 107014 vehicles of which 12840 were trucks and 94174 were passenger vehicles
    - PM Peak Total 113401 vehicles of which 7323 were trucks and 104800 were passenger vehicles
- Other Control and Traffic Data: Some of the intersections are signalized and traffic signal data were collected from the research team, which included the location, type of signal control and the timing plan. In addition, on some street segments counts were obtained that were used for validation purposes.

For the purpose of computing overall pollutant emissions from the traffic in the project area the study made use of a package developed by EPA known as MOBILE6. This package was linked with VISTA, which provided the inputs required by MOBILE6 to compute the emissions by running the simulation on the network. The emissions at the street level were computed thanks to the capability of VISTA to produce the parameters: VMT (Vehicle Miles Traveled) and Average Speed of Vehicles at the street level.

These estimates are presented in detailed tables in the report, which include the 100 links with the highest observed traffic volumes classified by truck and passenger car traffic; the links with the lowest average speed, which are considered problematic in terms of traffic congestion; the links that contribute the most to fuel consumption on this network; the movements that present the highest queue length and delay, which is an indication of intersections that are problematic on this network; and the links with the highest rate of pollutant emissions. The total fuel consumption for the morning peak (6:00-10:00 AM) is estimated to be 8,823 gallons, the total estimated emission of pollutants are: 148.436 kilograms of Total Organic Gases (TOG), 727.354

Kilograms of carbon monoxide (CO) and 38.244 Kilograms of oxides of nitrogen (NO_x). Similar quantities are produced in the afternoon peak. It is notable that in the afternoon peak the number of passenger vehicles is higher while the number of trucks is lower. The congestion appears to be higher in the afternoon peak as the VMT is smaller but the Vehicle-Hours are higher. This is also reflected in the total fuel consumed as well as the pollutants emitted.

III.b. Air quality modeling

Although the transportation and traffic modeling produced estimates for some pollutant emissions for the most important links in the traffic network, a more detailed air quality modeling exercise using the output of the traffic modeling was carried out for PM_{10} using EPA's ISCST3 Dispersion model to examine the spatial variability of PM concentrations.

The steps taken in the air quality modeling work were the following:

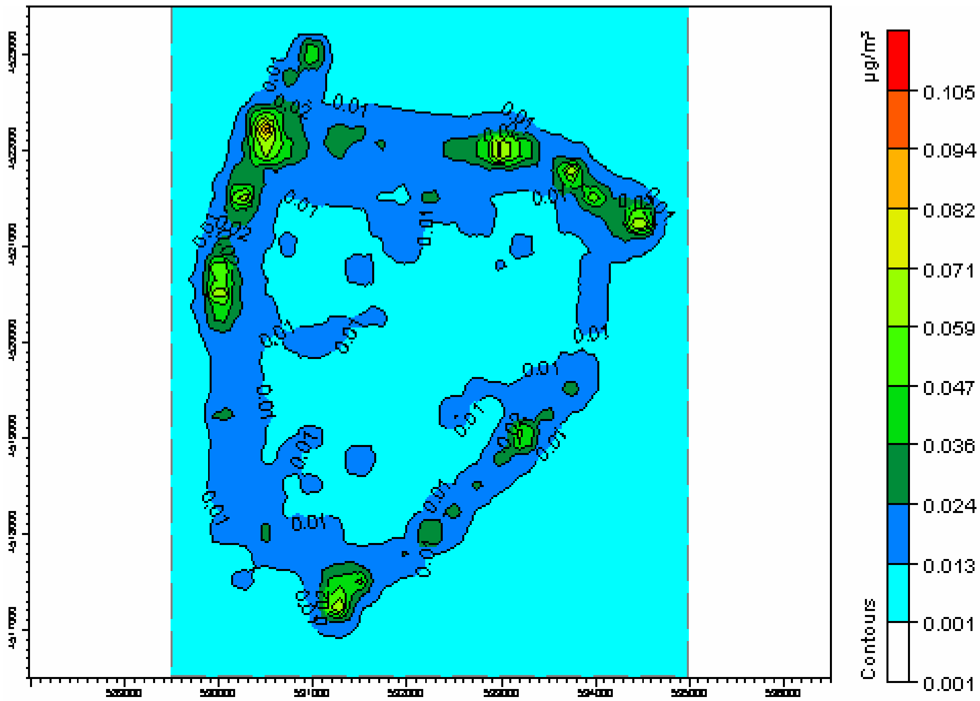
- Provide traffic estimates (veh/hour) for vehicle type and for each road segment for peak hour data provided.
- Use locations of roadway end points to locate roads and lengths of roads.
- Calculate Vehicle Miles Traveled for each road segment.
- Use age distribution and vehicle mix of vehicles provided with corresponding emission factors for PM10 from EPA's MOBILE6 emissions model to assign emission rates for each road segment.
- Input emissions geometry and rates to EPA's ISCST3 Dispersion model.
- Use a year of sequential meteorological data from LaGuardia Airport to drive ISCST3.
- Establish scaling factors to be applied by ISCST3 to each hour of predicted concentrations. These will adjust the peak hour emissions for the following factors:
  - Time (hour) of day
  - Season
  - Day of week
- Apply the same scaling factors to all roadway segments.

The output of the air quality model for PM_{10} includes:

- PM_{10} concentrations predicted at all receptors for each day.
- The highest and second-highest values archived for each receptor location.
- Annual average concentrations calculated for each receptor.

An example of the output is shown in Figure 9, which shows the maximum annual average predicted PM_{10} concentrations ($\mu g/m^3$) for the five year period 1991-1995.

Figure 9. PM_{10} concentrations



The main findings of the air quality modeling are:

- Data from the traffic modeling described above was used with EPA emission factors to generate PM emissions for base (current) case from roadways in the South Bronx.
- Traffic Volume and VMT of trucks are about 5% of the total.
- PM Emissions from trucks are about 18% of the total.
- PM Emissions from diesel engines are 4 to 20 times greater than gasoline engines for similar sized vehicles per VMT.
- Predicted concentrations are highest along main traffic arteries. Maximum Annual average concentrations are consistently in the range of 0.1 $\mu g/m^3$.
- Maximum 24-hour average concentrations are in similar areas and range from .31 to .50 $\mu g/m^3$
- Wind data from LaGuardia shows consistent year-to-year patterns and is reasonable for use with future scenarios.

IV. Waste transfer scenario analyses using transportation and air quality modeling

Section IV of the report describes several scenario analyses in the area of traffic and air quality modeling. These analyses were conducted to examine how sensitive the results were to removing some waste transfer stations or relocating them. Three scenarios were analyzed. In the first scenario three waste transfer stations were closed and the flows to these stations were diverted to other transfer stations in proportion to their market share. In the second scenario the same three waste transfer stations were closed and their flows were removed. In the third scenario the three waste stations were relocated to different addresses. Figure 10 shows the base case of traffic flows associated with waste transfer stations. Figure 11 shows the results of the second scenario, where three waste transfer stations were removed from the model. The other scenarios are described in Section IV.

Figure 10. South Bronx daily traffic associated with waste transfer stations - base case

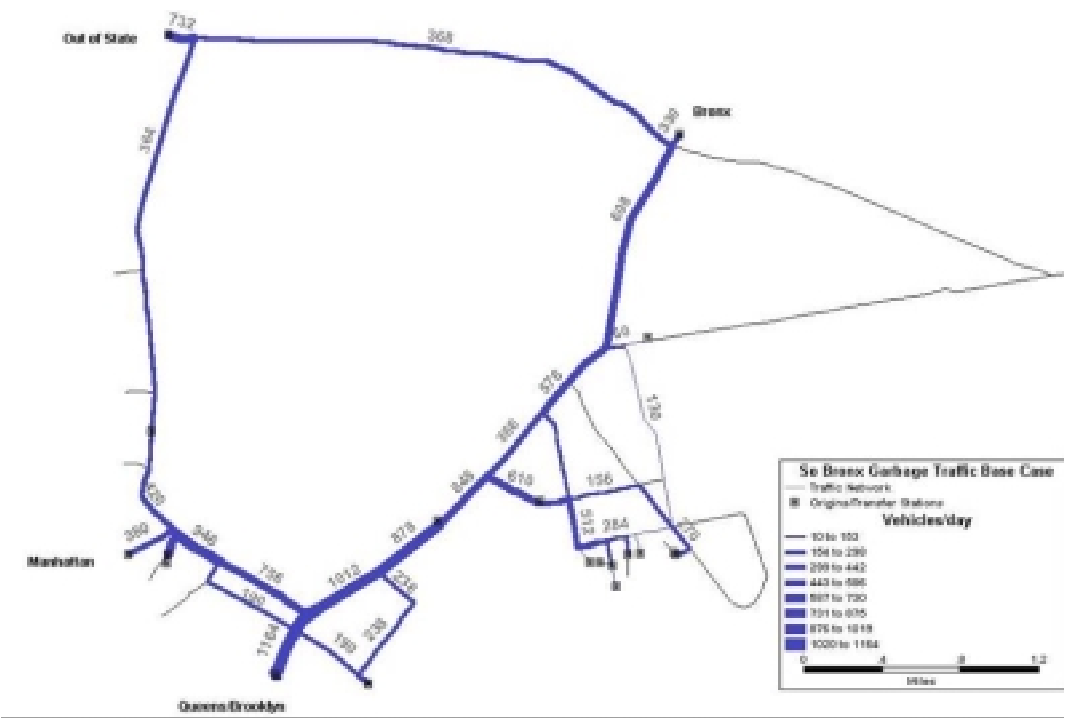
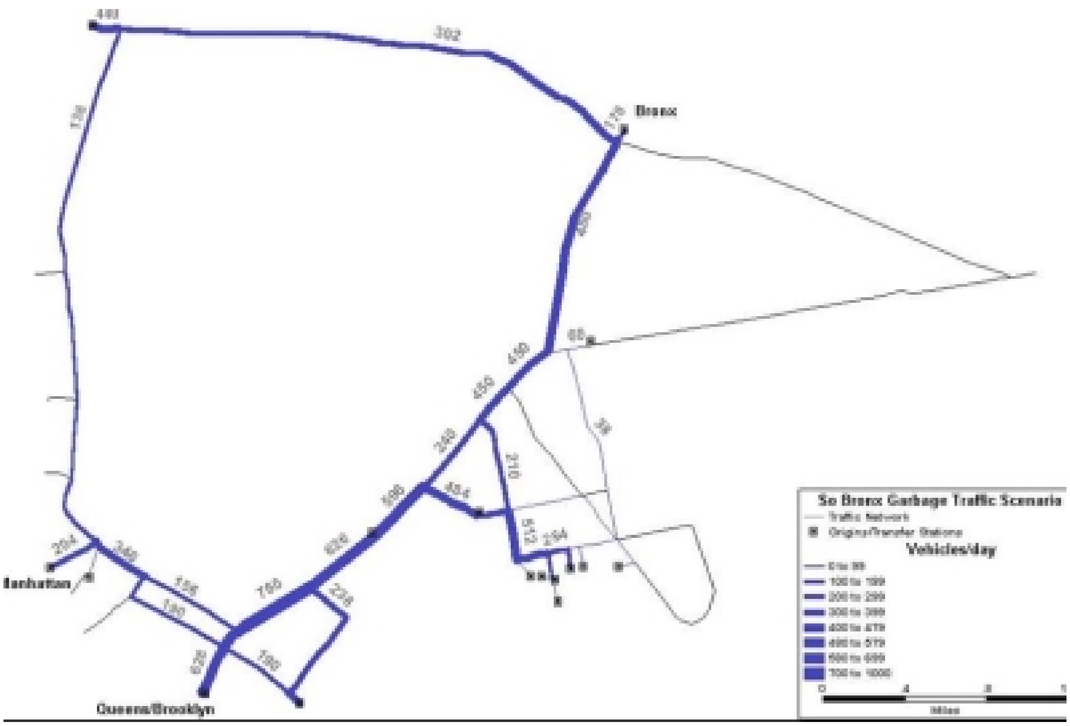


Figure 11. Second scenario: three waste transfer stations closed



These scenarios were also analyzed using the particulate matter air quality model. Figure 12 shows the predicted PM10 concentrations associated with the base case traffic flows associated with waste transfer stations. Figure 13 does the same for scenario 2, where three waste transfer stations are removed. A more detailed description of the results for all the scenarios is found in Section IV of the report.

Figure 12. Base Case Scenario: Annual average PM_{10} concentrations

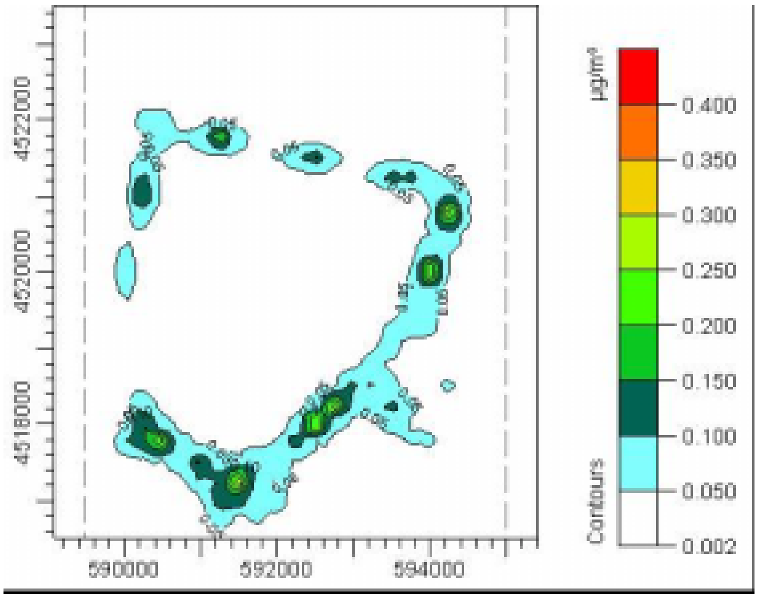
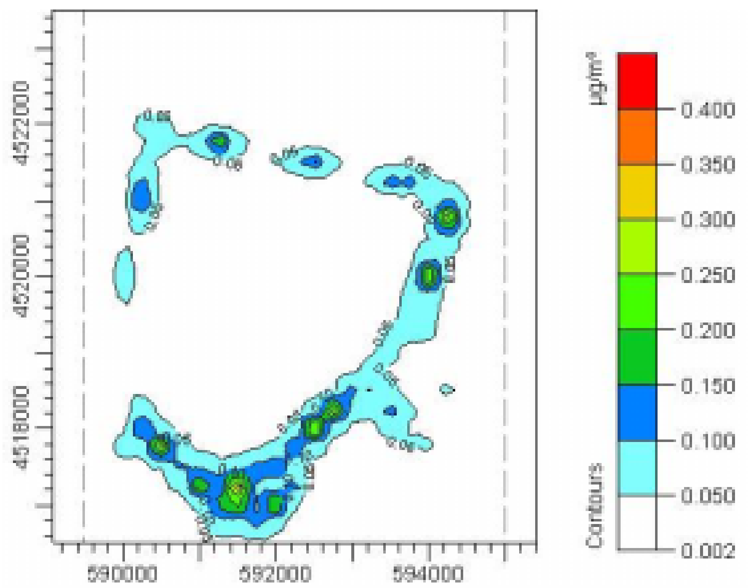


Figure 13. Scenario 2: Annual average PM_{10} concentrations with three waste transfer stations removed



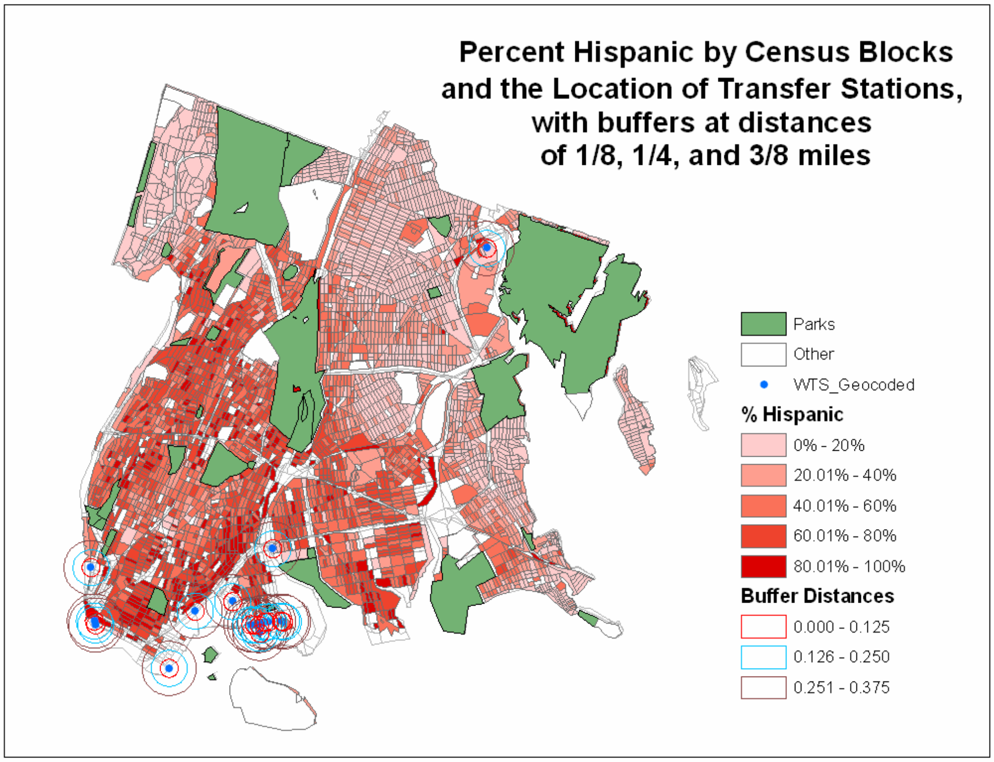
V. Environmental justice analyses

This section of the report includes a review of the literature on environmental justice, which describes a number of studies that have examined the spatial location of undesirable facilities relative to race, ethnicity and income. It also describes studies that have looked at the issue of whether adverse environmental uses are sited near minority and low-income populations, or if minorities and low-income residents tend to locate in areas where these uses are already present, described as the theory of "minority move-in." The literature review also describes a number of studies that have focused specifically in the New York City area, and ends with a discussion of the limitations of environmental justice research and future needs in the field.

In addition to the environmental justice literature review, this section also presents a detailed environmental justice analysis of Bronx County using geographic information systems (GIS). The two main objectives of the environmental justice analyses presented in this report are: (1) to develop and test the use of GIS techniques and models that will facilitate and streamline the analysis of demographic and socio-economic data about the people living in close proximity to these Waste Transfer Stations; and (2) to determine whether a disproportionate number of people from specific racial or ethnic or socioeconomic groups live in proximity to these sites.

The analysis of the racial, ethnic, and socioeconomic characteristics of the population around the existing Waste Transfer Stations in the Bronx was conducted primarily for those residing within one mile of the Waste Transfer Stations. A set of four distances ranging from ¼ mile, ½, ¾ and 1 mile buffers of the Waste Transfer Sites were evaluated for the relative stability of these characteristics in the immediate vicinity of the sites. Figure 14 shows a map of the location of waste transfer stations in Bronx County with buffers around them, as well as the percentage of the population that is Hispanic by Census Blocks.

Figure 14. Percent Hispanic by Census Blocks and Waste Transfer Stations in the South Bronx



Information on racial and ethnic characteristics was obtained from the 2000 Census data at the Census Block level (which is the smallest geographic unit for which these data from the census are available). Information on socioeconomic characteristics -- income, poverty and housing values – was obtained from the 2000 Census data aggregated at the Census Block Group level (which is the smallest geographic unit for which these data from the census are available).

The general findings with respect to socio-economic, racial and ethnic characteristics – including race, ethnicity, household income, poverty and housing value -- of the population that live within a mile or less of the Waste Transfer Stations (WTS) locations are summarized briefly below. For a fuller discussion see the section on Conclusions.

- Populations living in close proximity (within 1 mile) to the south Bronx Waste Transfer Sites tend to be more Black and Hispanic than in the Bronx as a whole.
- Their socioeconomic characteristics – median household income, poverty status, value of owner-occupied housing units – are generally lower within one mile distance from the Waste Transfer Stations than in the Study Area, the Bronx as a whole, and the other boroughs.

VI. Policy recommendations and conclusions

The final section concludes the report with two chapters. The first is a discussion of potential strategies to improve environmental quality in the study area. The second is a discussion of the main lessons learned during Phases II & III of the project as described in this report. Initial policy recommendations are drawn from the conclusions. A more comprehensive set of policy recommendations will be made at a later stage in the project when all the research components are finalized.

Chapter 2

Air quality in the South Bronx: Comparing ground-level measurements of air pollutants with data from the New York State Department of Environmental Conservation (NYSDEC) monitoring network[1]

Carlos Restrepo, Rae Zimmerman, George Thurston, Jessica Clemente, John Gorczynski, Mianhua Zhong, Martin Blaustein and Lung Chi Chen

The South Bronx has one of the highest asthma rates in the country. Community residents feel this health outcome is related to poor air quality. They also feel that the air quality data provided by the New York State Department of Environmental Conservation (DEC) through their network of monitoring stations may not reflect the poor quality of the air they breathe. This is due to the fact that these monitoring stations are usually located about 15 meters above ground. In 2001 the South Bronx Environmental Studies project collected air quality data at various locations throughout the study area. They were collected at ground level by a mobile laboratory placed in a van. On average, the van collected hourly data at each location for periods of three to four weeks.[2] This report compares those data with data collected by DEC's monitoring stations in Bronx County during the same periods. The goal of this comparison is to see whether there are significant differences between ground-level measurements made by the project's van and measurements recorded by DEC's stations. The pollutants included in the report are carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), fine particulate matter ($PM_{2.5}$), and sulfur dioxide (SO_2).

I. Air Quality Monitoring Locations

Table 1 shows the location of DEC's monitoring stations for which data were available for comparison to the project's van data. Table 2 shows the location of the van during the three periods for which data were compared. Table 3 shows the EPA standards which are also compared to both the van's measured concentrations and those of DEC's monitoring stations. Table 4 lists some of the main sources of the pollutants discussed in this report.

Table 1. NYS DEC Air Quality Sampling Station Locational Information

Station ID	Location	Height Above Ground	Within Study Area?
709406	Bronx Botanical Garden, 200th St. at Southern Blvd.	15 meters	No

[1] This report was developed into a paper that was published in October 2004. The full reference for the paper is: Carlos Restrepo, Rae Zimmerman, George Thurston, Jessica Clemente, John Gorczynski, Mianhua Zhong, Martin Blaustein and Lung Chi Chen. 2004. "A comparison of ground-level air quality data with New York State Department of Environmental Conservation monitoring stations data in South Bronx, New York. *Atmospheric Environment*. Volume 38. Pages 5295-5304.

[2] The data for the project's van was taken from the project's web page created by NYU's Nelson Institute for Environmental Medicine: http://www.nyu.edu/projects/southbronxhealth/

709407	IS 52 681 Kelly St., off 156th St.	15 meters	Yes
709408	IS 74 730 Bryant Ave.	15 meters	Yes
709409	PS 154 333 E. 135th St.	15 meters	Yes

Table 2. Location of the Project's Van in 2001

Location	**Period**
P.S. 154	August 1-29, 2001
Hunts Point Avenue and 163rd Street	November 7-29, 2001
Noble Field Park	December 2-31, 2001

Table 3. National Ambient Air Quality Standards (NAAQS) for Selected Pollutants

Air Pollutant	**Standard (Primary)**	**Averaging Time**
Carbon monoxide (CO)	9 ppm 35 ppm	8 hours 1 hour
Nitrogen dioxide (NO_2)	0.05 ppm	1 year
Ozone (O_3)	0.08 ppm 0.12 ppm	8 hours 1 hour
Fine Particulate Matter ($PM_{2.5}$)	15 ug/m3 65 ug/m3	1 year 24 hours
Sulfur dioxide (SO_2)	0.03 ppm 0.14 ppm	1 year 24 hours

Table 4. Main Sources of Air Pollutants

Air Pollutant	**Main Sources**
Carbon monoxide (CO)	Vehicular traffic and other combustion
Particulate matter	Diesel vehicles, industry, wood burning
Ozone (O_3)	Formed from precursors such as auto emissions
Sulfur dioxide (SO_2)	Coal power plants, smelters, food processing, paper and pulp mills
Nitrogen dioxide (NO_2)	Combustion from automobiles and industry. Precursor for O_3

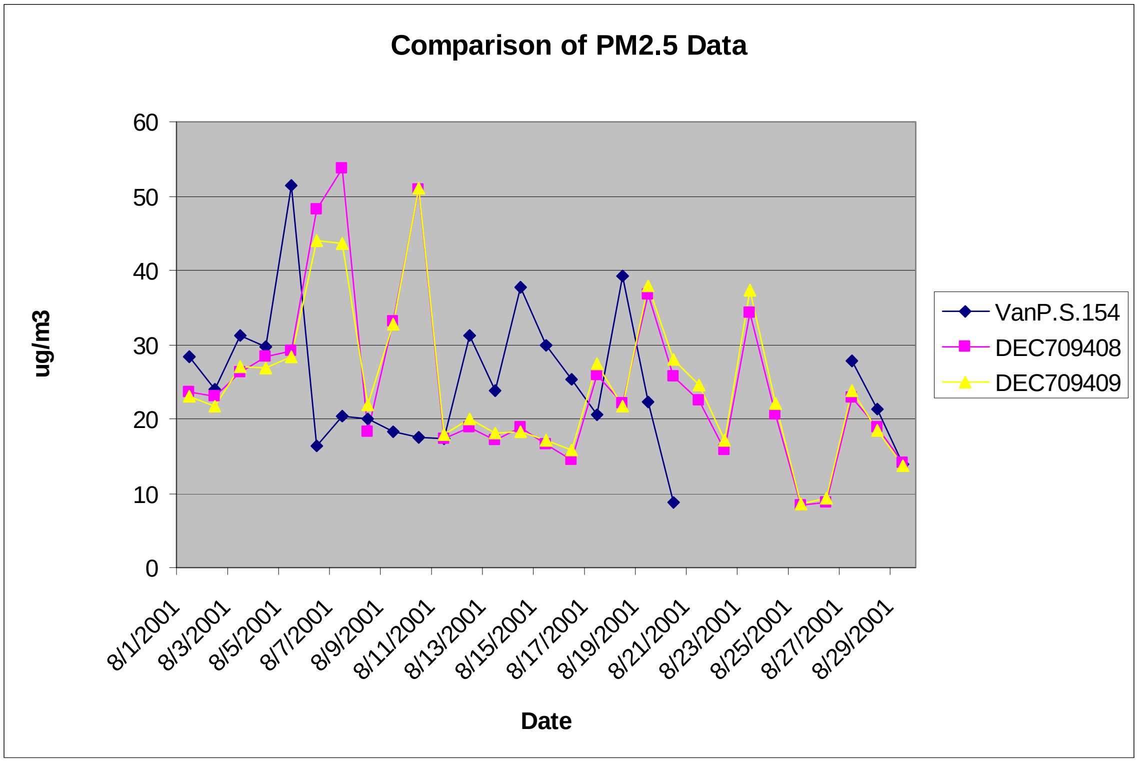
Source: Koenig, Jane Q. 2000. *Health Effects of Ambient Air Pollution: How Safe is the air we breathe*. London: Kluwer Academic Publishers. Page 31.

The following sections of this report show the data comparisons for each pollutant in graphical form.

II. Fine Particulate Matter ($PM_{2.5}$)

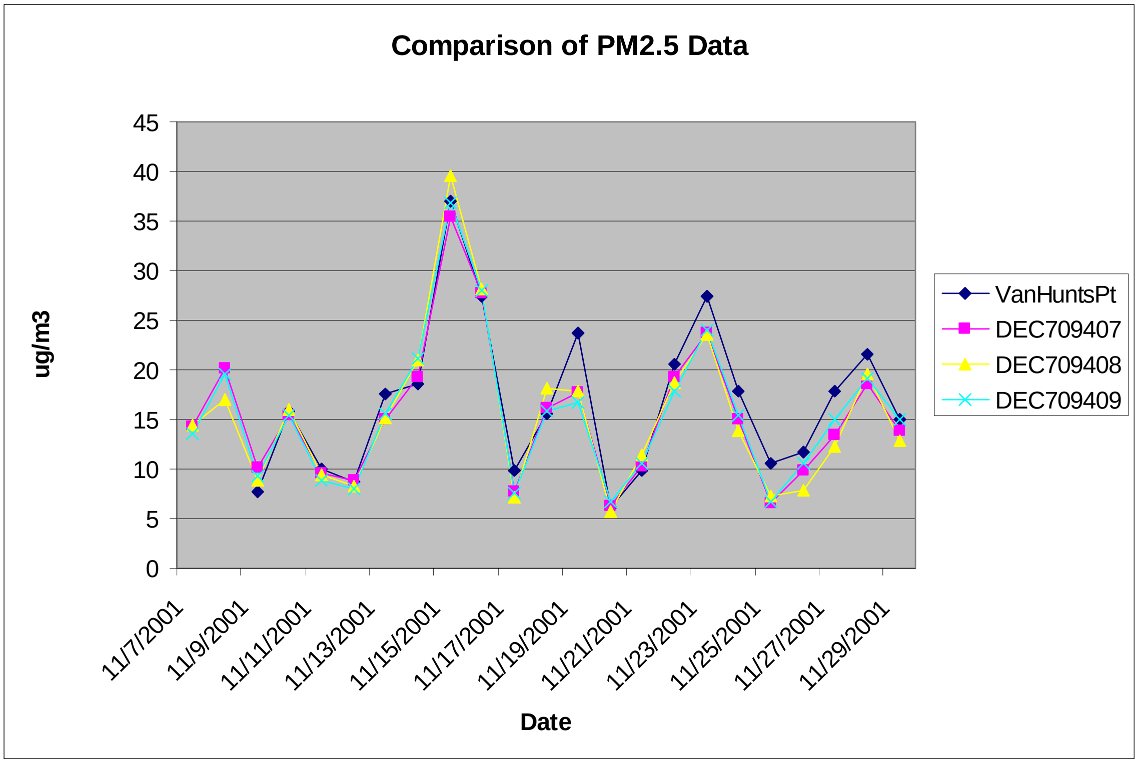
This section compares the daily average concentrations of $PM_{2.5}$ recorded by the project's van with those of DEC monitoring stations located in Bronx County. The first table and graph compare the van data from P.S. 154 for the period August 1 - August 29, 2001 with the available measurements from DEC monitoring stations for the same period. Data are available from stations 709408 and 709409. The data shown are 24 hour averages. As the graph shows, these values do not exceed EPA's 24-hr standard, which is currently set at 65 µg/m^3. The measurements do not suggest that the van's data are higher than those of DEC stations in other parts of the Bronx. The 24-hr averages are shown in the table below. Perhaps the most relevant comparison at the first site is with station 709409, which is located at P.S. 154. That's the same location where the van was stationed during this period. As the data show, the concentrations measured by the van were higher that those recorded by station 709409 for some days but lower for others. Overall, there does not appear to be systematically higher concentrations at ground level than at the height of DEC's station for this period.

Station	Average value for the period
Van	25.05 µg/m^3
DEC-709408	24.64 µg/m^3
DEC-709409	24.76 µg/m^3
EPA 24-hr Standard	65 µg/m^3
EPA Annual Standard	15 µg/m^3



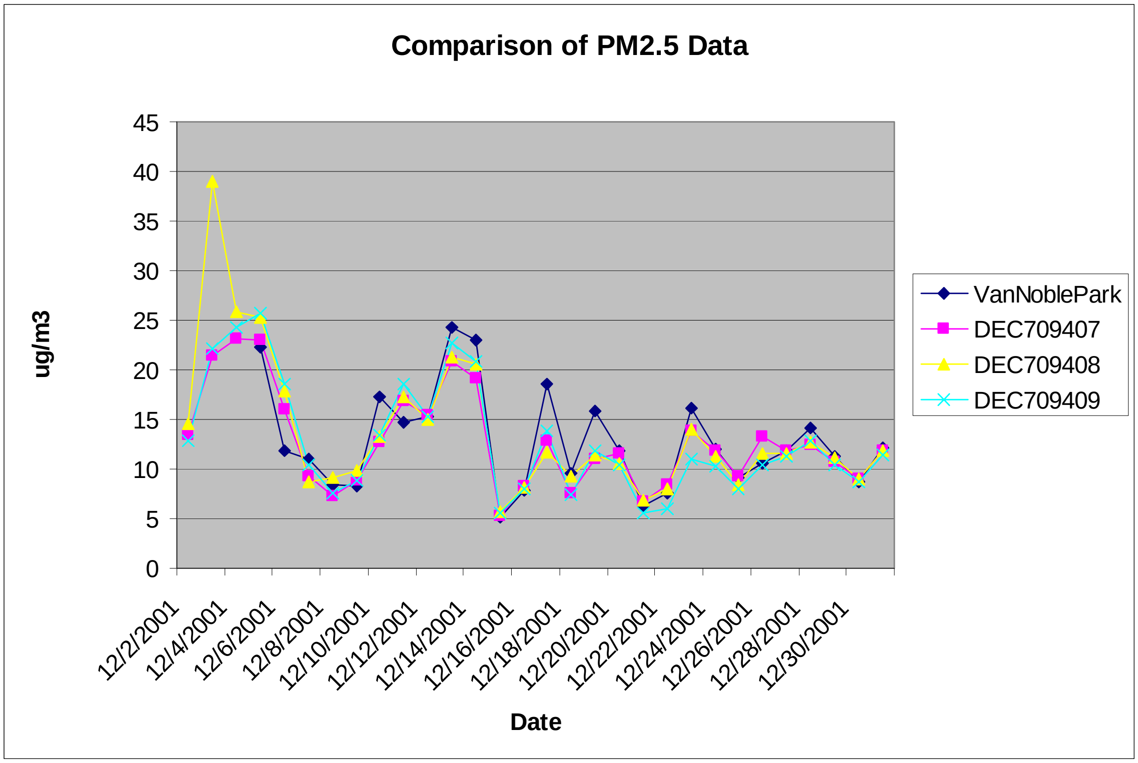
The comparison for the values taken by the van at 163rd Street and Hunts Point Avenue during the period November 7-November 29, 2001 shows similar results. The measurements are very consistent in terms of value and trend with those taken by DEC stations in other locations of the Bronx. In this case, measurements are available for three different DEC stations. The 24-hr averages are shown in the table below.

Station	**Average value for the period**
Van	16.70 µg/m^3
DEC-709407	15.41 µg/m^3
DEC-709408	15.39 µg/m^3
DEC-709409	15.55 µg/m^3
EPA 24-hr Standard	65 µg/m^3
EPA Annual Standard	15 µg/m^3



The data taken by the project's van at Noble Field Park during the period December 2 - December 31, 2001 is compared to DEC data from the same three stations below. As with the previous comparisons for this pollutant, the van measurements are very similar to those of DEC stations in other locations in the Bronx. The averages are shown in the table below, and the daily values are shown in the following graph.

Station	Average value for the period
Van	12.79 μg/m^3
DEC-709407	12.78 μg/m^3
DEC-709408	13.69 μg/m^3
DEC-709409	12.82 μg/m^3
EPA 24-hr Standard	65 μg/m^3
EPA Annual Standard	15 μg/m^3

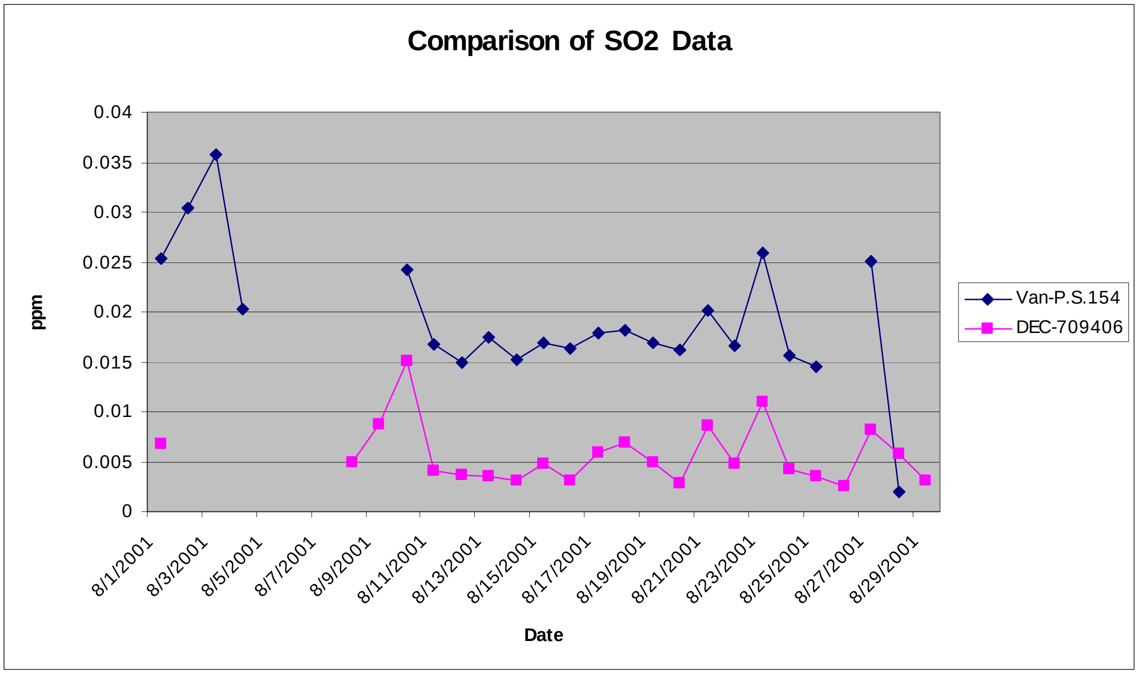


In general, it seems that the measurements of $PM_{2.5}$ taken by the van in these three different locations during 2001 are similar to those recorded by DEC stations in Bronx County. It appears that $PM_{2.5}$ concentrations are pretty uniform in this area.

III. Sulfur Dioxide (SO_2)

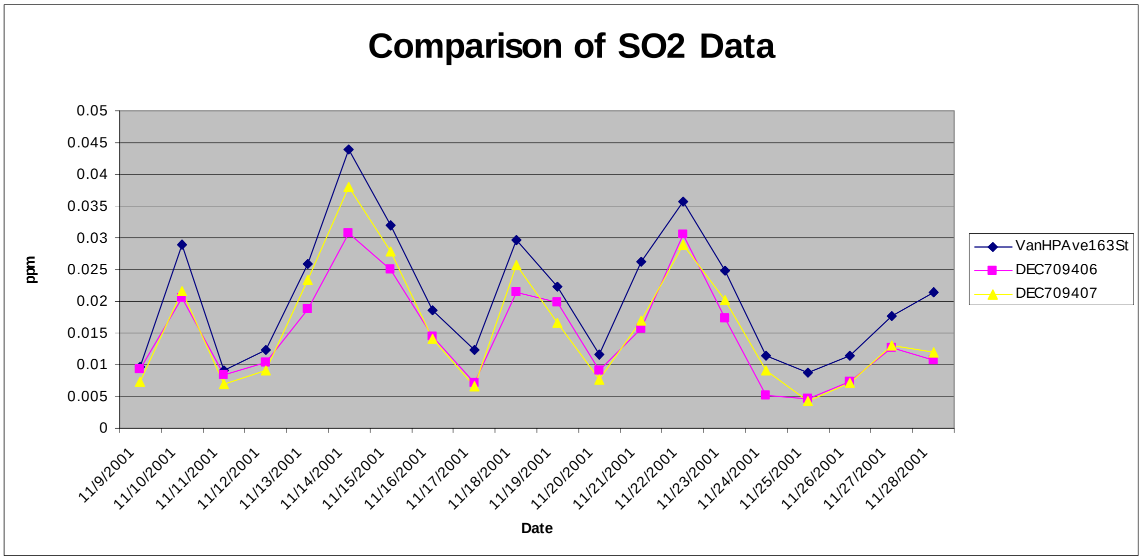
The graph and table below compare the van's measurements for the period August 1-29, 2001 at P.S. 154 with measurements from DEC monitoring station 709406. There are no data from other stations for that period. As shown, the van's measurements show substantially higher concentrations, ranging between two and three times higher than those recorded by DEC's station. However, the van's measured concentrations are still substantially lower than EPA's 24 hour average standard.

Station	Average value for the period
Van	0.0192 ppm
DEC-709406	0.0056 ppm
EPA 24-hr SO_2 Standard	0.14 ppm



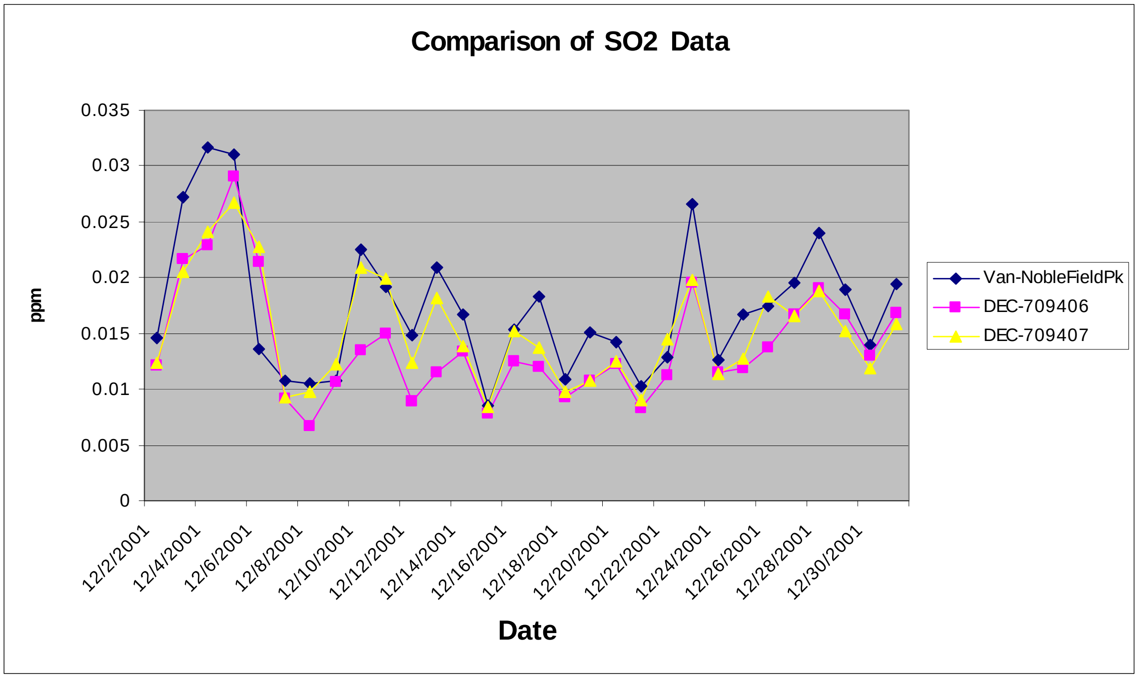
The next comparison is for measurements of SO_2 concentrations for the period November 9-29, 2001. The van was located at Hunts Point Avenue and 163rd St. During this period there are data for two DEC stations: 709406 and 709407. The data are similar in terms of day to day changes. There is close correspondence between the concentrations measured by the two DEC stations. The data recorded by the van are generally higher. These results are shown below. As with the previous comparison, these 24 hour averages are much lower than EPA's standard.

Station	**Average value for the period**
Van	0.0207 ppm
DEC-709406	0.0149 ppm
DEC-709407	0.0158 ppm
EPA 24 hr SO_2 Standard	0.14 ppm



The same can be said for the comparison for the period December 2-30, 2001. During that period the van was located at Noble Field Park. Data are available from DEC stations 709406 and 709407 for comparison. The van measurements are higher than those recorded by DEC stations but well within EPA's standard.

Station	**Average value for the period**
Van	0.0173 ppm
DEC-709406	0.0140 ppm
DEC-709407	0.0152 ppm
EPA 24 hr SO_2 Standard	0.14 ppm

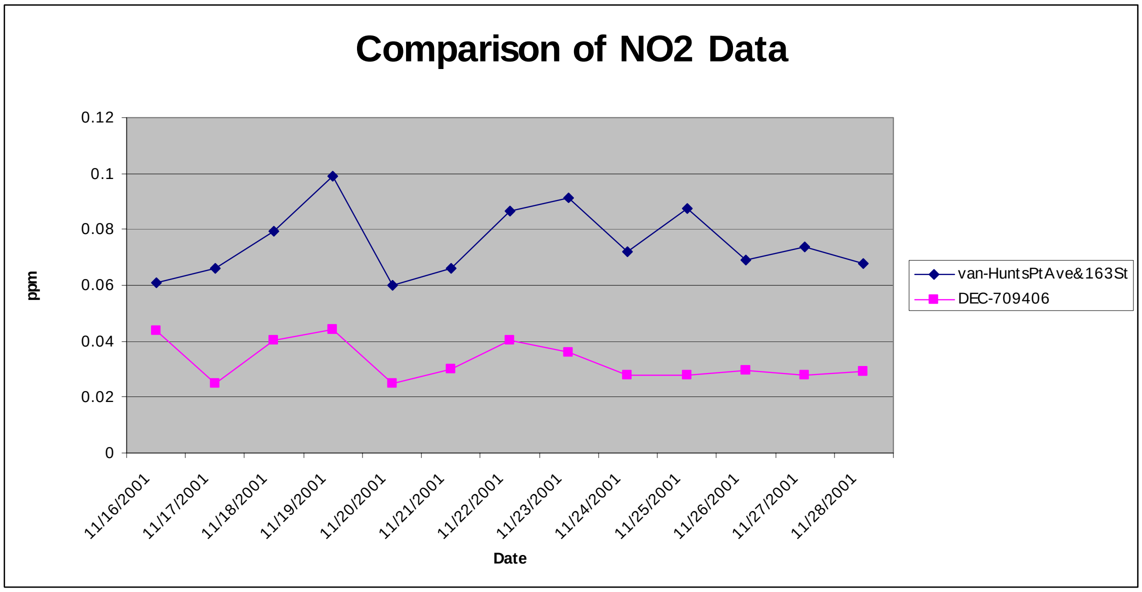


In general, the SO_2 concentrations measured by the van are higher than those measured by DEC stations. The most pronounced difference is for the first comparison, when the van was located at P.S. 154. During this period the van's measurements are two to three times higher than DEC station measurements in other parts of the Bronx. However, the van measurements are still well below the standard established by EPA.

IV. Nitrogen Dioxide (NO_2)

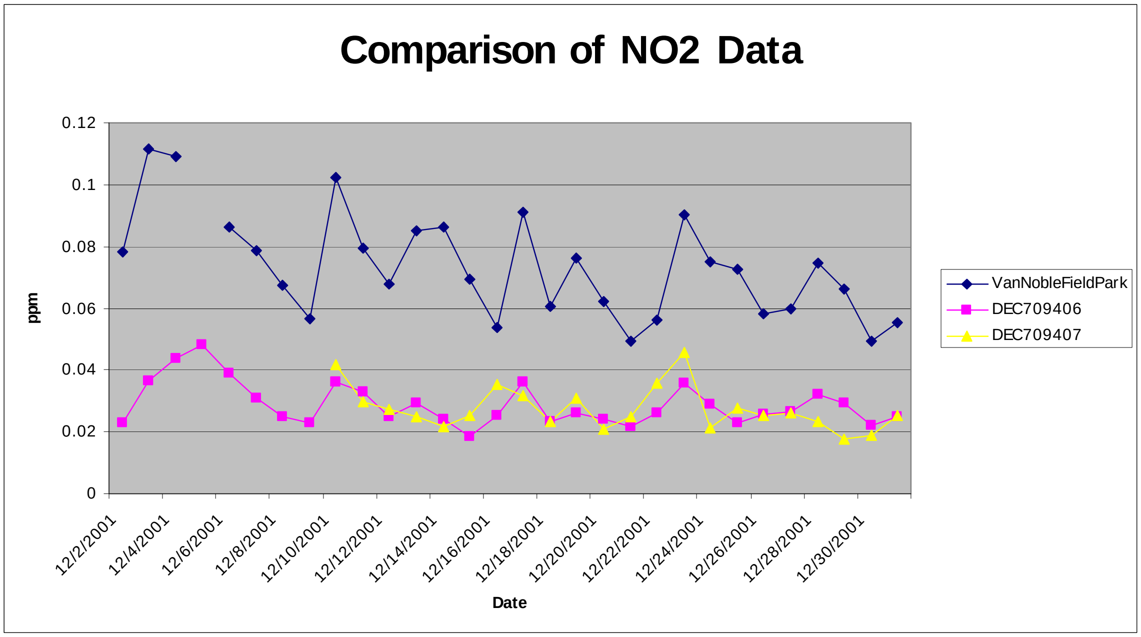
The comparison of NO_2 data is available for two periods in 2001. The first one is from November 16-28. During this period the van was located at Hunts Point Avenue and 163rd Street. There are data from one DEC station - 709406 - for this period. The results are shown in the following table and graph. The comparison suggests that the van measurements are much higher than those recorded at the DEC station. For NO_2, EPA has established a 1-year average standard. If the concentrations recorded by the van during this period were to hold for a year, they would surpass the standard significantly.

Station	Average value for the period
Van	0.0753 ppm
DEC-709406	0.0328 ppm
EPA 1-year NO_2 Standard	0.05 ppm



The other comparison for NO_2 is for the period December 2-31, 2001. During this period the van was located at Noble Field Park. The concentrations measured by two DEC stations in Bronx County during this period are similar to each other but significantly lower than the van measurements. As with the previous case, if the van's measurements are representative of concentrations of NO_2 for the whole year they would exceed EPA's 1 year standard by a wide margin.

Station	Average value for the period
Van	0.0734 ppm
DEC-709406	0.0288 ppm
DEC-709407	0.0275 ppm
EPA 1-year NO2 Standard	0.05 ppm

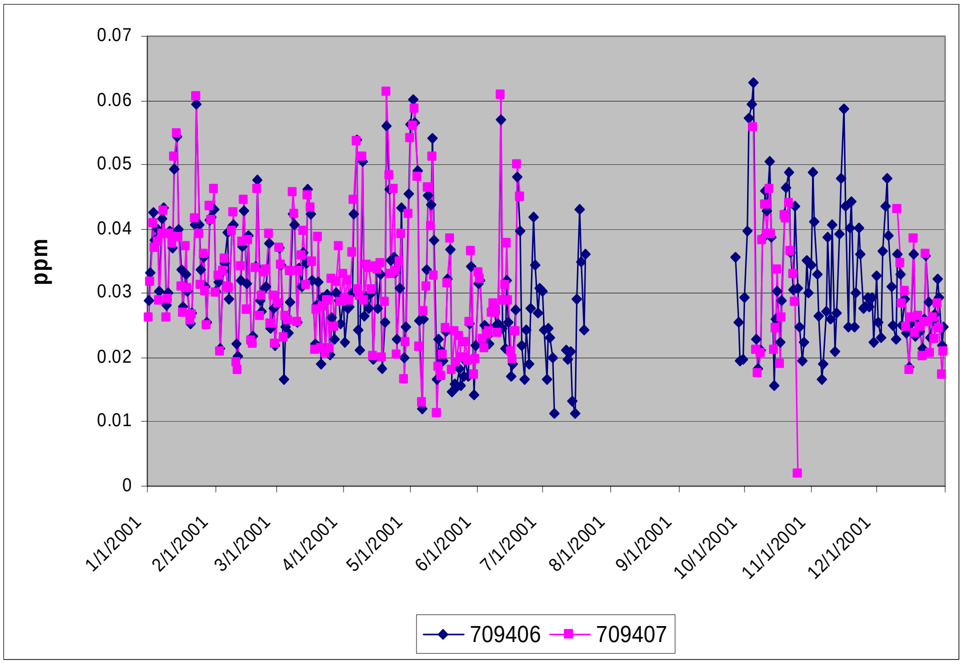


For NO_2, the concentrations measured by the van are much higher than those measured by DEC monitoring stations. The standard established by EPA for NO_2 is a one-year average which makes it difficult to compare to this data. If the van's measurements are representative of NO_2 concentrations throughout the year, EPA's standard would be exceeded by a wide margin. Daily NO_2 concentrations do not seem to exhibit strong seasonal variations in Bronx County. The table and graph below describe the available NO_2 data for 2001 from two DEC stations: 709406 and 709407. The mean values for the concentrations of NO2 in 2001 are not much different from the mean values obtained for the periods November 16-28 and December 2-31 described in the tables above.

Average daily measurements of NO2 concentrations, DEC 2001

DEC Station	No. of Observations	Minimum	Maximum	Mean (ppm)	Std. Deviation
709406	265	.01	.06	.0312	.01033
709407	242	.00	.06	.0316	.01006

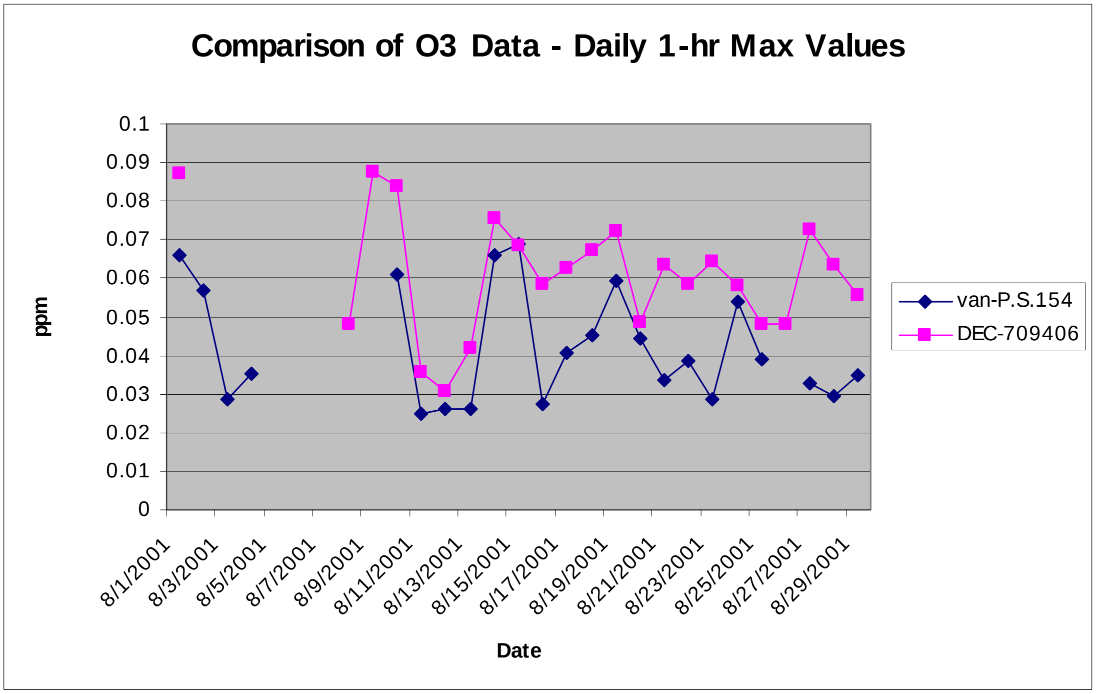
Average daily values of NO2 concentrations during 2001



V. Ozone (O_3)

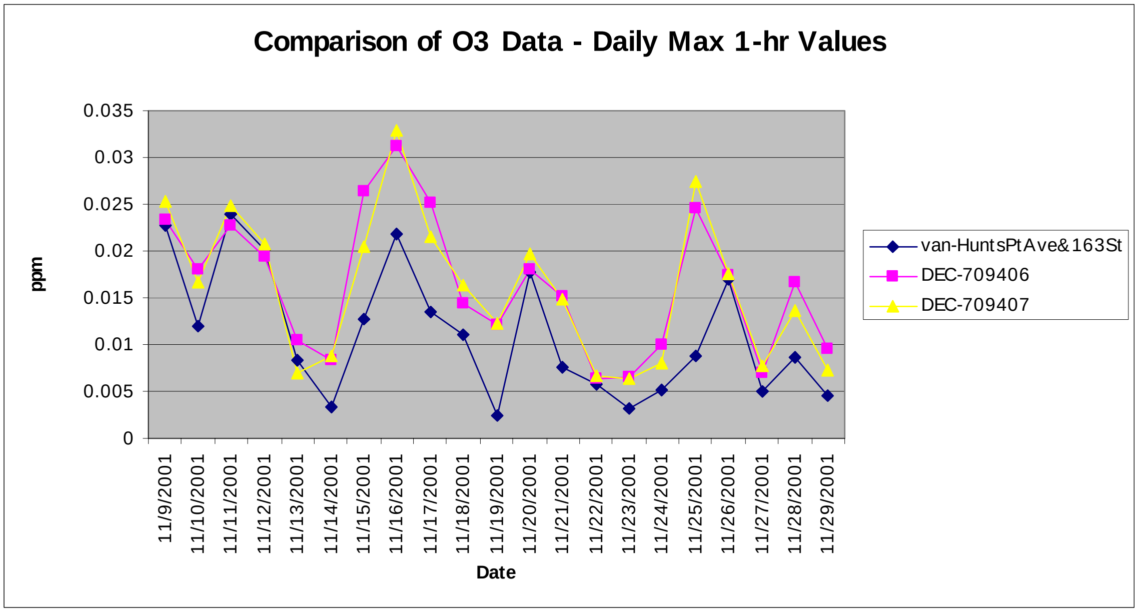
The first comparison of O_3 data is for the period August 1-29, 2001. During this period the van was located at P.S. 154. Data for comparison are available with DEC station 709406. In order to compare the data to an EPA standard, the daily 1-hr maximum value was selected. As shown in the table and graph below, the values recorded by the van are lower than those recorded by DEC station 709406. None of the maximum one hour concentration values during this period, for either the van or the DEC station, exceed EPA's standard. Ozone is a regional pollutant so DEC's stations which are located 15 meters above ground may pick up regional concentrations of ozone better than ground level measurements.

Station	Average value for the period
Van	0.0420 ppm
DEC-709406	0.0608 ppm
EPA 1-hr O_3 Standard	0.12 ppm



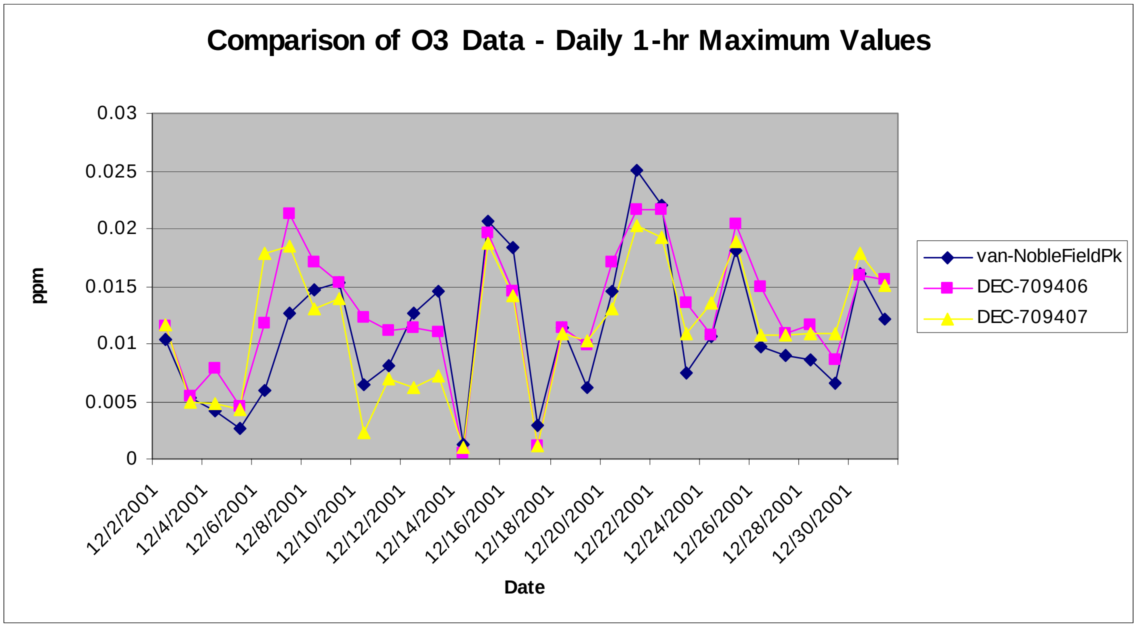
The second comparison for ozone is for the period November 9-29, 2001. During this period the van was located at Hunts Point Avenue and 163rd Street. Data for comparison are available from DEC stations 709406 and 709407. As with the previous comparison, the van's measured daily 1-hour maxima are generally lower than those measured by DEC's stations. The data are shown in the table and graph below.

Station	**Average value for the period**
Van	0.0112 ppm
DEC-709406	0.0163 ppm
DEC-709407	0.0160 ppm
EPA 1-hr O_3 Standard	0.12 ppm



The third comparison for ozone is for the period December 2-31, 2001. During this period the van was located at Noble Field Park. During this period the van's measurements were similar to those recorded by stations 709406 and 709407. The data are shown in the table and graph shown below.

Station	Average value for the period
Van	0.0111 ppm
DEC-709406	0.0127 ppm
DEC-709407	0.0113 ppm
EPA 1-hr O_3 Standard	0.12 ppm

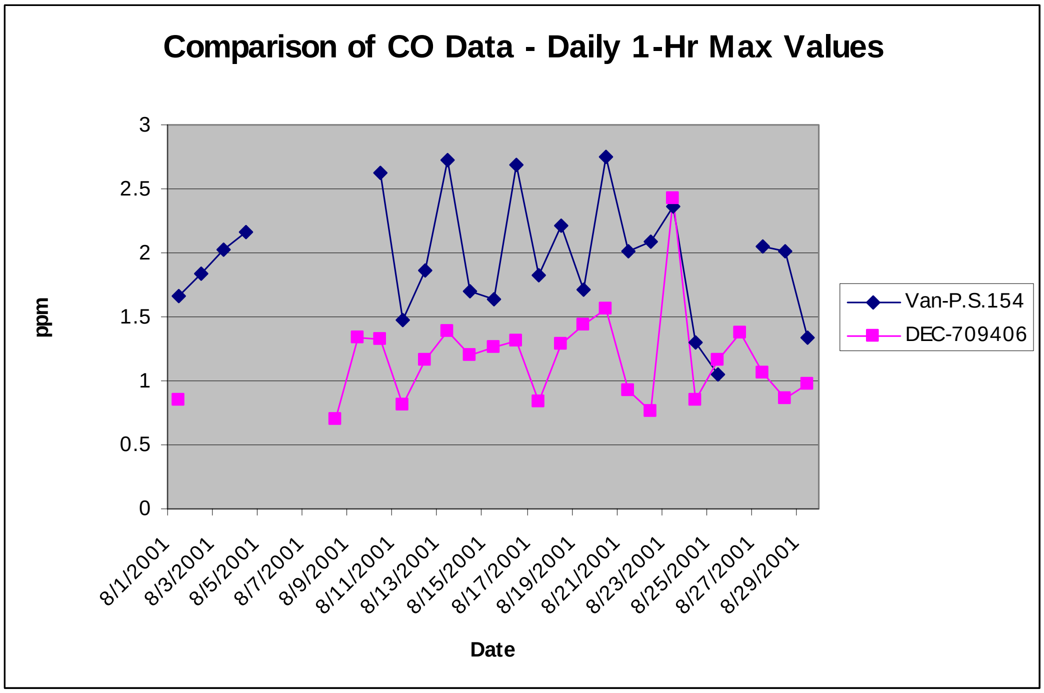


In general, it appears that the maximum 1-hour average concentrations recorded each day by the project's van are lower than those recorded by DEC's monitoring stations. During the periods for which data are available, both the van's and DEC's monitoring stations' measured concentrations are well below EPA's 1-hour standard.

VI. Carbon Monoxide (CO)

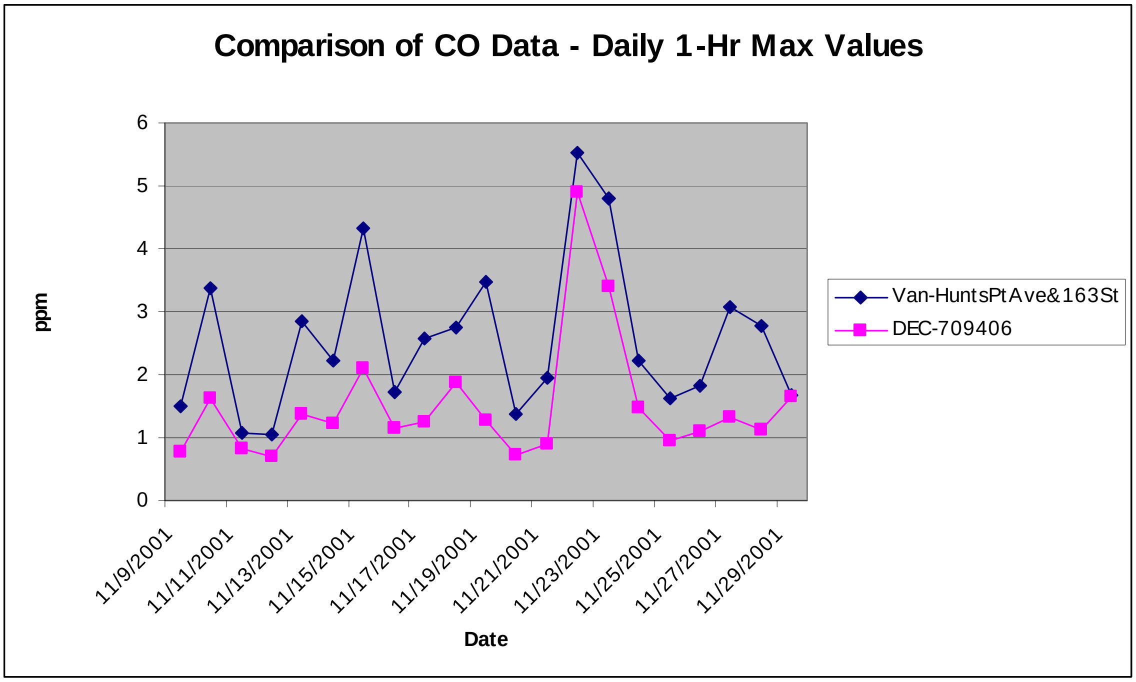
As with ozone, the data for carbon monoxide are presented as daily maximum 1-hour concentrations. This allows the data to be compared to one of EPA's CO standard. The one-hour standard is currently set at 35 ppm. As with the other pollutants, the first comparison is for the period August 1-28, 2001. During this period the van was located at P.S. 154. Data for comparison for this period are available from DEC station 709406. This is the only station which monitors CO in Bronx County. As the table and graph below show, during this period the daily maxima recorded by the van are significantly higher than those recorded by the DEC station.

Station	Average value for the period
Van	1.962 ppm
DEC-709406	1.169 ppm
EPA 1-hr CO Standard	35 ppm



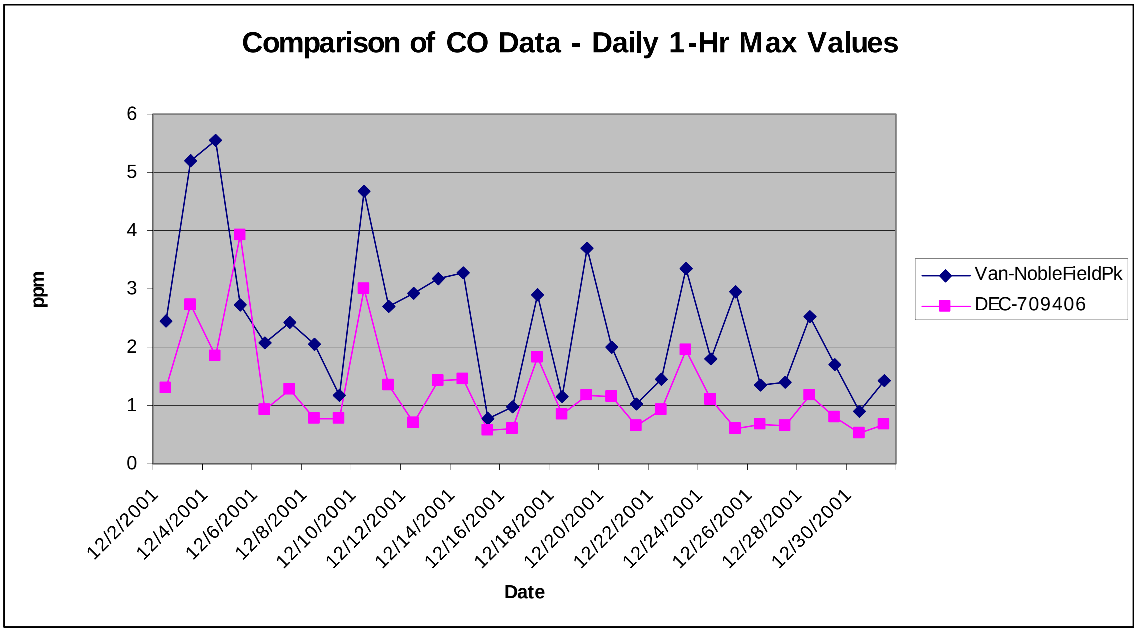
The second comparison is for the period November 9-29, 2001. During this period the van was located at Hunts Point Avenue and 163rd Street. As with the previous comparison, the highest daily 1-hour averages recorded by the van during this period were consistently higher than those recorded by DEC station 709406. The data are presented in the table and graph shown below.

Station	Average value for the period
Van	2.564 ppm
DEC-709406	1.512 ppm
EPA 1-hr CO Standard	35 ppm



The third comparison for carbon monoxide is for the period December 2-31, 2001. During this period the van was located at Noble Field Park. As with the previous two comparisons, the highest daily 1-hour averages recorded by the van were generally higher than those recorded by DEC's monitoring station. The data are presented in the table and graph shown below.

Station	Average value for the period
Van	2.390 ppm
DEC-709406	1.246 ppm
EPA 1-hr CO Standard	35 ppm



These comparisons suggest that the highest carbon monoxide 1-hour averages recorded each day by the project's van are generally higher than those recorded by DEC station 709406. However, both sets of measurements are well below EPA's 1-hour standard.

VII. Statistical Tests of Significance

A one way ANOVA analysis was carried out for the five pollutants to compare the means of van and DEC monitoring station data using SPSS. For each pollutant the comparison of means was carried out three times according to the availability of data: August, November and December. These were the three periods when the van collected data. The two tables below describe the location of DEC monitoring stations and van locations. All DEC stations in the Bronx are located 15 meters above ground. The intake of the van is located 4 meters above ground.

NYS DEC Air Quality Monitoring Station Information

Station ID	Location	Height Above Ground
709406	Bronx Botanical Garden, 200th St. at Southern Blvd.	15 meters
709407	I.S. 52 681 Kelly St., off 156th St.	15 meters
709408	I.S. 74 730 Bryant Ave.	15 meters
709409	P.S. 154 333 E. 135th St.	15 meters

Location of the Project's Van in 2001

Location	**Period**
P.S. 154	August 1-29, 2001
Hunts Point Avenue and 163rd Street	November 7-29, 2001
Noble Field Park	December 2-31, 2001

A comparison of means for August data for NO_2 is not possible because the DEC stations did not collect data during August, 2001. The results were as follows:

For nitrogen dioxide (NO_2) there are large differences between the van data and DEC data. In the comparison of means for the November and December periods the F test suggests rejecting the hypothesis that the means are equal.

For sulfur dioxide (SO_2) the van measurements are substantially higher than DEC stations in the month of August but similar in November and December. The results of the F test suggest that the hypothesis that the means are equal should be rejected for the August data but not for the November and December data.

For carbon monoxide (CO) the van measurements are substantially higher than DEC measurements. Only one DEC station measured CO concentrations in Bronx County during 2001 (station 709406). The results of the F tests suggest that the hypothesis that the means are equal should be rejected for the three sets of data (August, November and December).

For ozone (O_3) the van measurements are lower than DEC stations in August and November and similar in December. The results of the F tests suggest that the hypothesis that the means are equal should be rejected for August and November but not for December.

For particulate matter ($PM_{2.5}$), the van measurements are consistently similar to DEC stations. The results of the F tests suggest that the hypothesis that the means are equal should not be rejected for all the data sets under consideration.

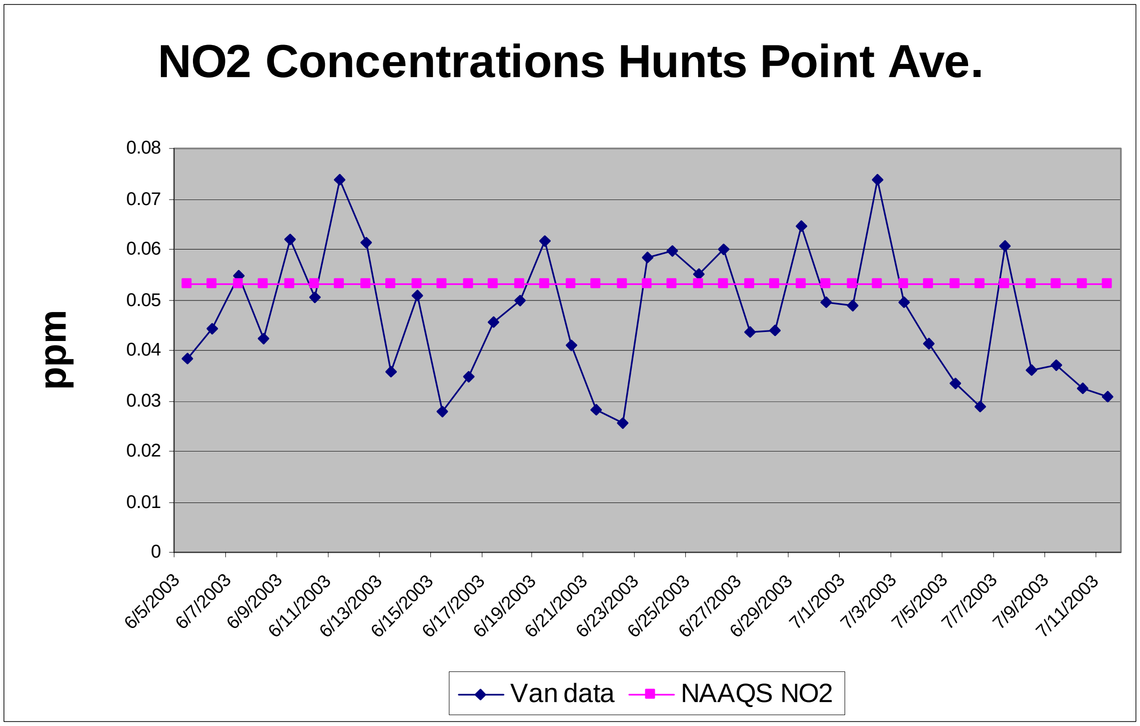
A more detailed description of the one-way ANOVA analyses carried out is shown in Appendix 1.

VIII. Update of Nitrogen Dioxide (NO_2) data

The findings of the comparisons included in this report suggest that the most significant difference between the project’s van air quality measurements and DEC monitoring stations refers to nitrogen dioxide (NO2). Additional measurements for NO_2 from the van taken in June and July 2003 are shown in the table and graph below. These measurements were taken at Hunts Point Avenue.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
NO2	37	.03	.07	.0469	.01296
Valid N (listwise)	37				



As the graph shows, the values are lower than those recorded by the van in other locations in 2001. However, they are still significantly higher than the values recorded by DEC stations in 2001 and comparable to the EPA annual standard. Since the EPA standard is an annual average, a direct comparison with it would require one year's worth of daily data.

IX. Summary of findings:

- For $PM_{2.5}$ the ground-level measurements are similar in value and trend with those of DEC stations. For example, during the period November 7-29, 2001, the average daily concentration recorded by the van was 16.70 μg/m^3. The average values for three DEC monitoring stations in the area ranged between 15.39 and 15.54 μg/m^3.

- In the case of ozone, the concentrations recorded at ground level were generally lower than those recorded by DEC stations. During the period November 7-29, the average daily concentration of O_3 recorded by the van was 0.0035 ppm. Two DEC stations in the area recorded daily averages of 0.0059 ppm and 0.0062 ppm. In order to compare the data with an EPA standard, the highest 1-hour average value was selected each day of the period and compared to DEC data. As with the daily averages, the daily maximum 1-hour averages recorded by the project's van were generally lower than those recorded by the DEC stations. During the periods for which data were collected both the van's and DEC's measured concentrations were below EPA's standard.

- For the other pollutants the concentrations measured by the project were substantially higher than those recorded by DEC's monitoring stations. For NO_2 the daily average concentrations recorded at ground level are over twice as high as those recorded by DEC stations. If the van's data are representative of concentrations of NO_2 in the area for the whole year, EPA's annual standard would be exceeded. NO_2 measurements taken by the van at Hunt’s Point Avenue in 2003 show values that are lower than those taken at other locations in 2001 but higher than DEC values taken in that year.

- In the case of SO_2, ground level measurements recorded by the project's van are also substantially higher than DEC measurements. They are about 40% greater than DEC's values. However, the van's measured concentrations as well as DEC's data suggest concentrations that are well below EPA's 24-hour average standard for SO_2.

- Similarly, CO concentrations measured at ground level tend to be higher than those recorded by DEC's stations. As with ozone, 1-hour average maximum values were selected each day in order to compare the data with EPA's 1-hour standard. Both the van's and DEC's measurements suggest concentrations of CO that are well below EPA's standard.

- In general, there appears to be good agreement among DEC stations on average pollutant concentrations. However, there are substantial differences between the data collected by DEC monitoring stations and those recorded by the project's van for some pollutants. The most striking differences appear to be for NO_2, SO_2 and CO, with the van's measurements being substantially higher than those of DEC's stations.

Future van measurements could be made at the same location as DEC's stations in order to make more direct comparisons between ground level measurements and measurements 15 meters above ground. Such comparisons would have important policy implications if the ground-level measurements are found to be consistently higher than DEC station measurements for some pollutants. It would suggest more ground-level measurements are needed to monitor potential health problems arising from air pollution and would suggest changing the location of monitoring stations.

APPENDIX 1: One-Way ANOVA Analyses

1. Nitrogen Dioxide (NO_2)

Comparison of means for November data

Oneway

Warnings

Post hoc tests are not performed for NO2NOV because there are fewer than three groups.

Descriptives

NO2NOV

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	13	.0753	.01234	.00342	.0678	.0828	.06	.10
2.00	13	.0328	.00706	.00196	.0285	.0370	.02	.04
Total	26	.0540	.02381	.00467	.0444	.0637	.02	.10

1.00 refers to van data and 2.00 refers to DEC station 709406.

Test of Homogeneity of Variances

NO2NOV

Levene Statistic	df1	df2	Sig.
4.874	1	24	.037

ANOVA

NO2NOV

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.012	1	.012	116.169	.000
Within Groups	.002	24	.000		
Total	.014	25			

The results of the F test suggest that the hypothesis that the means are equal should be rejected.

Comparison of means for December data

Oneway

Descriptives

NO2DEC

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	29	.0734	.01693	.00314	.0670	.0799	.05	.11
2.00	30	.0288	.00697	.00127	.0262	.0314	.02	.05
3.00	22	.0275	.00704	.00150	.0244	.0306	.02	.05
Total	81	.0444	.02462	.00274	.0390	.0499	.02	.11

In the above table 1.00 refers to the van data, 2.00 refers to DEC station 709406, and 3.00 refers to DEC station 709407.

Test of Homogeneity of Variances

NO2DEC

Levene Statistic	df1	df2	Sig.
13.263	2	78	.000

ANOVA

NO2DEC

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.038	2	.019	141.509	.000
Within Groups	.010	78	.000		
Total	.048	80			

The results of the F test suggest that the hypothesis that the means are equal for the three samples should be rejected.

Post Hoc Tests

Multiple Comparisons

Dependent Variable: NO2DEC
Tukey HSD

(I) MONITOR1	(J) MONITOR1	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.0446*	.00302	.000	.0374	.0518
	3.00	.0460*	.00328	.000	.0381	.0538
2.00	1.00	-.0446*	.00302	.000	-.0518	-.0374
	3.00	.0014	.00325	.908	-.0064	.0091
3.00	1.00	-.0460*	.00328	.000	-.0538	-.0381
	2.00	-.0014	.00325	.908	-.0091	.0064

*. The mean difference is significant at the .05 level.

Homogeneous Subsets

NO2DEC

Tukey HSD[a,b]

MONITOR1	N	Subset for alpha = .05 1	2
3.00	22	.0275	
2.00	30	.0288	
1.00	29		.0734
Sig.		.905	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 26.485.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

2. Sulfur Dioxide (SO_2)

Comparison of means for August data

Oneway

Warnings

Post hoc tests are not performed for SO2AUG because there are fewer than three groups.

Descriptives

SO2AUG

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Minimum	Maximum
1.00	22	.0192	.00674	.00144	.0162	.0222	.00	.04
2.00	23	.0057	.00303	.00063	.0043	.0070	.00	.02
Total	45	.0123	.00856	.00128	.0097	.0149	.00	.04

1.00 refers to van data and 2.00 to DEC station 709406.

Test of Homogeneity of Variances

SO2AUG

Levene Statistic	df1	df2	Sig.
6.350	1	43	.016

ANOVA

SO2AUG

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.002	1	.002	76.877	.000
Within Groups	.001	43	.000		
Total	.003	44			

The results of the F test suggest that the hypothesis that the means are equal should be rejected.

Comparison of means for November data

Oneway

Descriptives

SO2NOV

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	20	.0207	.01005	.00225	.0160	.0254	.01	.04
2.00	20	.0150	.00789	.00176	.0113	.0187	.00	.03
3.00	20	.0158	.00930	.00208	.0115	.0202	.00	.04
Total	60	.0172	.00932	.00120	.0148	.0196	.00	.04

1.00 refers to van data. 2.00 refers to DEC station 709406 and 3.00 refers to DEC station 709407.

Test of Homogeneity of Variances

SO2NOV

Levene Statistic	df1	df2	Sig.
.766	2	57	.469

ANOVA

SO2NOV

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.000	2	.000	2.276	.112
Within Groups	.005	57	.000		
Total	.005	59			

The results of the F test suggest that the hypothesis that the means are equal should not be rejected.

Post Hoc Tests

Multiple Comparisons

Dependent Variable: SO2NOV
Tukey HSD

(I) MONITOR4	(J) MONITOR4	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.0057	.00289	.126	-.0012	.0127
	3.00	.0048	.00289	.223	-.0021	.0118
2.00	1.00	-.0057	.00289	.126	-.0127	.0012
	3.00	-.0009	.00289	.950	-.0078	.0061
3.00	1.00	-.0048	.00289	.223	-.0118	.0021
	2.00	.0009	.00289	.950	-.0061	.0078

Homogeneous Subsets

SO2NOV

Tukey HSD[a]

MONITOR4	N	Subset for alpha = .05
		1
2.00	20	.0150
3.00	20	.0158
1.00	20	.0207
Sig.		.126

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 20.000.

Comparison of December data

Oneway

Descriptives

SO2DEC

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	30	.0173	.00610	.00111	.0150	.0196	.01	.03
2.00	30	.0140	.00511	.00093	.0121	.0159	.01	.03
3.00	30	.0152	.00483	.00088	.0134	.0171	.01	.03
Total	90	.0155	.00549	.00058	.0144	.0167	.01	.03

1.00 refers to van data. 2.00 refers to DEC station 709406 and 3.00 refers to DEC station 709407.

Test of Homogeneity of Variances

SO2DEC

Levene Statistic	df1	df2	Sig.
.672	2	87	.513

ANOVA

SO2DEC

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.000	2	.000	2.946	.058
Within Groups	.003	87	.000		
Total	.003	89			

The results of the F test suggest that the hypothesis that the means are equal should not be rejected.

Post Hoc Tests

Multiple Comparisons

Dependent Variable: SO2DEC
Tukey HSD

(I) MONITOR5	(J) MONITOR5	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
1.00	2.00	.0033*	.00139	.048	.0000	.0066
	3.00	.0021	.00139	.305	-.0013	.0054
2.00	1.00	-.0033*	.00139	.048	-.0066	.0000
	3.00	-.0013	.00139	.627	-.0046	.0020
3.00	1.00	-.0021	.00139	.305	-.0054	.0013
	2.00	.0013	.00139	.627	-.0020	.0046

*. The mean difference is significant at the .05 level.

Homogeneous Subsets

SO2DEC

Tukey HSD[a]

MONITOR5	N	Subset for alpha = .05: 1	2
2.00	30	.0140	
3.00	30	.0152	.0152
1.00	30		.0173
Sig.		.627	.305

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.000.

3. Carbon Monoxide (CO)

Comparison of means for August data

Oneway

Warnings

Post hoc tests are not performed for COAUG because there are fewer than three groups.

Descriptives

COAUG

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	23	1.9624	.46472	.09690	1.7614	2.1633	1.05	2.75
2.00	23	1.1691	.37052	.07726	1.0089	1.3293	.70	2.43
Total	46	1.5657	.57750	.08515	1.3942	1.7372	.70	2.75

1.00 refers to van data and 2.00 refers to DEC station 709406.

Test of Homogeneity of Variances

COAUG

Levene Statistic	df1	df2	Sig.
1.593	1	44	.214

ANOVA

COAUG

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7.236	1	7.236	40.971	.000
Within Groups	7.771	44	.177		
Total	15.008	45			

The result of the F test suggests that the hypothesis that the means are equal should be rejected.

Comparison of means for November data

Oneway

Warnings

Post hoc tests are not performed for CONOV because there are fewer than three groups.

Descriptives

CONOV

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	21	2.5637	1.21474	.26508	2.0107	3.1166	1.05	5.53
2.00	21	1.5124	.98350	.21462	1.0647	1.9601	.71	4.91
Total	42	2.0380	1.21436	.18738	1.6596	2.4164	.71	5.53

1.00 refers to van data and 2.00 refers to DEC station 709406.

Test of Homogeneity of Variances

CONOV

Levene Statistic	df1	df2	Sig.
2.072	1	40	.158

ANOVA

CONOV

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	11.605	1	11.605	9.501	.004
Within Groups	48.857	40	1.221		
Total	60.462	41			

The results of the F test suggest that the hypothesis that the means are equal should be rejected.

Comparison of means for December data

Oneway

Warnings

Post hoc tests are not performed for CODEC because there are fewer than three groups.

Descriptives

CODEC

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	30	2.3904	1.24401	.22712	1.9259	2.8550	.78	5.54
2.00	30	1.2458	.79377	.14492	.9494	1.5422	.54	3.93
Total	60	1.8181	1.18467	.15294	1.5121	2.1242	.54	5.54

1.00 refers to van data and 2.00 refers to DEC station 709406.

Test of Homogeneity of Variances

CODEC

Levene Statistic	df1	df2	Sig.
5.996	1	58	.017

ANOVA

CODEC

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	19.651	1	19.651	18.048	.000
Within Groups	63.151	58	1.089		
Total	82.803	59			

The results of the F test suggest that they hypothesis that the means are equal should be rejected.

4. Ozone (O3)

Comparison of means for August data

Oneway

Warnings

Post hoc tests are not performed for O3AUG because there are fewer than three groups.

Descriptives

O3AUG

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	23	.0160	.00681	.00142	.0131	.0190	.01	.03
2.00	23	.0262	.00840	.00175	.0226	.0298	.01	.04
Total	46	.0211	.00915	.00135	.0184	.0238	.01	.04

1.00 refers to van data and 2.00 refers to DEC station 709406.

Test of Homogeneity of Variances

O3AUG

Levene Statistic	df1	df2	Sig.
1.386	1	44	.245

ANOVA

O3AUG

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.001	1	.001	20.428	.000
Within Groups	.003	44	.000		
Total	.004	45			

The results of the F test suggest that the hypothesis that the means are equal should be rejected.

Comparison of November data

Oneway

Descriptives

O3NOV

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	21	.0035	.00333	.00073	.0020	.0050	.00	.01
2.00	21	.0059	.00351	.00076	.0043	.0075	.00	.01
3.00	21	.0062	.00451	.00098	.0042	.0083	.00	.02
Total	63	.0052	.00395	.00050	.0042	.0062	.00	.02

1.00 refers to van data, 2.00 refers to DEC station 709406 and 3.00 refers to DEC station 709407.

Test of Homogeneity of Variances

O3NOV

Levene Statistic	df1	df2	Sig.
2.220	2	60	.117

ANOVA

O3NOV

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.000	2	.000	3.219	.047
Within Groups	.001	60	.000		
Total	.001	62			

The results of the F test suggest that they hypothesis that the means are equal should be rejected.

Post Hoc Tests

Multiple Comparisons

Dependent Variable: O3NOV
Tukey HSD

(I) MONITO10	(J) MONITO10	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.0024	.00118	.112	-.0052	.0004
	3.00	-.0027	.00118	.059	-.0056	.0001
2.00	1.00	.0024	.00118	.112	-.0004	.0052
	3.00	-.0003	.00118	.954	-.0032	.0025
3.00	1.00	.0027	.00118	.059	-.0001	.0056
	2.00	.0003	.00118	.954	-.0025	.0032

Homogeneous Subsets

O3NOV

Tukey HSD[a]

MONITO10	N	Subset for alpha = .05
		1
1.00	21	.0035
2.00	21	.0059
3.00	21	.0062
Sig.		.059

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 21.000.

Comparison of December data

Oneway

Descriptives

O3DEC

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	30	.0049	.00289	.00053	.0038	.0060	.00	.01
2.00	30	.0052	.00341	.00062	.0039	.0065	.00	.01
3.00	30	.0046	.00346	.00063	.0033	.0059	.00	.01
Total	90	.0049	.00324	.00034	.0042	.0056	.00	.01

1.00 refers to van data, 2.00 refers to DEC station 709406 and 3.00 refers to DEC station 709407.

Test of Homogeneity of Variances

O3DEC

Levene Statistic	df1	df2	Sig.
.652	2	87	.524

ANOVA

O3DEC

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.000	2	.000	.229	.796
Within Groups	.001	87	.000		
Total	.001	89			

The result of the F test suggests that the hypothesis that the means are equal should not be rejected.

Post Hoc Tests

Multiple Comparisons

Dependent Variable: O3DEC
Tukey HSD

(I) MONITO11	(J) MONITO11	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.0003	.00084	.932	-.0023	.0017
	3.00	.0003	.00084	.946	-.0017	.0023
2.00	1.00	.0003	.00084	.932	-.0017	.0023
	3.00	.0006	.00084	.778	-.0014	.0026
3.00	1.00	-.0003	.00084	.946	-.0023	.0017
	2.00	-.0006	.00084	.778	-.0026	.0014

Homogeneous Subsets

O3DEC

Tukey HSD[a]

MONITO11	N	Subset for alpha = .05
		1
3.00	30	.0046
1.00	30	.0049
2.00	30	.0052
Sig.		.778

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.000.

5. Particulate Matter ($PM_{2.5}$)

Comparison of means for August Data

Oneway

Descriptives

PMAUG

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	23	25.0519	9.31496	1.94230	21.0238	29.0800	8.83	51.39
2.00	29	24.6422	11.33561	2.10497	20.3303	28.9540	8.29	53.68
3.00	29	24.7600	10.18741	1.89175	20.8849	28.6351	8.64	51.06
Total	81	24.8007	10.25607	1.13956	22.5329	27.0685	8.29	53.68

1.00 refers to van data, 2.00 refers to DEC station 709408 and 3.00 refers to DEC station 709409.

Test of Homogeneity of Variances

PMAUG

Levene Statistic	df1	df2	Sig.
.251	2	78	.779

ANOVA

PMAUG

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.228	2	1.114	.010	.990
Within Groups	8412.731	78	107.856		
Total	8414.959	80			

The results of the F test suggest that the hypothesis that the means are equal should not be rejected.

Post Hoc Tests

Multiple Comparisons

Dependent Variable: PMAUG
Tukey HSD

(I) MONITO12	(J) MONITO12	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.4097	2.89975	.989	-6.5185	7.3380
	3.00	.2919	2.89975	.994	-6.6364	7.2201
2.00	1.00	-.4097	2.89975	.989	-7.3380	6.5185
	3.00	-.1178	2.72733	.999	-6.6341	6.3985
3.00	1.00	-.2919	2.89975	.994	-7.2201	6.6364
	2.00	.1178	2.72733	.999	-6.3985	6.6341

Homogeneous Subsets

PMAUG

Tukey HSD[a,b]

MONITO12	N	Subset for alpha = .05 1
2.00	29	24.6422
3.00	29	24.7600
1.00	23	25.0519
Sig.		.989

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 26.680.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Comparison of means for November data

Oneway

Descriptives

PMNOV

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	21	16.7003	7.72647	1.68605	13.1833	20.2174	6.18	36.94
2.00	21	15.2478	7.26249	1.58481	11.9419	18.5536	6.31	35.47
3.00	21	15.3585	8.16313	1.78134	11.6427	19.0743	5.69	39.51
4.00	21	15.4539	7.55476	1.64858	12.0150	18.8928	6.74	36.87
Total	84	15.6901	7.56664	.82559	14.0481	17.3322	5.69	39.51

1.00 refers to van data, 2.00 refers to DEC station 709407, 3.00 refers to DEC station 709408, and 4.00 refers to station 709409.

Test of Homogeneity of Variances

PMNOV

Levene Statistic	df1	df2	Sig.
.134	3	80	.939

ANOVA

PMNOV

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	29.022	3	9.674	.164	.920
Within Groups	4723.066	80	59.038		
Total	4752.088	83			

The result of the F test suggests that the hypothesis that the means are equal should not be rejected.

Post Hoc Tests

Multiple Comparisons

Dependent Variable: PMNOV
Tukey HSD

(I) MONITO13	(J) MONITO13	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
1.00	2.00	1.4526	2.37122	.928	-4.7692	7.6744
	3.00	1.3418	2.37122	.942	-4.8799	7.5636
	4.00	1.2464	2.37122	.953	-4.9753	7.4682
2.00	1.00	-1.4526	2.37122	.928	-7.6744	4.7692
	3.00	-.1108	2.37122	1.000	-6.3325	6.1110
	4.00	-.2061	2.37122	1.000	-6.4279	6.0156
3.00	1.00	-1.3418	2.37122	.942	-7.5636	4.8799
	2.00	.1108	2.37122	1.000	-6.1110	6.3325
	4.00	-.0954	2.37122	1.000	-6.3172	6.1264
4.00	1.00	-1.2464	2.37122	.953	-7.4682	4.9753
	2.00	.2061	2.37122	1.000	-6.0156	6.4279
	3.00	.0954	2.37122	1.000	-6.1264	6.3172

Homogeneous Subsets

PMNOV

Tukey HSD[a]

MONITO13	N	Subset for alpha = .05: 1
2.00	21	15.2478
3.00	21	15.3585
4.00	21	15.4539
1.00	21	16.7003
Sig.		.928

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 21.000.

Comparison of means for December data

Oneway

Descriptives

PMDEC

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	27	12.7935	5.02136	.96636	10.8071	14.7799	5.14	24.23
2.00	27	12.0481	4.33431	.83414	10.3335	13.7627	5.31	23.05
3.00	27	12.2710	4.66355	.89750	10.4261	14.1158	5.74	25.26
4.00	27	12.0423	5.22416	1.00539	9.9757	14.1089	5.58	25.77
Total	108	12.2887	4.76470	.45848	11.3798	13.1976	5.14	25.77

1.00 refers to van data, 2.00 refers to DEC station 709407, 3.00 refers to DEC station 709408 and 4.00 refers to DEC station 709409.

Test of Homogeneity of Variances

PMDEC

Levene Statistic	df1	df2	Sig.
.366	3	104	.778

ANOVA

PMDEC

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10.091	3	3.364	.145	.933
Within Groups	2419.062	104	23.260		
Total	2429.153	107			

The result of the F test suggests that the hypothesis that the means are equal should not be rejected.

Post Hoc Tests

Multiple Comparisons

Dependent Variable: PMDEC
Tukey HSD

(I) MONITO14	(J) MONITO14	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.7454	1.31262	.941	-2.6819	4.1727
	3.00	.5225	1.31262	.979	-2.9048	3.9499
	4.00	.7512	1.31262	.940	-2.6761	4.1786
2.00	1.00	-.7454	1.31262	.941	-4.1727	2.6819
	3.00	-.2229	1.31262	.998	-3.6502	3.2045
	4.00	.0058	1.31262	1.000	-3.4215	3.4332
3.00	1.00	-.5225	1.31262	.979	-3.9499	2.9048
	2.00	.2229	1.31262	.998	-3.2045	3.6502
	4.00	.2287	1.31262	.998	-3.1986	3.6560
4.00	1.00	-.7512	1.31262	.940	-4.1786	2.6761
	2.00	-.0058	1.31262	1.000	-3.4332	3.4215
	3.00	-.2287	1.31262	.998	-3.6560	3.1986

Homogeneous Subsets

PMDEC

Tukey HSD[a]

MONITO14	N	Subset for alpha = .05
		1
4.00	27	12.0423
2.00	27	12.0481
3.00	27	12.2710
1.00	27	12.7935
Sig.		.940

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 27.000.

Chapter 3

Transportation and Traffic Modeling for the South Bronx Environmental Health and Policy Study

José Holguín-Veras, Ellen Thorson, Athanasios Ziliaskopoulos, Kyriacos Mouskos, David Sackey, Arun Kochar and Curtis Barret

I.Introduction

This report discusses the methodology and key results corresponding to the work conducted for the "Transportation and Traffic Modeling for the South Bronx Environmental Health and Policy Study." This chapter describes the tasks of Traffic Simulation, Transportation Demand Analysis, and provides an overview of the key findings. This report was put together by Professor José Holguín-Veras and Ms. Ellen Thorson with the cooperation of Professor Athanasios Ziliaskopoulos, Professor Kyriacos Mouskos, and a set of graduate students, including David Sackey, Arun Kochar and Curtis Barret.

II.Network Identification and Modeling Needs

The first step of the project was to identify the boundaries of the study area. The study area, shown in Figure 1, is delimited by the I-95/Cross Bronx in the North, Bruckner Blvd., the Hunts Point peninsula, and 134th Street in the South, and Major Deegan Exp. in the West. The study area selected contains the portions of the South Bronx with the most acute environmental problems.

Once the boundaries of the project were identified, the necessary modeling needs for transportation planning and traffic simulation were identified in consultations with the Project Manager from New York University, Professor Rae Zimmerman, and the environmental modeler, Dr. Bruce Egan. It was decided that the key focus of the transportation and traffic modeling exercise must be to provide the input necessary for appropriate environmental modeling. In this regard, the Measures of Effectiveness (MOEs) to be used in the study were defined to a great extent by the needs of the environmental modeling process.

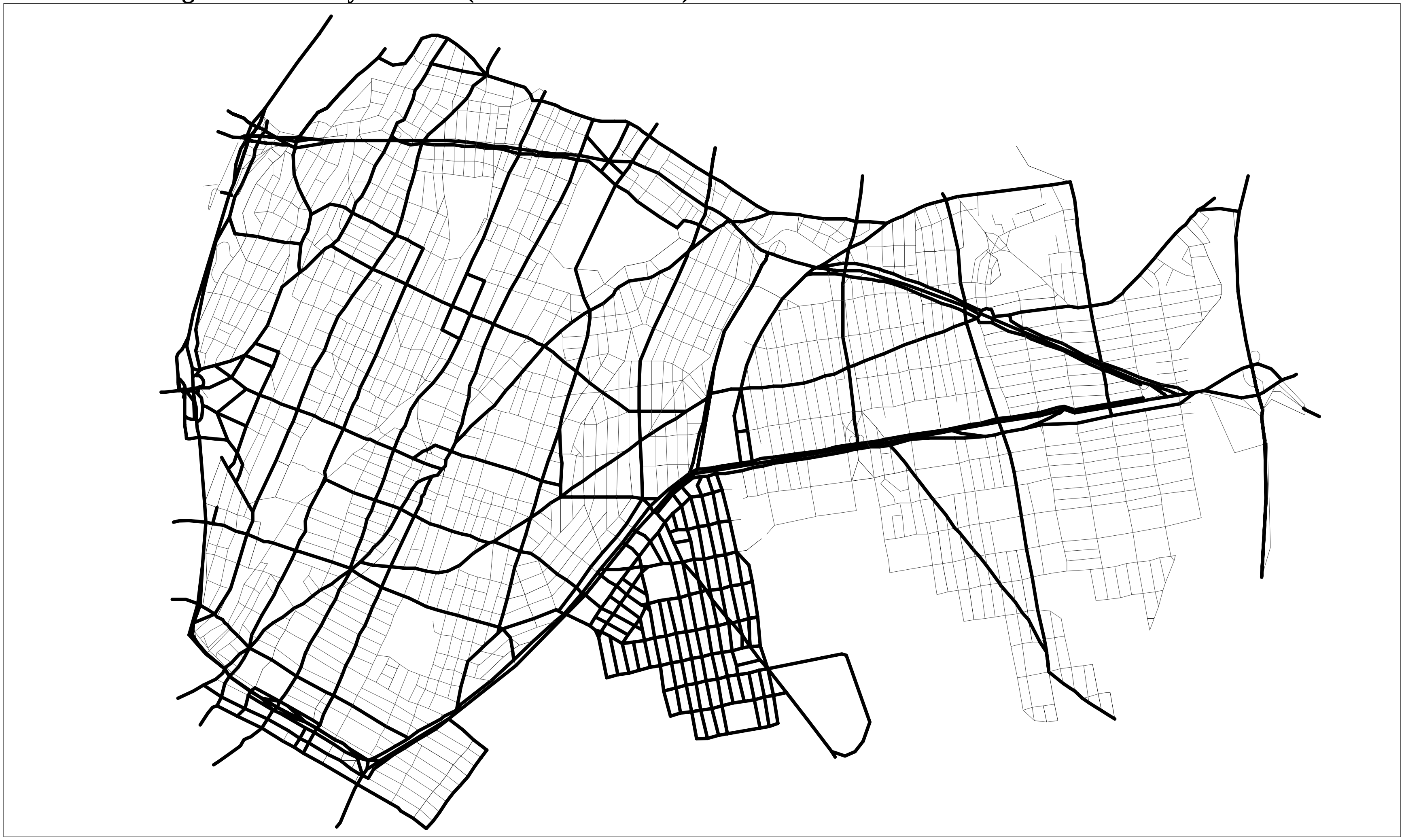
The project team also defined the primary network to be used in the simulation process. This network, a subset of the one shown in Figure 1, represents the links that became part of the simulation process. The decision to simplify the network was absolutely necessary because of the data constraints. The primary network is shown in Figure 2.

The project team defined the input data, and the corresponding format, for the environmental modeling process. Two tests were conducted to ensure that the project team members were able to produce the input file needed for environmental analyses. Both tests were successful.
A Geographic Information System (GIS) was created with the network of the study area. The GIS was designed to store all the relevant data for both traffic and environmental modeling. All necessary geometric, traffic flow data and traffic surveillance/control equipment either in place or planned were coded (and/or converted from existing databases) into the GIS. The resulting

GIS was used to store and consolidate the data gathered during the project, particularly traffic and network data. The following section provides a summary of the data collected during this project.

Figure 1: Study area

Figure 2: Primary network (in thick black lines)



III.Review of Existing Data Sources and Identification of Data Needs

Based on the identification of available data sources conducted in the first phase of the South Bronx Environmental Health and Policy Study, the project team identified the following data needs:

- **Traffic data** which consists of vehicular traffic counts at the different segments of the highway network in the study area. Sources of data: NYSDOT, NYCDOT, and Urbitran and Associates.

- **Traffic control data** which consists of signal timing, lane designation, traffic coordination plans and the like. Sources of data: NYCDOT and manual observations by the project team Holguin-Veras and Associates.

- **Descriptors of the key features of commercial vehicles** such as breakdown by fuel type, size, age, etc. which are needed for environmental modeling purposes. Sources of data: Vehicle Inventory and Use Survey (VIUS).

The following sections provide brief descriptions of the work done in the different areas.

4.1 Traffic data

An important sub-task is related with the preparation and assembly of the traffic data needed for preliminary modeling of traffic and, ultimately, air pollution. In this regard, the project team assembled the traffic data sets already collected by the local agencies and converted the hard copies into electronic files which were included as part of the GIS system of the project. The process followed consisted of:

- Contacting NYSDOT and NYCDOT to obtain accurately the locations of traffic monitoring stations in the South Bronx, including electronic files for traffic data, and updates of the traffic data.

- Conversion of the traffic data, originally in paper copies, to electronic files.

- Geocoding of the traffic data into the project GIS.

- Estimation of traffic volumes per hour, both peak and average estimates by vehicle type.

- Geocoding and interpolation of NYS/NYCDOT data where data is inadequate or missing.

The bulk of the traffic data was provided by the NYSDOT Region 11. The data included traffic counts from 1999, 2000, and 2001.

The project team analyzed the data sets corresponding to the different years and concluded that the most complete data set is the one for 2001. Figure 3 shows the actual Average Annual Daily Traffic (AADT) for the different highway segments from the 2001 data set. As shown, the available traffic data is relatively limited (approximately 35 traffic stations). This situation provides the rationale for simplifying the simulation exercise. The project team proceeded to complement the traffic data for 2001 with estimates of the traffic counts made from the other years for those highway segments with no 2001 data.

Figure 4 shows the traffic data superimposed on the primary network, which also has a significant number of data gaps, though not as severe as in the case shown in Figure 3. Finally, Figure 5 provides an illustration of the peak hour traffic in key segments of the network.

4.2 Traffic control data

The project team contacted the Office of the Freedom of Information Act at NYCDOT to obtain permission to receive the traffic control data for the study area. The NYCDOT provided a study that was undertaken using traffic flow data in 1995 for a subsection of the South Bronx Environmental Health and Policy Study area as defined earlier, as well as traffic signal data for the key intersections. These data were incorporated in the Visual Interactive System for Transport Algorithms (VISTA) model.

Figure 3: Average Annual Daily Traffic (AADT) for 2001

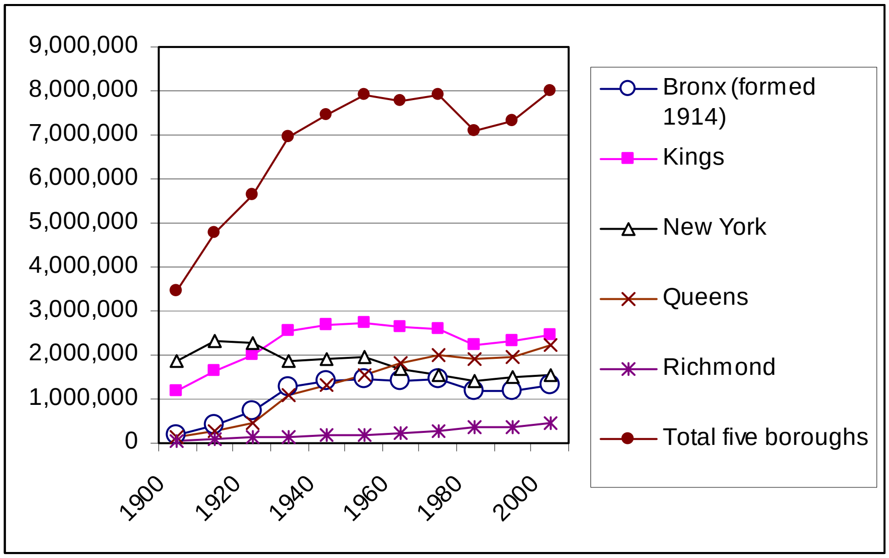
Figure 4: AADT in primary network

Figure 5: Peak hour traffic in the network

IV.Socio-economic features of passenger transportation demand in the Bronx

The population of Bronx County has largely followed the same pattern as New York City. After peaking at 1.47 million people in 1970, the population of the Bronx declined to 1.17 million in 1980, and then climbed back up to 1.20 million in 1990 and 1.33 million in 2000 (see Figure 6).

Figure 6: Population in New York City boroughs 1900-2000



Source: U.S. Bureau of the Census

The percentage of unemployment, measured as a percentage of the labor force, (see Table 1), for the Bronx County (14.3%) exceeds the values corresponding to both New York City (9.6%) and New York State (7.1%). Equally significant, the census data show that unemployment in the Bronx increased from 11.9% (1990) to 14.3% (2000) indicating that the Bronx not only did not benefit from the stock market boom, but that its economic situation deteriorated.

Table 1: Employment status in Bronx County (1990-2000)

	1990	2000
EMPLOYMENT STATUS		
Population 16 years and over	**905,919**	**975,755**
In labor force	502,324	500,716
Civilian labor force	501,669	500,345
Employed	441,957	428,654
Unemployed	59,712	71,691
Percent of civilian labor force	11.9	14.3
Armed Forces	655	371
Not in labor force	403595	475039

Source: Table DP-2 Profile of Selected Social Characteristics 1990 and 2000, Bureau of the Census

In terms of household income, the census data found no noticeable changes between the censuses, once the figures are adjusted for inflation (see Table 2). This is consistent with the finding made about unemployment in Bronx County.

Table 2: Income distribution (1990-2000)

	1990		**2000**	
INCOME IN 1989, 1999 (1)				%
Households	423,191	100.0	463,242	100.0
Less than $10,000	121,678	28.8	109,177	23.6
$10,000 to $14,999	37,006	8.7	40,001	8.6
$15,000 to $24,999	73,093	17.3	63,874	13.8
$25,000 to $34,999	58,045	13.7	60,959	13.2
$35,000 to $49,999	60,105	14.2	65,028	14.0
$50,000 to $74,999	47,593	11.2	65,911	14.2
$75,000 to $99,999	16,024	3.8	30,029	6.5
$100,000 to $149,999	7,262	1.7	19,618	4.2
$150,000 or more	2,385	0.6		
$150,000 to $199,999			4,351	0.9
$200,000 or more			4,294	0.9
Median household income (dollars) (2)	21,944	(X)	27,611	(X)

(1) The Bureau of Labor Statistics' Consumer Price Index (CPI-U-RS) is 187.1 for 1989 and 244.1 for 1999. To adjust 1989 median, mean, and per capita dollar values to 1999 constant dollars, multiply 1989 dollar values by 244.1/187.1, or by 1.304650.

(2) (X) Not applicable

Source: Table DP-2 Profile of Selected Social Characteristics 1990 and 2000, Bureau of the Census

Two different sources provide data about the overall pattern of trips in the Bronx. The first one is the journey to work data, collected as part of the population census. The second one is the "Nationwide Personal Transportation Survey" (NPTS). This section provides a brief summary of their key findings pertaining to Bronx County. (Unfortunately, none of these data sources provide estimates for the South Bronx).

The Census data provide useful information about commute to work patterns in Bronx County (see Table 3). The census data indicate that, following the national trend, residents in Bronx County became more reliant on passenger cars. As shown, the percentage of respondents who drive alone to work increased from 24.9% in 1980 to 27.0% in 1990, which is significant given the extensive transit system available in New York City. This shift came at the expense of transit that experienced a reduction in share from 56.6% in 1980 to 53.7% in 1990. The journey to work data highlight an increase in the mean travel time to work, from 38.9 minutes per trip (1990) to 43.0 minutes (2000), that represents a 10% increase in ten years.

Table 3: Journey to work 1990-2000

	1990		2000	
COMMUTING TO WORK		%		%
Workers 16 years and over	429,777	100.0	415,075	100.0
Car, truck, or van - - drove alone	107,020	24.9	112,159	27.0
Car, truck, or van - - carpooled	40,769	9.5	38,726	9.3
Public transportation (including taxicab)	243,201	56.6	222,835	53.7
Walked	30,422	7.1	30,076	7.2
Other means	2,986	0.7	3,523	0.8
Worked at home	5,379	1.3	7,756	1.9
Mean travel time to work (minutes) (1)	38.9	(X)	43.0	(X)

(1) (X) Not applicable.

Source: Table DP-2 Profile of Selected Social Characteristics 1990 and 2000, Bureau of the Census

The trip length distribution for the journey to work is shown in Table 4. This table contains the number of trips made for the various trip lengths (in minutes), which could be interpreted as the statistical distribution for probabilistic analyses. (The data corresponding to the 2000 Census has not yet been released.)

Table 4: Trip length distribution for journey to work (1990)

Travel Time to Work	
Minutes	**Trips**
0 - 4	4,884
5 - 9	16,247
10 - 14	30,206
15 - 19	37,283
20 - 24	36,030
25 - 29	13,328
30 - 34	63,942
35 - 39	11,029
40 - 44	19,606
45 - 59	74,444
60 - 89	96,713
90 or more	20,686
Average	39 Minutes

Source: 1990 Journey to Work Data, Bureau of the Census

The 1990 Nationwide Personal Transportation Survey provides estimates of the total number of trips made in Bronx County (shown in Table 5). As shown, work trips comprise 24% of the total number of trips made. The breakdown by transportation mode indicates that, in 1990, transit was the predominant form of transportation for work trips, with 54% of the total. For all other trips, motor vehicle transportation is the dominant mode with 40% of the trips.

Table 5: Breakdown of trips purpose and mode (NPTS, 1990)

	County Total Trip Purposes in Thousands				
	Work Trips	Other Trips	Total Trip Purposes	Work Trips %	Other Trips %
Motor vehicle	144	602	746	19%	81%
Mass transit	262	347	609	43%	57%
Other modes	75	557	632	12%	88%
Total	481	1506	1987	24%	76%
Motor vehicle	30%	40%	38%		
Mass transit	54%	23%	31%		
Other modes	16%	37%	32%		
Total	100%	100%	100%		

	County Average Vehicle Occupancy			
	Work Trips	Shopping	Social/Rec	Other
Auto	1.31	2.05	2.42	1.84

Source: 1990 Nationwide Personal Transportation Survey

Table 6 shows the breakdown of destinations for the journey to work from the 1990 population census (the 2000 data are not available yet). These numbers represent the places of work of Bronx residents.

Table 6: Counties of destination for journey to work trips (1990)

From Bronx County to:	Total number of trips/day			Total	Generic mode share %		
	Auto	Transit	Other	Workers*	Auto Trips	Mass Transit	Other Modes
New York City-Subtotal	**120,573**	**226,434**	**32,202**	**379,209**	**32%**	**60%**	**8%**
Bronx	73,906	68,756	30,552	173,214	43%	40%	18%
Kings	5,528	10,527	228	16,283	34%	65%	1%
New York	30,633	138,491	1,194	170,318	18%	81%	1%
Queens	10,118	8,138	194	18,450	55%	44%	1%
Staten Island	388	522	34	944	41%	55%	4%
Long Island-Subtotal	**2,458**	**1,168**	**99**	**3,725**	**66%**	**31%**	**3%**
Nassau	1,918	1,038	79	3,035	63%	34%	3%
Suffolk	540	130	20	690	78%	19%	3%
Hudson Valley-Subtotal	**19,660**	**7,690**	**531**	**27,881**	**71%**	**28%**	**2%**
Westchester	18,554	7,327	509	26,390	70%	28%	2%
Rockland	875	187	10	1,072	82%	17%	1%
Putnam	86	36	0	122	70%	30%	0%
Orange	60	80	0	140	43%	57%	0%
Dutchess	85	60	12	157	54%	38%	8%
New York State-Subtotal	**142,691**	**235,292**	**32,832**	**410,815**	**35%**	**57%**	**8%**
New Jersey-Subtotal	**6,546**	**3,350**	**158**	**10,054**	**65%**	**33%**	**2%**
Bergen	3,749	2,284	99	6,132	61%	37%	2%
Essex	463	162	27	652	71%	25%	4%
Hudson	1,035	690	0	1,725	60%	40%	0%
Middlesex	249	83	0	332	75%	25%	0%
Monmouth	49	0	0	49	100%	0%	0%
Morris	208	34	0	242	86%	14%	0%
Passaic	364	35	7	406	90%	9%	2%
Somerset	96	37	16	149	64%	25%	11%
Union	333	25	9	367	91%	7%	2%
Connecticut	**1,249**	**194**	**11**	**1,454**	**86%**	**13%**	**1%**
Total Region	**150,486**	**238,836**	**33,001**	**422,323**	**36%**	**57%**	**8%**

Note: * It represents the workers captured in the Census.

V. Descriptors of the key features of commercial vehicles

An important piece of information for environmental modeling is related to the key features of the commercial vehicles in the study area. Since obtaining accurate estimates of the characteristics of the truck fleets using the South Bronx was not possible because of project constraints, the project team decided to produce estimates based on the 1997 Vehicle Inventory and Use Survey (VIUS) which is a study conducted every five years by the US Department of Commerce (at the time of conducting the analyses, the 2002 VIUS had not been released). The VIUS collects data about truck fleets in the Nation that could be used to produce tabulations at the State level.

Table 7 shows the breakdown by type of fuel and model year for both the entire US and the State of New York. Table 8 shows the breakdown by engine type and type of fuel. Table 9 shows the breakdown by truck size and fuel type. The classification used in Table 9 is described below:

Light - The average vehicle weight is 10,000 lbs. or less.
Medium - The average vehicle weight is 10,001 to 19,500 lbs.
Light-heavy - The average vehicle weight is 19,501 to 26,000 lbs.
Heavy-heavy - The average vehicle weight is 26,001 lbs. or more.

Table 10 shows the breakdown by axle type and engine type. Table 11 shows the breakdown by model year and vehicle size. Table 12 shows the breakdown by miles per gallon and engine type. Table 13 shows the breakdown by engine displacement and engine type. Table 14 shows the breakdown by gross vehicle weight and engine type.

Table 7: Type of fuel and model year (US and New York)

BASTATE	US Total											
MDLYR	Total	1998-97	'96	'95	'94	'93	'92	'91	'90	'89	'88	Pre '88
ENGTYP												
Total	72800252	4903972	5655686	6007569	5699832	5028878	3954694	3988459	3832564	4298131	4141205	25289261
Leaded gasoline	3769288	139089	181006	216697	205913	128350	117998	116176	111608	119830	124616	2308005
Unleaded gasoline	63683354	4397838	5086496	5259967	5046958	4542413	3588375	3584239	3450006	3910692	3758387	21057982
Diesel	4913343	359399	380635	512807	432653	341744	227263	270726	251453	253054	245181	1638429
Liquefied gas (LPG or LNG)	116899	980	1812	3746	7084	3628	10007	12250	1766	2732	2946	69947
Other	124208	3336	805	8695	2000	8769	7339	2083	10160	8740	3147	69135
Not reported	193161	3330	4932	5657	5223	3973	3714	2986	7571	3083	6927	145763

BASTATE	New York											
MDLYR	Total	1998-97	'96	'95	'94	'93	'92	'91	'90	'89	'88	Pre '88
ENGTYP												
Total	2713651	225829	277370	276863	182862	167395	128281	177397	88800	168184	176721	843948
Leaded gasoline	133160	22474	8842	13748	13140	4544	-	4544	4544	362	9088	51874
Unleaded gasoline	2399877	188531	257861	250020	161022	147927	123087	157175	72613	156607	159445	725590
Diesel	169831	14823	10602	13095	8338	14925	5194	15317	11644	6671	7826	61397
Liquefied gas (LPG or LNG)	5746	-	-	-	362	-	-	362	-	-	362	4660
Other	4544	-	-	-	-	-	-	-	-	4544	-	-
Not reported	492	-	65	-	-	-	-	-	-	-	-	427

Table 8: Engine type and type of fuel (US and New York)

BASTATE	US Total						
ENGTYP	Total	Leaded gasoline	Unleaded gasoline	Diesel	Liquefied gas (LPG or LNG)	Other	Not reported
PKENGSZE							
Total	72800252	3769288	63683354	4913343	116899	124208	193161
4 cylinders	11040466	432271	10431073	161602	63	13603	1854
6 cylinders	32365358	1296533	28431493	2564499	17008	47061	8764
8 cylinders	27067107	1684714	23413394	1722596	89874	56589	99941
All other cylinders	62163	1653	57687	2668	-	-	155
Not reported	2265158	354117	1349706	461978	9954	6956	82446

BASTATE	New York						
ENGTYP	Total	Leaded gasoline	Unleaded gasoline	Diesel	Liquefied gas (LPG or LNG)	Other	Not reported
PKENGSZE							
Total	2713651	133160	2399877	169831	5746	4544	492
4 cylinders	377535	13140	353956	10439	-	-	-
6 cylinders	1432821	67798	1277602	78579	4298	4544	-
8 cylinders	851167	48013	736472	64807	1448	-	428
All other cylinders	65	-	-	65	-	-	-
Not reported	52063	4208	31847	15942	-	-	65

Table 9: Truck size and fuel type (US and New York)

BASTATE	US Total						
ENGTYP	Total	Leaded gasoline	Unleaded gasoline	Diesel	Liquefied gas (LPG or LNG)	Other	Not reported
VEHSZE							
Total	72800252	3769288	63683354	4913343	116899	124208	193161
Light	68099912	3614262	62409809	1763429	77783	116839	117790
Medium	1435528	82369	777007	509709	14968	4260	47216
Light-heavy	729263	44138	296206	355683	15878	1569	15789
Heavy-heavy	2535549	28519	200332	2284522	8270	1540	12366

BASTATE	New York						
ENGTYP	Total	Leaded gasoline	Unleaded gasoline	Diesel	Liquefied gas (LPG or LNG)	Other	Not reported
VEHSZE							
Total	2713651	133160	2399877	169831	5746	4544	492
Light	2561846	126945	2360935	64696	4660	4544	65
Medium	56865	3389	26653	26099	362	-	362
Light-heavy	26986	1709	8917	15570	724	-	65
Heavy-heavy	67955	1116	3372	63466	-	-	-

Note:
Light - The average vehicle weight is 10,000 lbs. or less.
Medium - The average vehicle weight is 10,001 to 19,500 lbs.
Light-heavy - The average vehicle weight is 19,501 to 26,000 lbs.
Heavy-heavy - The average vehicle weight is 26,001 lbs. or more.

Table 10: Axle type and engine type (NY)

BASTATE	New York						
ENGTYP	Total	Leaded gasoline	Unleaded gasoline	Diesel	Liquefied gas (LPG or LNG)	Other	Not reported
AXLRE							
Total	2713651.3	133159.74	2399877.4	169831.48	5746.341	4543.901	492.407
Single 1	2499637.3	127865.24	2299048.5	63026.949	5022.289	4543.901	130.381
Single 2	127103.31	3882.18	72269.361	49865.686	724.052	-	362.026
Single 3	19151.106	195.861	1674.24	17281.005	-	-	-
Single 4	3151.545	-	-	3151.545	-	-	-
Straight 1	9269.644	-	9204.164	65.48	-	-	-
Straight 2	10783.228	724.052	9928.216	130.96	-	-	-
Straight 3	4298.237	-	-	4298.237	-	-	-
Straight 4	1840.405	-	855.012	985.393	-	-	-
Straight 5	7757.894	65.48	5811.821	1880.593	-	-	-
Straight 6	788.953	-	724.052	64.901	-	-	-
Straight 7	65.48	-	-	65.48	-	-	-
Straight 8	260.762	-	-	260.762	-	-	-
Straight 9	427.506	-	-	427.506	-	-	-
Straight 10	-	-	-	-	-	-	-
Straight 11	326.242	-	-	326.242	-	-	-
Straight 12	-	-	-	-	-	-	-
Straight 13	1050.294	362.026	-	688.268	-	-	-
Straight 14	-	-	-	-	-	-	-
Straight 15	-	-	-	-	-	-	-
Straight 16	1364.687	-	362.026	1002.661	-	-	-
Straight 17	-	-	-	-	-	-	-
Straight 18	-	-	-	-	-	-	-
Straight 19	260.183	64.901	-	195.282	-	-	-
Straight 20	-	-	-	-	-	-	-
Straight 21	-	-	-	-	-	-	-
Straight 22	-	-	-	-	-	-	-
Straight 23	-	-	-	-	-	-	-
Straight 24	-	-	-	-	-	-	-
Tractor 1	259.604	-	-	259.604	-	-	-
Tractor 2	1499.006	-	-	1499.006	-	-	-
Tractor 3	-	-	-	-	-	-	-
Tractor 4	843.713	-	-	843.713	-	-	-
Tractor 5	3518.096	-	-	3518.096	-	-	-
Tractor 6	389.985	-	-	389.985	-	-	-
Tractor 7	389.985	-	-	389.985	-	-	-
Tractor 8	13294.855	-	-	13294.855	-	-	-
Tractor 9	2941.664	-	-	2941.664	-	-	-
Tractor 10	-	-	-	-	-	-	-

Tractor 11	324.505	-	-	324.505	-	-	-
Tractor 12	260.183	-	-	260.183	-	-	-
Tractor 13	129.802	-	-	129.802	-	-	-
Tractor 14	-	-	-	-	-	-	-
Tractor 15	-	-	-	-	-	-	-
Tractor 16	-	-	-	-	-	-	-
Tractor 17	737.157	-	-	737.157	-	-	-
Tractor 18	-	-	-	-	-	-	-
Tractor 19	-	-	-	-	-	-	-
Tractor 20	-	-	-	-	-	-	-
Tractor 21	81.086	-	-	81.086	-	-	-
Tractor 22	964.599	-	-	964.599	-	-	-
Tractor 23	129.802	-	-	129.802	-	-	-
Tractor 24	194.703	-	-	194.703	-	-	-
Tractor 25	-	-	-	-	-	-	-
Tractor 26	64.901	-	-	64.901	-	-	-
Tractor 27	-	-	-	-	-	-	-
Tractor 28	-	-	-	-	-	-	-
Tractor 29	-	-	-	-	-	-	-
Tractor 30	-	-	-	-	-	-	-
Tractor 31	-	-	-	-	-	-	-
Tractor 32	-	-	-	-	-	-	-
Tractor 33	-	-	-	-	-	-	-
Tractor 34	-	-	-	-	-	-	-
Tractor 35	-	-	-	-	-	-	-
Tractor 36	-	-	-	-	-	-	-
Tractor 37	90.88	-	-	90.88	-	-	-
Tractor 38	-	-	-	-	-	-	-
Tractor 39	-	-	-	-	-	-	-
Tractor 40	-	-	-	-	-	-	-
Tractor 41	-	-	-	-	-	-	-
Tractor 42	-	-	-	-	-	-	-
Tractor 43	-	-	-	-	-	-	-
Tractor 44	-	-	-	-	-	-	-

Table 11: Model year and vehicle size (NY)

BASTATE	New York				
VEHSZE	Total	Light	Medium	Light-heavy	Heavy-heavy
MDLYR					
Total	2713651	2561846	56865	26986	67955
1998,1997	225829	214696	6088	1086	3958
1996	277370	271625	2234	301	3210
1995	276863	266815	4408	1348	4292
1994	182862	173142	3744	2434	3543
1993	167395	161263	3593	551	1988
1992	128281	123182	2074	855	2169
1991	177397	169837	2138	2238	3186
1990	88800	80862	2334	1288	4316
1989	168184	159521	4309	130	4223
1988	176721	168498	1972	1051	5200
Pre-1988	843948	772405	23971	15703	31869

Table 12: Miles per gallon and engine type (NY)

BASTATE	New York						
ENGTYP	Total	Leaded gasoline	Unleaded gasoline	Diesel	Liquefied gas (LPG or LNG)	Other	Not reported
MPGCK							
Total	2713651.3	133159.74	2399877.4	169831.48	5746.341	4543.901	492.407
Less than 5 mpg	-	-	-	-	-	-	-
5 to 6 mpg	-	-	-	-	-	-	-
7 to 8 mpg	8842.138	-	8842.138	-	-	-	-
9 to 10 mpg	199562.27	8842.138	186421.89	4298.237	-	-	-
11 to 12 mpg	336114.99	8842.138	318430.72	8842.138	-	-	-
13 to 14 mpg	319190.84	22228.177	292664.42	4298.237	-	-	-
15 to 16 mpg	481474.62	31315.979	445614.74	-	-	4543.901	-
17 to 18 mpg	496955.89	17684.276	453482.2	21491.185	4298.237	-	-
19 to 20 mpg	315598.61	17929.94	293370.43	4298.237	-	-	-
21 to 24 mpg	288434.56	13386.039	261908.15	13140.375	-	-	-
25 to 29 mpg	57530.959	4543.901	52987.058	-	-	-	-
30 mpg or more	13386.039	-	13386.039	-	-	-	-
Not reported or not applicable	196560.36	8387.148	72769.638	113463.07	1448.104	-	492.407

Table 13: Engine displacement and engine type (NY)

BASTATE	New York						
ENGTYP	Total	Leaded gasoline	Unleaded gasoline	Diesel	Liquefied gas (LPG or LNG)	Other	Not reported
PKCID							
Total	2713651.3	133159.74	2399877.4	169831.48	5746.341	4543.901	492.407
1-99 (Gasoline)	36351.208	-	36351.208	-	-	-	-
100-149 (Gasoline)	196253.77	8596.474	187657.29	-	-	-	-
150-169 (Gasoline)	134164.13	4543.901	129620.23	-	-	-	-
170-199 (Gasoline)	367292.37	9087.802	358204.57	-	-	-	-
200-249 (Gasoline)	533914.04	36105.544	497808.5	-	-	-	-
250-269 (Gasoline)	274136.89	18175.604	255961.28	-	-	-	-
270-299 (Gasoline)	21609.81	4298.237	17311.573	-	-	-	-
300-309 (Gasoline)	365745.56	8842.138	356903.43	-	-	-	-
310-349 (Gasoline)	118183.16	9087.802	109095.36	-	-	-	-
350-359 (Gasoline)	333336.89	20089.156	313247.73	-	-	-	-
360-369 (Gasoline)	49126.408	4543.901	44582.507	-	-	-	-
370-399 (Gasoline)	6888.815	-	6888.815	-	-	-	-
400-449 (Gasoline)	7521.266	789.532	6731.734	-	-	-	-
450 & over (Gasoline)	39891.557	362.026	39529.531	-	-	-	-
Not reported (Gasoline)	48621.279	8637.619	39983.66	-	-	-	-
1-249 (Diesel)	10257.868	-	-	10257.868	-	-	-
250-299 (Diesel)	458.36	-	-	458.36	-	-	-
300-349 (Diesel)	4890.883	-	-	4890.883	-	-	-
350-369 (Diesel)	17944.159	-	-	17944.159	-	-	-
370-399 (Diesel)	22765.124	-	-	22765.124	-	-	-
400-429 (Diesel)	8632.254	-	-	8632.254	-	-	-
430-449 (Diesel)	34623.025	-	-	34623.025	-	-	-
450-469 (Diesel)	9601.516	-	-	9601.516	-	-	-
470-499 (Diesel)	1756.45	-	-	1756.45	-	-	-
500-549 (Diesel)	4092.808	-	-	4092.808	-	-	-
550-599 (Diesel)	1210.371	-	-	1210.371	-	-	-
600-649 (Diesel)	8151.684	-	-	8151.684	-	-	-
650-699 (Diesel)	8260.493	-	-	8260.493	-	-	-
700-749 (Diesel)	4839.234	-	-	4839.234	-	-	-
750-799 (Diesel)	1793.156	-	-	1793.156	-	-	-
800-849 (Diesel)	-	-	-	-	-	-	-
850 & over (Diesel)	13796.028	-	-	13796.028	-	-	-
Not reported (Diesel)	16758.063	-	-	16758.063	-	-	-
1-99 (Other)	-	-	-	-	-	-	-
100-149 (Other)	-	-	-	-	-	-	-
150-199 (Other)	-	-	-	-	-	-	-
200-249 (Other)	-	-	-	-	-	-	-
250-299 (Other)	-	-	-	-	-	-	-
300-349 (Other)	8842.138	-	-	-	4298.237	4543.901	-
350-399 (Other)	724.052	-	-	-	724.052	-	-
400-449 (Other)	724.052	-	-	-	724.052	-	-
450 & over (Other)	-	-	-	-	-	-	-
Not reported (Other)	-	-	-	-	-	-	-

Table 14: Gross vehicle weight and engine type (NY)

BASTATE	New York						
ENGTYP	Total	Leaded gasoline	Unleaded gasoline	Diesel	Liquefied gas (LPG or LNG)	Other	Not reported
PKGVW							
Total	2713651.3	133159.74	2399877.4	169831.48	5746.341	4543.901	492.407
6000 lbs. or less	1760735.2	67421.523	1684717.2	4298.237	4298.237	-	-
6001 to 10000 lbs.	782421.56	59523.221	663388.05	54604.354	362.026	4543.901	-
10001 to 14000 lbs.	21884.239	724.052	16388.948	4047.187	362.026	-	362.026
14001 to 16000 lbs.	7240.52	-	3620.26	3620.26	-	-	-
16001 to 19500 lbs.	6219.343	-	4771.239	1448.104	-	-	-
19501 to 26000 lbs.	70897.865	4706.338	23538.862	41928.613	724.052	-	-
26001 to 33000 lbs.	8078.68	327.4	1178.64	6572.64	-	-	-
33001 lbs. and greater	56173.845	457.202	2274.181	53312.081	-	-	130.381
Unknown	-	-	-	-	-	-	-
Not reported	-	-	-	-	-	-	-

VI. Waster transfer stations in the South Bronx

This section will give a general description of the transportation of New York City garbage, focusing on the waste transfer stations located in the South Bronx. It will then present a method for modeling the flows of garbage into and out of the South Bronx. Finally, it will present the results for several scenarios involving the waste transfer stations.

7.1 General Description

Estimates of the amount of residential garbage produced daily by New York City vary from 11,000 tons (Johnson, 2000) to 13,000 tons (Stewart, 2001). This garbage is handled by 13 waste transfer stations, 6 of which are located outside of the city (Lipton, 2001). All of the Bronx's household trash is handled by Republic Services at its South Bronx waste transfer station (Waldman, 1999). The 13,000 tons of household garbage represents almost half of the total amount of garbage that these transfer stations handle daily, the rest is commercial garbage (Stewart, 2001). Table 15 shows the amount of garbage produced by each borough.

Table 15: Household garbage by borough (Lipton, 2000)

Borough	Tons/day	Annual Cost($000,000)	Contractor	Destination
Bronx	1800	30	Republic	Rail and truck to VA
Part of Brooklyn	2490	44	Waste Man	Truck to VA and elsewhere
Man/SI	3200	61	American Ref-Fuel	Truck to Newark incinerator/landfills
Queens/rest of Bkln	4675	105	Undecided	Truck to incinerators/landfills
Total	12165			

Sources: NY City Dept of Sanitation, NYC Comptroller's office

Prior to the closing of the Fresh Kills landfill in Staten Island, Department of Sanitation trucks would drop off their 10-ton loads at neighborhood depots in the four boroughs other than Staten Island after which the garbage would be transported by barge to the Staten Island land fill. In Staten Island, the trucks would deliver their garbage directly to Fresh Kills (Lipton, 2001). After the closing of Fresh Kills, the city's garbage is predominantly transported to landfills or incinerators by truck.

Table 16 shows the ultimate destinations for New York City's household garbage and Table 17 shows the mode and route used for about 7,000 of the 13,000 daily tons. The 13 waste transfer stations, the source of the garbage they handle, and the ultimate destinations are shown in Figure 7.

Table 16: Destinations for New York City household garbage(Johnson, 2002)

Destination	Tons/day	Percentage
Pennsylvania	7480	68

Virginia	1540	14
NY State, NJ, Ohio	1980	18
Total	11,000	

Table 17: Mode and route for New York City household garbage (Lipton, 2001)

Source	Trucks	Tons	Route
By truck			
Manhattan/Queens	300	3000	George Washington Bridge
	130	1300	Lincoln Tunnel
	50	500	Holland Tunnel
Staten Island	70	700	Goethals Bridge
Bronx	90	900	
By rail			
Bronx		950	rail to Albany – onto VA
Total tons		7350	

The South Bronx has more than 24 waste transfer stations and Republic Services handles all of the Bronx's household waste from its transfer station (Waldman, 1999). 950 tons/day are transported from the Bronx by rail up to Albany and on to Virginia (Lipton, 2001), apparently by Waste Management (Stewart, 2001). Information about the South Bronx waste transfer stations is shown in Table 18. Table 19 shows the market shares for the waste transfer stations. Figure 8 is a map of the South Bronx with the locations of the stations, Figure 9 shows the capacity of the stations, and Figure 10 shows their actual output.

Figure 7: Origins and destinations of New York City garbage

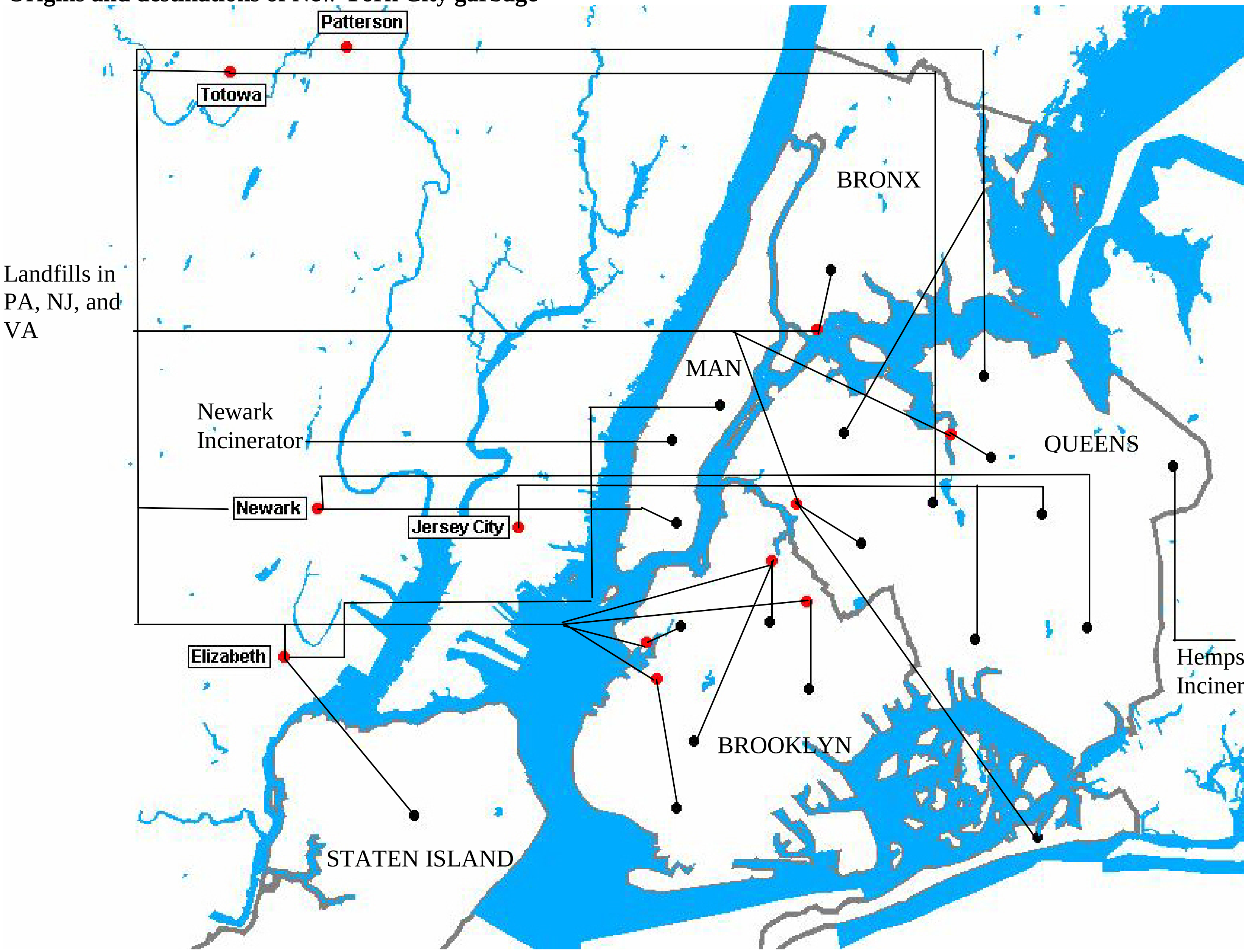


Table 18: Waste Transfer Stations in the South Bronx (2002)

		Capacity				Capacity	Output
		(tons/	(cu yds/			(tons/	(tons/
Company	**Type**	**day)**	**day)**	**Company**	**Type**	**day)**	**day)**
A.J. Recycling	CDD	1200	1600	A.J. Recycling	NP	1200	984.48
American Marine Rail	PSW	5200	6930				
Bronx City Recycling, Inc. (1390 Viele Ave)	FMW	150	200				
				Bronx City Recycling, Inc.(1190 Commerce)	F		238.6
Con Agg	FMW			Con Agg	F		1746
Con Edison	FMW						
Continental Recycling/Waste Management of NY, LLC	CDD			Waste Management/Baretto	NP	1037	155.89
East Bay Recycling	PSW	1125	1500				
Equinox Associates/Bronx County Recycling	FMW			Bronx County Recycling	F		429.11
				Felix Equities	F		
G&M Transfer, Inc.	CDD	330	440	G&M Transfer, Inc.			
Harlem River Yard Transfer/USA Waste Services of NYC, Inc.	PSW	5625	7500	USA Waste Services of NYC, Inc.			
Hunts Point Recycling	PSW	2250	2999				
Hunts Point Recycling (IESI)	PSW	2250	3000				
IESI	PSW	375	499				
IESI	PSW	1088	1450	IESI	P	225	191.01
Integrated Recycling	PSW	6825	9100				
J. Danna & Sons	CDD	405	540	J. Danna & Sons	NP	405	208.12
				Justus Recycling	F		241.58
Kid's Waterfront	CDD			Kid's Waterfront	NP	750	395.63
Paper Fibres Corp.	PSW	574	765	Paper Fibres Corp.	P	74	156.51
Republic Services, Inc./Waste Services of NY, Inc.	PSW	3000	4000	Waste Services of NY	P	2999	354.54
S & K Acquisitions	REC	934	1245				
Urbanski Recycling	CDD						
USA Waste Services of NYC, Inc.	PSW			USA Waste Services of NYC, Inc.	P	3000	1282.93
Waste Management	PSW	1500	2000				
Waste Management	CDD	1686	2250				
Waste Management	PSW	1686	2250				
Waste Management of New York, LLC/Gunhill Trucking	CDD	1050	1400	Waste Management of New York	NP	1050	265.58
Waste Management/Metropolitan Transfer Station	PSW	2362	3150	Waste Management	P	825	754.47
WM of New York, Inc.	PSW	10575	14100	Republic Services	P		
Sources:				**Source:**			
1 Original List				Department of Sanitation Data, Provided by New York Lawyers			
2 Big Apple Garbage Sentinel				for the Public Interest, 2nd quarter, 2002			
www.johnmccrory.com/bags/background/bg_05.html				P = putrescible, NP = nonputrescible, F = fill material			
PSW=Putrescible Solid Waste, FMW=Fill Material Waste, CDD = Construction and Demolition Debris							
REC=Recyclables and Recovery, RMW=Regulated Medical Waste							

Figure 8: Waste Transfer Stations in the South Bronx (2002)

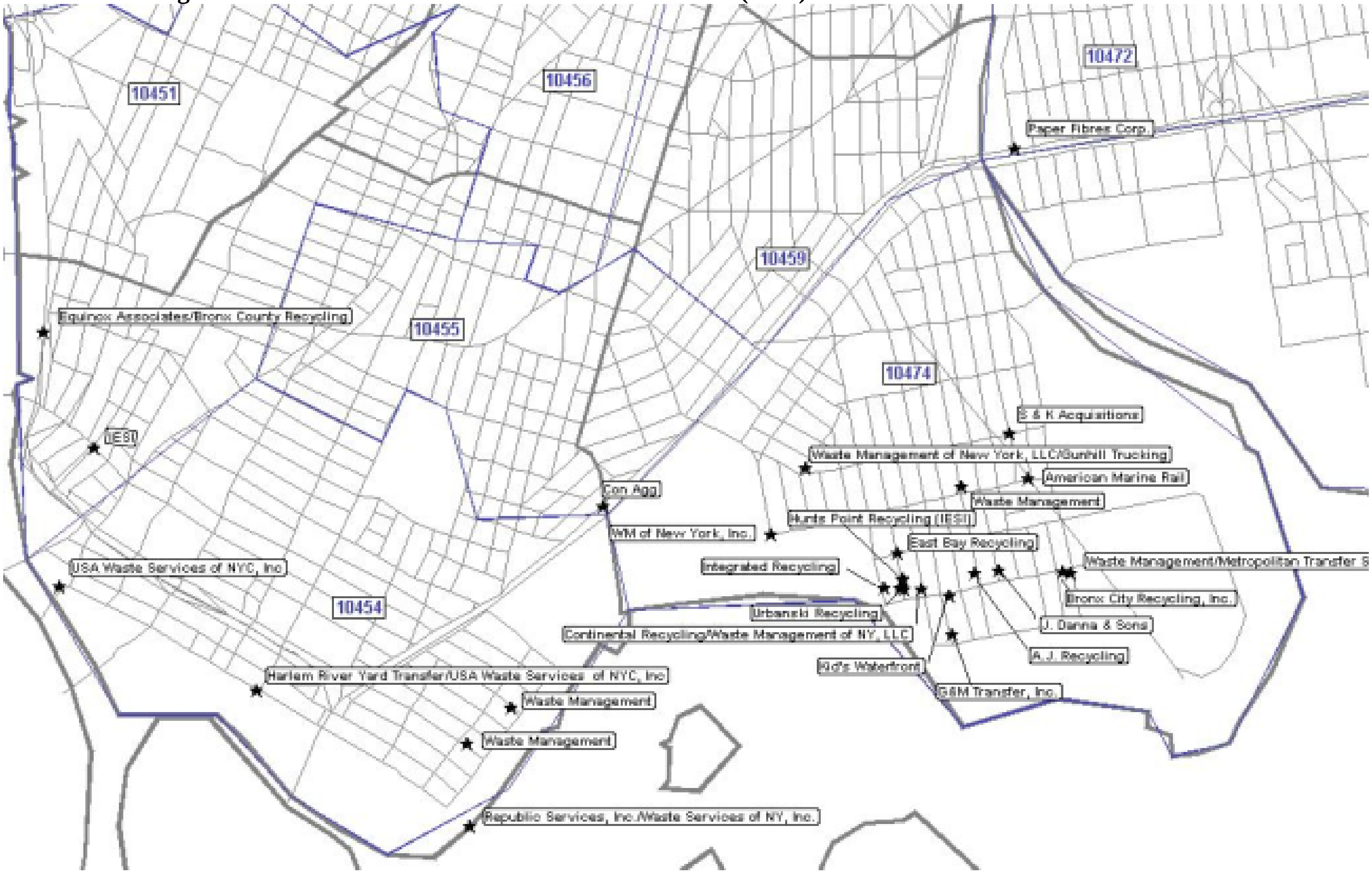


Figure 9: Tons/Day Capacity at Waste Transfer Stations (2002)

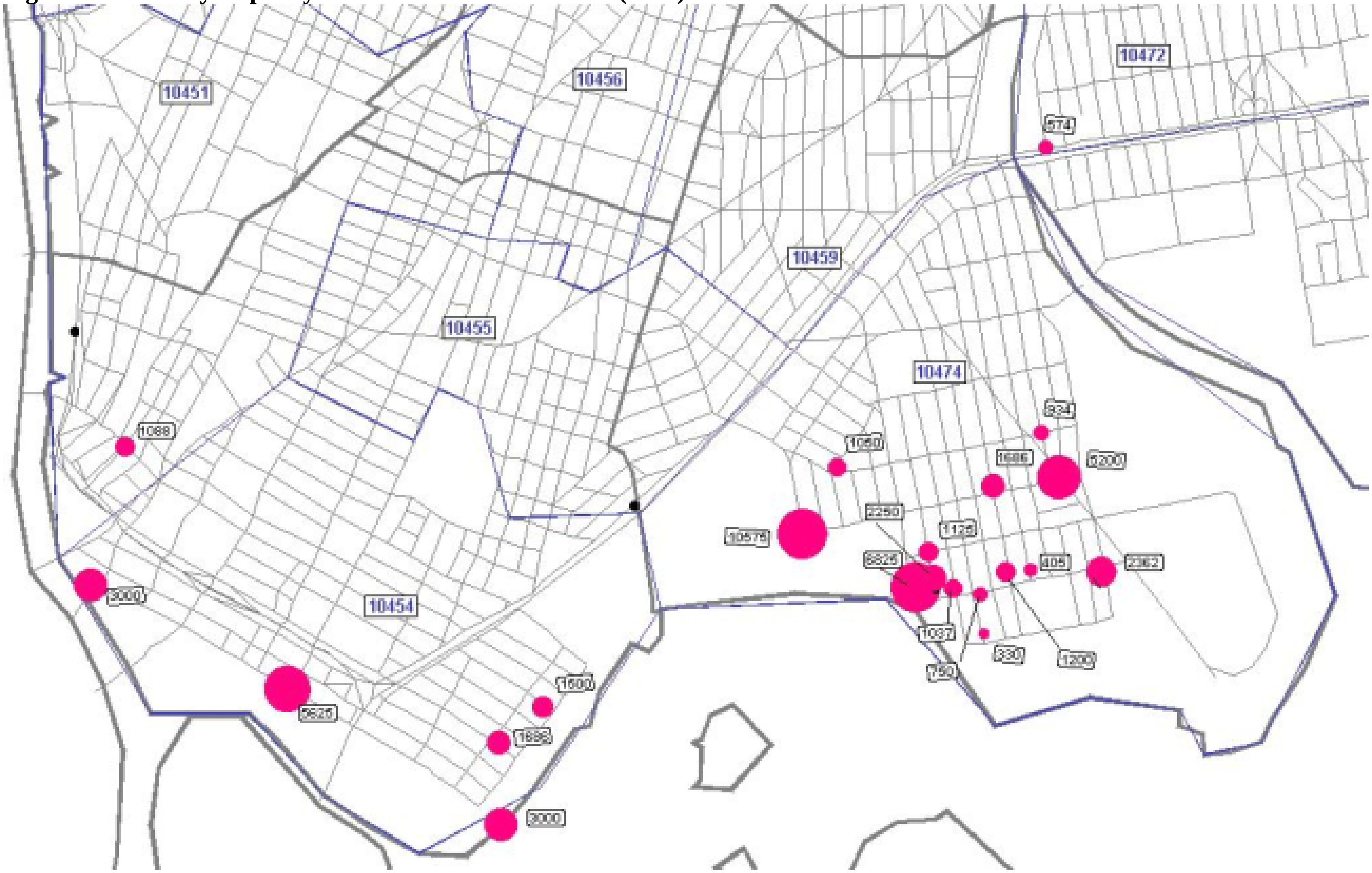


Figure 10: Tons/Day Output at Waste Transfer Stations (2002)

Table 19: Market shares for the South Bronx waste transfer stations (2002)

Company	Type	Capacity (tons/ day)	Output (tons/ day)	Percent of Total Output
USA Waste Services of NYC, Inc.	P	3000	1282.93	17.31
Waste Management	P	825	754.47	10.18
Waste Services of NY	P	2999	354.54	4.78
IESI	P	225	191.01	2.58
Paper Fibres Corp.	P	574	156.51	2.11
Hunts Point Recycling	P	Closed	5.92	0.08
Total putrescible output			2745.38	
A.J. Recycling	NP	1200	984.48	13.29
Kid's Waterfront	NP	750	395.63	5.34
Waste Management of New York	NP	1050	265.58	3.58
J. Danna & Sons	NP	405	208.12	2.81
Waste Management/Baretto	NP	1037	155.89	2.10
Total nonputrescible output			2009.7	
Con Agg	F		1746	23.56
Bronx County Recycling	F		429.11	5.79
Justus Recycling	F		241.58	3.26
Bronx City Recycling, Inc.(1190 Commerce)	F		238.6	3.22
Total fill material output			2655.29	
Total output			7410.37	

7.2 Modeling South Bronx Garbage Flows

The flow of garbage through the South Bronx transfer stations has two parts: (1) from the boroughs of the Bronx, Brooklyn, Queens, and Manhattan to the transfer stations, and (2) from the transfer stations to landfills or incinerators outside of the state. The trips from the boroughs to the transfer stations were assumed to be made by 10-ton garbage trucks (Lipton, 2001) and the trips from the transfer stations to outside of the city by 23-ton trucks (NYC DOS, 2004). To model the trip from the boroughs to the transfer stations, an origin-destination matrix was calculated by using a biproportional assignment in which the origins were assumed to be proportional to the populations of four boroughs as reported in the 2000 Census and the destinations were proportional to the garbage flows to each South Bronx transfer station as reported by the Department of Sanitation Bureau of Planning and Budget for the second quarter of 2003. Table 20 shows the 2000 Census population figures and Table 21 shows the total flows to each borough broken down by type – putrescible, nonputrescible, and fill. The locations of the transfer stations are shown in Figure 10. The resulting O-D matrices are shown in Table 22.

The commodity flows were converted into truck trips by dividing the matrix elements by the relevant vehicle capacity. It was assumed that for each loaded trip there was a corresponding empty trip the other way, so the transpose of the loaded trip matrix was added to the loaded trip matrix to arrive at the total trip matrix. These truck trips were then assigned to a simplified South Bronx network consisting of the interstate highways (the Major Deegan, the Bruckner, and the Sheridan Expressways), the Third Avenue Bridge, the Triboro Bridge, and the major truck routes in the Hunts Point area. Nineteen nodes were included in the network – 15 nodes represented the transfer stations, one node each represented the boroughs of Manhattan, Brooklyn/Queens, and the Bronx, and one node represented out-of-state. These nodes were connected to the network by dummy links. The assignment was done using a shortest path algorithm based on travel time. Link travel times were estimated by dividing the link length by an average of the simulated travel speeds.

For the trip from the transfer stations to out-of-state, the following assumptions were made:

1) All but 950 tons of Municipal Solid Waste goes by truck over the GW Bridge.
2) The other 950 tons of MSW leaves by rail from the Waste Management facility on Lincoln Ave, the Harlem River Yards (Lipton, 2001).

Thus, the outflow from this transfer station was taken to be 3054.15 – 950 = 2104.15 tons. The commodity flow matrix then consisted of the flows from each of the 15 transfer stations as origins to the node representing out-of-state as the destination. The elements in this matrix were divided by the 23-ton capacity to arrive at the loaded trip matrix and the transpose of this matrix was added to calculate the total trip matrix. These trips were then assigned to the network using the same method described above. The resulting assignments are shown in Figure 11 (incoming trips), Figure 12 (outgoing trips), and Figure 13 (total trips).

Table 20. 2000 Census population figures and proportions

Borough	Population	Proportion
Queens NY	2,229,379	0.2947
Kings NY	2,465,326	0.3259
New York NY	1,537,195	0.2032
Bronx NY	1,332,650	0.1762
Total	7,564,550	1.0000

Table 21. South Bronx waste transfer stations.

Type	ID	Company	Address	Zip Code	Tons	Proportion
Putrescible	1	WASTE MANAGEMENT OF NY, LLC	98 LINCOLN AVE	10454	3,054	0.5329
	2	WASTE SERVICES OF NY, INC.	920 E 132ND ST	10454	1,491	0.2602
	3	PAPER FIBERS CORP.	960 BRONX RIVER AVI	10472	217	0.0379
	4	IESI NY CPRP.	325 CASANOVA	10474	205	0.0357
	5	METROPOLITAN TRANSFER STATION	287 HALLECK ST	10474	764	0.1333
Total					5,731	1.0000
Nonputres.	6	JOHN DANNA & SONS, INC.	318 BRYANT AVE	10474	138	0.0643
	7	WASTE MANAGEMENT OF NY, LLC	315 BARETTO ST	10474	54	0.0252
	8	WASTE MANAGEMENT OF NY, LLC	620 TRUXTON ST	10474	525	0.2451
	9	KIDS WATERFRONT CORP.	1264 VIELE AVE	10474	498	0.2327
	10	A J RECYCLING INC.	325 FAILE ST	10474	909	0.4246
	11	G. M. TRANSFER	216-222 MANIDA ST	10474	18	0.0082
Total					2,141	1.0000
Fill	12	BRONX COUNTY RECYCLING, LLC	475 EXTERIOR ST	10451	498	0.3365
	13	TILCON (CON AGG RECYCLING CORP.)	980 E 149TH ST	10455	707	0.4781
	14	BRONX CITY RECYCLING	1390 VIELE AVENUE	10474	176	0.1191
	15	FELIX EQUITIES INC.	290 E 132 STREET	10454	98	0.0663
Total					1,479	1.0000

Figure 10. South Bronx waste transfer stations (2003).

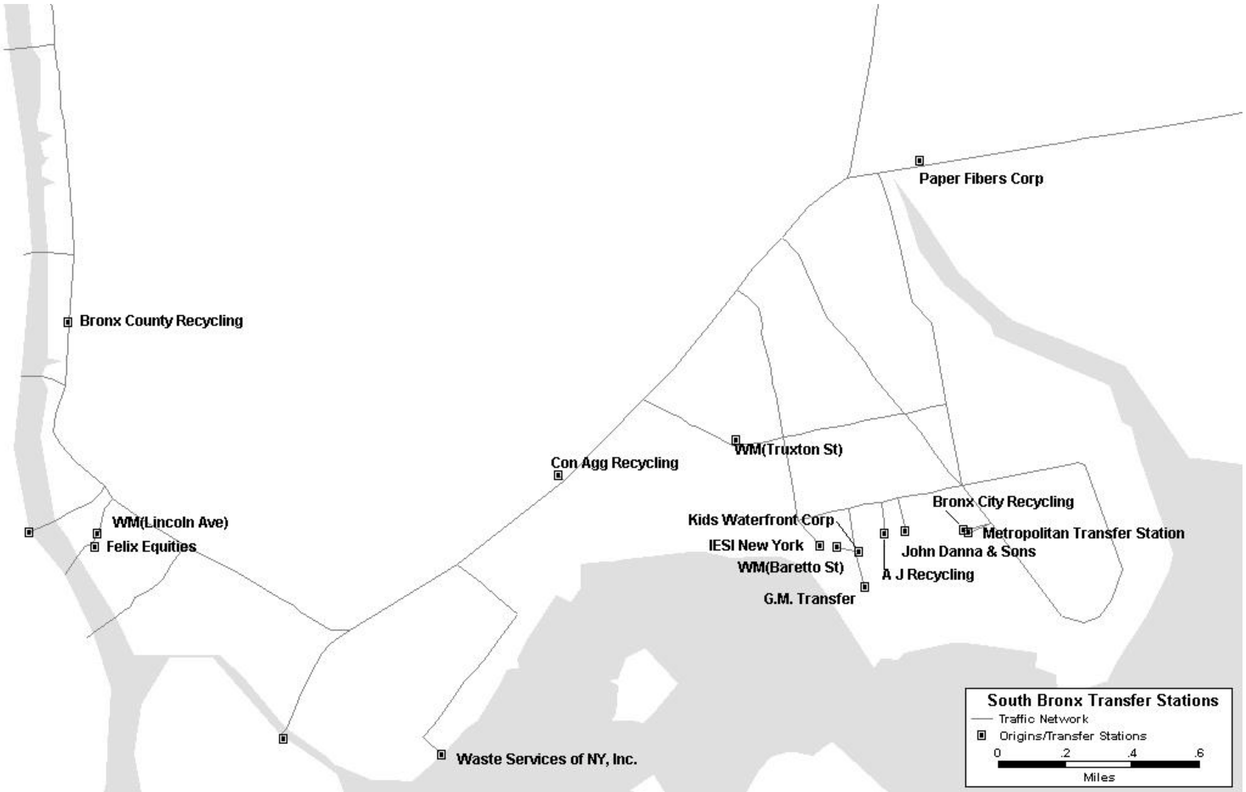


Table 22a. Putrescible garbage flows from the boroughs to the waste transfer stations in tons/day. The numbers in the first row are the transfer station ID numbers. The corresponding transfer station names can be found in Table 2.

	1	2	3	4	5	Origins
Bronx	538.05	262.73	38.23	36.03	134.58	1009.61
Manhattan	620.63	303.05	44.09	41.56	155.23	1164.58
Brooklyn	995.36	486.03	70.72	66.65	248.96	1867.73
Queens	900.10	439.52	63.95	60.27	225.13	1688.97
Destinations	3054.15	1491.33	216.99	204.51	763.91	5730.89

Table 22b. Nonputrescible garbage flows from the boroughs to the waste transfer stations.

	6	7	8	9	10	11	Origins
Bronx	24.24	9.50	92.45	87.78	160.18	3.11	377.26
Manhattan	27.96	10.96	106.64	101.25	184.77	3.58	435.16
Brooklyn	44.84	17.58	171.02	162.39	296.33	5.75	697.91
Queens	40.55	15.90	154.65	146.84	267.97	5.20	631.11
Destinations	137.59	53.94	524.76	498.26	909.26	17.63	2141.44

Table 22c. Fill garbage flows from the boroughs to the waste transfer stations.

	12	13	14	15	Origins
Bronx	87.70	124.60	31.03	17.29	260.62
Manhattan	101.16	143.73	35.80	19.94	300.63
Brooklyn	162.25	230.51	57.41	31.98	482.14
Queens	146.72	208.45	51.91	28.92	436.00
Destinations	497.83	707.28	176.15	98.13	1479.39

Figure 11. Garbage trips into the South Bronx.

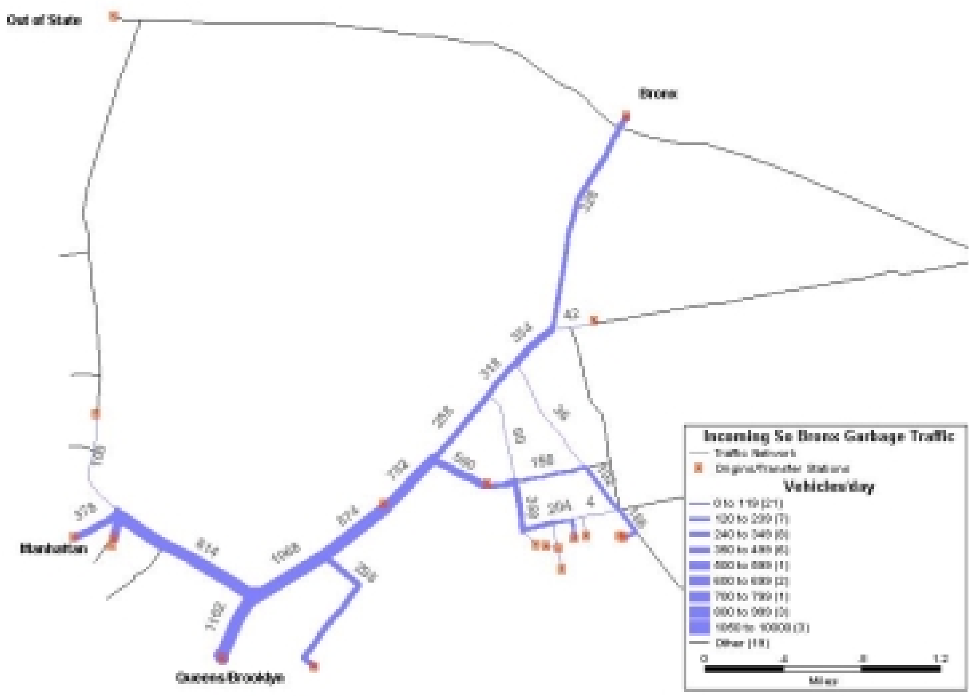


Figure 12. Garbage trips out of the South Bronx.

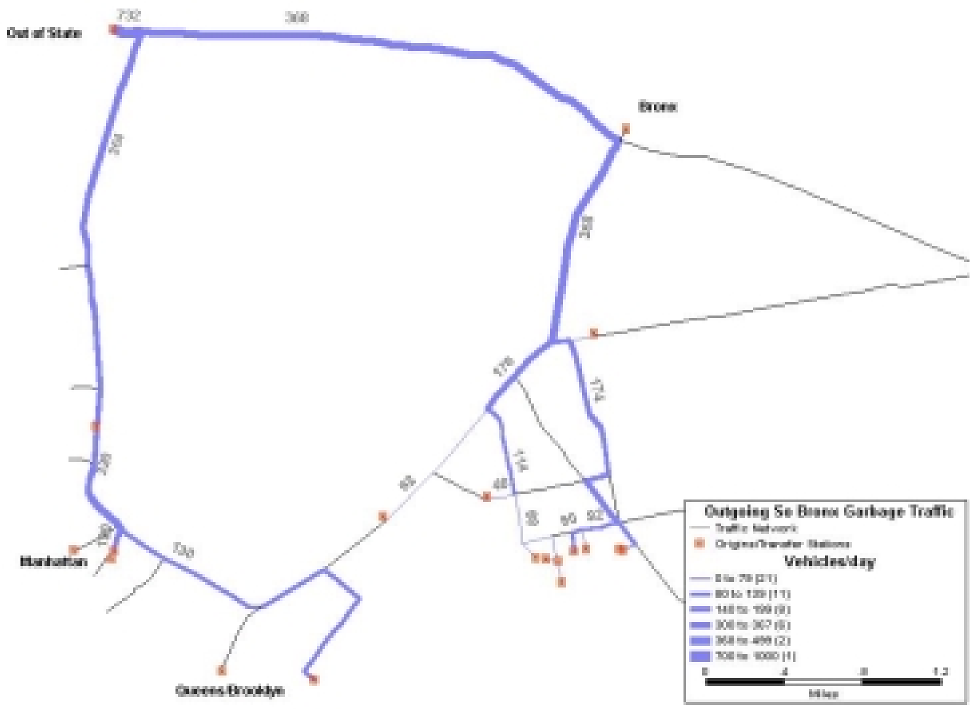
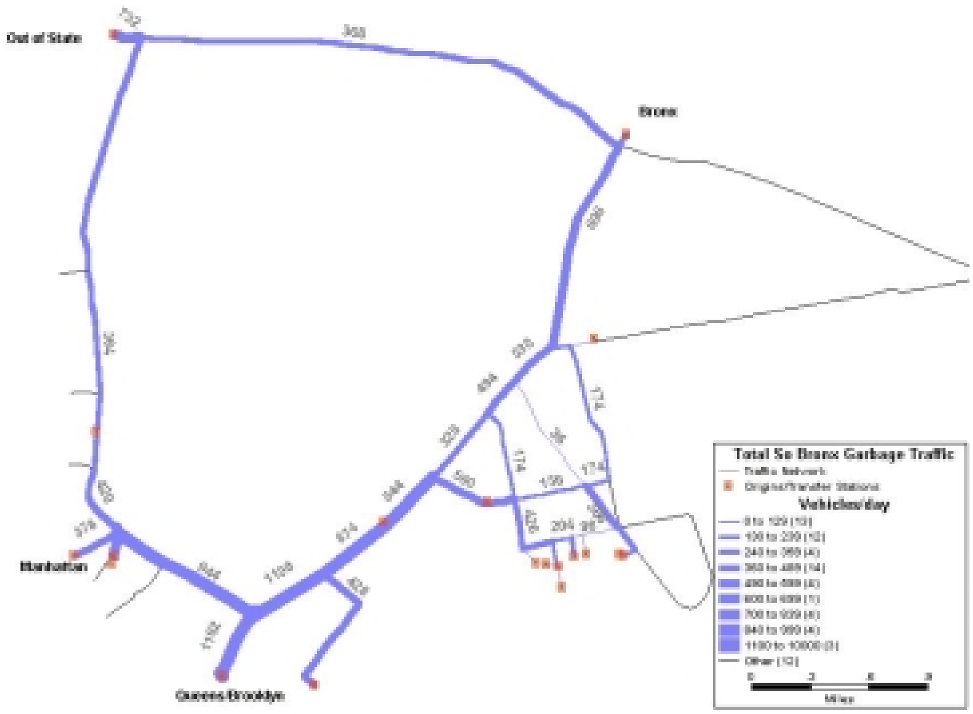


Figure 13. Total trips.



VII. Traffic simulation

A state of the art Dynamic Traffic Assignment (DTA)/Simulation software was used to model part of the South Bronx network, and analyze the traffic conditions and the environmental impact during a typical workday for the AM and PM peak conditions. Over the past two decades, extensive research has been conducted in the field of DTA to improve the realism with which cars are propagated through a network, and how they affect and are affected by time-varying flows within the network. This work considered both heavy commercial as well as passenger vehicles, recognizing their differential interactions and impacts on the environment and roadway conditions.

The model adopted for this study is an extension of Northwestern University's mesoscopic simulation-assignment model called VISTA (*Visual Interactive System for Transportation Algorithms*), modified to include multiple vehicle classes (i.e., truck and passenger car movements) as well as traffic signal control in the simulation. Vehicle emissions on any road network (total emissions on the network or/and emissions on a particular link) in *VISTA* can be obtained by supplying pertinent road network details to any standard emission-modeling package. In this study, the *EPA Mobile 6 Model* has been interfaced with VISTA to compute the emissions of NOx, CO, HC as well as of fuel consumption modules. It is important to highlight that these estimates of air pollution impacts are only intended to provide additional information on environmental impact estimates conducted by other team members.

Using the assignment-based multi-class DTA model, the simulator captures effects of congestion and traffic conditions for all vehicles calculated by the simulator. It has long been recognized that static models or traditional intersection movement simulators cannot provide a realistic representation of time-varying traffic conditions. Moreover, while much research has been done in DTA, the bulk of this work has focused on simplistic traffic simulation models that cannot capture well the realism of actual traffic networks.

This part of the study analyzes the typical morning and evening peak traffic conditions and evaluates the environmental impact of both passenger vehicles and heavy vehicles. Section 8.0 presents an overview of the data and model selection process. Section 8.1 describes the preparation of the input data. Section 8.2 describes the traffic modeling tools. Section 8.3 describes the dynamic traffic assignment as implemented in VISTA. Section IX is concerned with the main air quality modeling capabilities of VISTA as captured through the integrated EPA's Mobile 6 model and Section X presents the computational results and analyses.

8.0 Overview of data and model selection process

The major tasks in this study can be summarized as follow:

1. Preparation of Input Data
    a. Network Identification and Modeling Needs
    b. Review of Existing Data Sources and Identification of Data Needs
    c. Transportation Demand Modeling

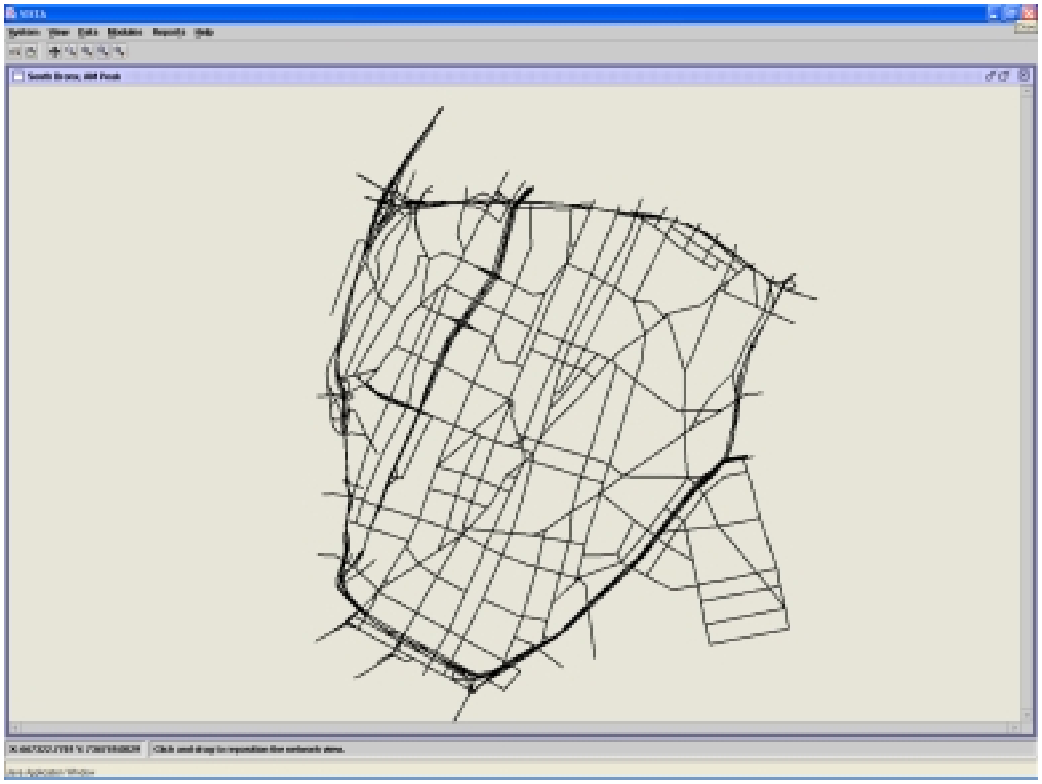
2. Traffic Modeling
   a. Selection of the Modeling Tools
   b. Identification of the MOEs
   c. Experimental Design (runs to be performed)

3. Experiments and Analysis
   a. Perform of Model Runs
   b. Analyses of Results

8.1 Preparation of Input Data

An important part of this study was concerned with first identifying the area of interest (the boundaries) and then obtaining, preparing and importing the necessary data into the model's database so that the experiments could be performed. The boundaries of the region of interest were defined by the project team (see Figure 1). This network was imported into the VISTA database. Figure 21 shows the network as it exists in VISTA. The project team obtained the necessary traffic data from various sources so that a reasonably complete set was assembled.

Figure 21: Representation of the South Bronx Area in VISTA's GIS



The main agencies/entities that maintain data on the South Bronx networks were the New York Metropolitan Transportation Council (NYMTC), the New York City MPO, the City Department of Transportation (NYCDOT), the City College of New York (CCNY) and consultants (Urbitran). Engineers and Planners from these agencies were contacted and the following data sets were obtained:

1. *Network Infrastructure Data:* The network selected consists of 1365 intersections (interchanges) and 2672 arterial and freeway segments.

2. *Network Demand Data:* The zoning system of NYMTC was used and the Origin-Destination data as supplied by Urbitran were mapped on the same network. The total number of ODs used was 10984; the PM and AM peak total demand are as follows:

   a. AM Peak Total 107014 vehicles of which 12840 were trucks and 94174 were passenger vehicles
   b. PM Peak Total 113401 vehicles of which 7323 were trucks and 104800 were passenger vehicles

3. *Other Control and Traffic Data:* Some of the intersections are signalized and traffic signal data were collected from the research team, which included the location, type of signal control and the timing plan. In addition, on some street segments counts were obtained that were used for validation purposes.

8.2 Traffic Modeling

8.2.1 Selection of the Modeling Tools

The project team comprehensively reviewed the market for available tools that enabled us to perform this study. The tools reviewed were (1) Traffic Assignment/Planning Tools; (2) Traffic Simulation and Optimization Tools; and (3) Integrated Assignment-Simulation tools. In terms of assignment tools the existing approaches include EMME/2, TransCad and TranPlan. Simulation tools included CORSIM and WATSIM in connection with SYNCHRO and TRANSYT 7F signal optimization tools. DTA-based integrated tools included Integration, DYNASMART, DYNAMIT and VISTA.

The planning tools were ruled out in the beginning stages of this study because they were considered inadequate, mostly due to their inability to capture traffic queues, signalized intersections and other realities of the South Bronx Network. These models tend to be aggregate, steady-state models and are incapable of capturing the necessary traffic propagation details that affect emission of pollutants. Since they are steady state models they cannot be used to model oversaturation conditions. The microscopic traffic simulation tools are capable of capturing the queue evolutions and traffic propagation, but they require a prohibitive effort in data collection for the resources of this project; namely, they all require detailed traffic turning movement flows on every intersection (signalized and unsignalized), calibration of car following and lane changing models and calibration of driving behavior. This means that data had to be collected for AM and PM periods for 1365 intersections and interchanges, on some of them with automated data collection devices (such as freeway interchanges), which was prohibitive for the budget allocated for this project.

The simulation and integrated tools are reviewed in Appendix F. Based on this review and analysis of the tools' functionalities the VISTA model was selected to be used for this study. VISTA seems to be available, stable and of commercial quality. A detailed description of the VISTA capabilities as they relate to this research is given in the following section.

8.3 The VISTA Framework

As explained above, the Visual Interactive System for Transportation Algorithms (VISTA) was adopted as the simulation-assignment and air quality analyses software. VISTA is a networked system, accessible through the public Internet (http://its.civil.nwu.edu/vista) or a private Intranet. The models represent traditional and cutting-edge transportation algorithms capable of handling large-scale real-time needs (as will be discussed). The client is a machine-independent Java application. CORBA was used to bridge the client with the modules and data, allowing the modules to be developed in languages other than Java. Other distributed-object technologies (RMI and DCOM for example) limit the languages or operating systems available for developing and deploying VISTA modules.

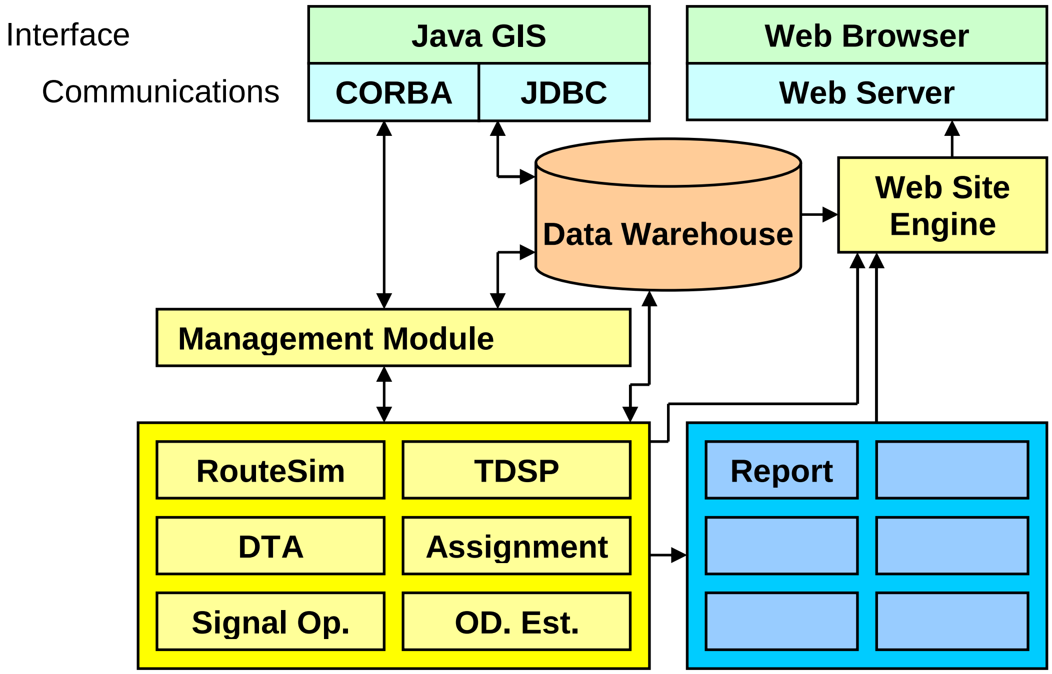
The VISTA system as used in this study includes:

- A Data Warehouse containing all the data needed by the models.
- Existing and new transportation models and tools (planning, engineering, control, monitoring, evaluation and operational).
- User interfaces for the various stakeholders (planners, engineers, policy makers, and operators) that enable access to the data and models from any computer hardware, at any location, at any time.
- The system uses CORBA to facilitate communication between the client application and the application server.
- Support capabilities for all relevant transportation applications.
- Functionality for interaction among users.
- Reporting tools.
- Security features providing access control and fine-grained permissions on data and models.
- Some basic administrative capabilities.

The system is intended for deployment at the state or regional level. The State Department of Transportation (DOT), the Metropolitan Planning Organizations (MPOs), County Engineers, City Engineers, Transit Agencies, Freight Agencies, and other stakeholders will have access to the system at various authorization levels to obtain/maintain data, run models and perform analysis. Policy makers at the Federal, State and Local governments will be able to monitor projects, obtain data, evaluate impacts of policies and make decisions. The overall structure of VISTA is outlined below.

The user interface is written entirely in Java, so it can easily be used on multiple platforms and across the Internet. It communicates with the Management Module through the Java Object Request Broker (ORB), allowing access to any user with a web browser and the Java plug-in. The Data Warehouse can be accessed through CORBA, C/C++ libraries, Open Database Connectivity (ODBC), and Java Database Connectivity (JDBC). Finally, by implementing an abstraction over the database interfaces, the underlying modules can easily migrate to work with a variety of other relational database management systems. By maintaining a Data Warehouse, the efficiency is improved in managing data and performing analysis.

Figure 22: VISTA structure



Furthermore, specific information requirements are often not known in advance when dealing with complex systems. These are the specific issues that have motivated the use of an RDBMS. Using a variety of access paths (JDBC, ODBC, and native libraries), the Data Warehouse allows any tool access to the data, through one of these paths. This approach allows for the straightforward implementation of complex querying and reporting through the GIS or the web. Furthermore, this design ensures that if a desired functionality is omitted, a user can acquire the desired information using third party tools without changing the framework.

The networked nature of the VISTA framework also enables the parallelization of resource-intensive models. Some of the algorithms in VISTA can be migrated from serial to parallel implementations with minimal effort. This allows multiple processors to execute a model in a fraction of the time a single processor would require. A secondary benefit of distribution is realized for the Data Warehouse. In a networked environment, many RDBMS packages can replicate data across multiple servers, adding a level of redundancy to protect the data.

8.3.1 VISTA DTA Procedure

The VISTA DTA model iterates between traffic simulation, shortest path calculations and traffic assignment. This section first describes the VISTA DTA iterative procedure, and then discusses the cell transmission model, which is used to propagate traffic. The simulator is a separate entity within VISTA called RouteSim. The DTA model implemented in VISTA is depicted in Figure 23. The flow chart shows that VISTA/DTA is an iterative procedure that alternates between traffic simulation, shortest path calculations and traffic assignment. The network and OD demand are entered into the model and converted to the required format. Specifically, the node and link network is converted into a cell network for use in the RouteSim cell transmission-based simulator. Further, the origin-destination (OD) demand data is converted into a dynamic demand table by assigning each vehicle a specific departure time. In a typical application, the static OD matrices (passenger cars and commercial vehicles) and 15-minute traffic counts from detectors along the links of the network are utilized by the VISTA's dynamic OD matrix algorithm to produce an estimate of the dynamic OD matrix.

In the first iteration the RouteSim simulator is executed with vehicles assigned to the free flow shortest paths, based on either their designated Origin departure or Destination arrival time. The vehicles are propagated into the network based on their assigned paths following the mesoscopic cell transmission model that is based on fundamental traffic flow relationships of volume, speed and density. We emphasize here that this is an important characteristic of simulation-based DTA models such as VISTA, DYNASMART and DYNAMIT. The link travel times resulting from that assignment pattern are then used to calculate a new set of shortest paths and the simulation is repeated with vehicles assigned to a combination of the previously calculated path sets. VISTA continues iterating between the mesoscopic simulation and vehicle assignment until the link travel times converge. This iterative procedure assigns vehicles to user equilibrium (UE) paths, and thus captures travelers' route choice behavior. Further information on the VISTA model and software can be found in Ziliaskopoulos et al., 1999 and Ziliaskopoulos and Walker, 2000, while results from other studies using the VISTA software can be found in Ziliaskopoulos et al., 2000 and Walker and Ziliaskopoulos, 2000.

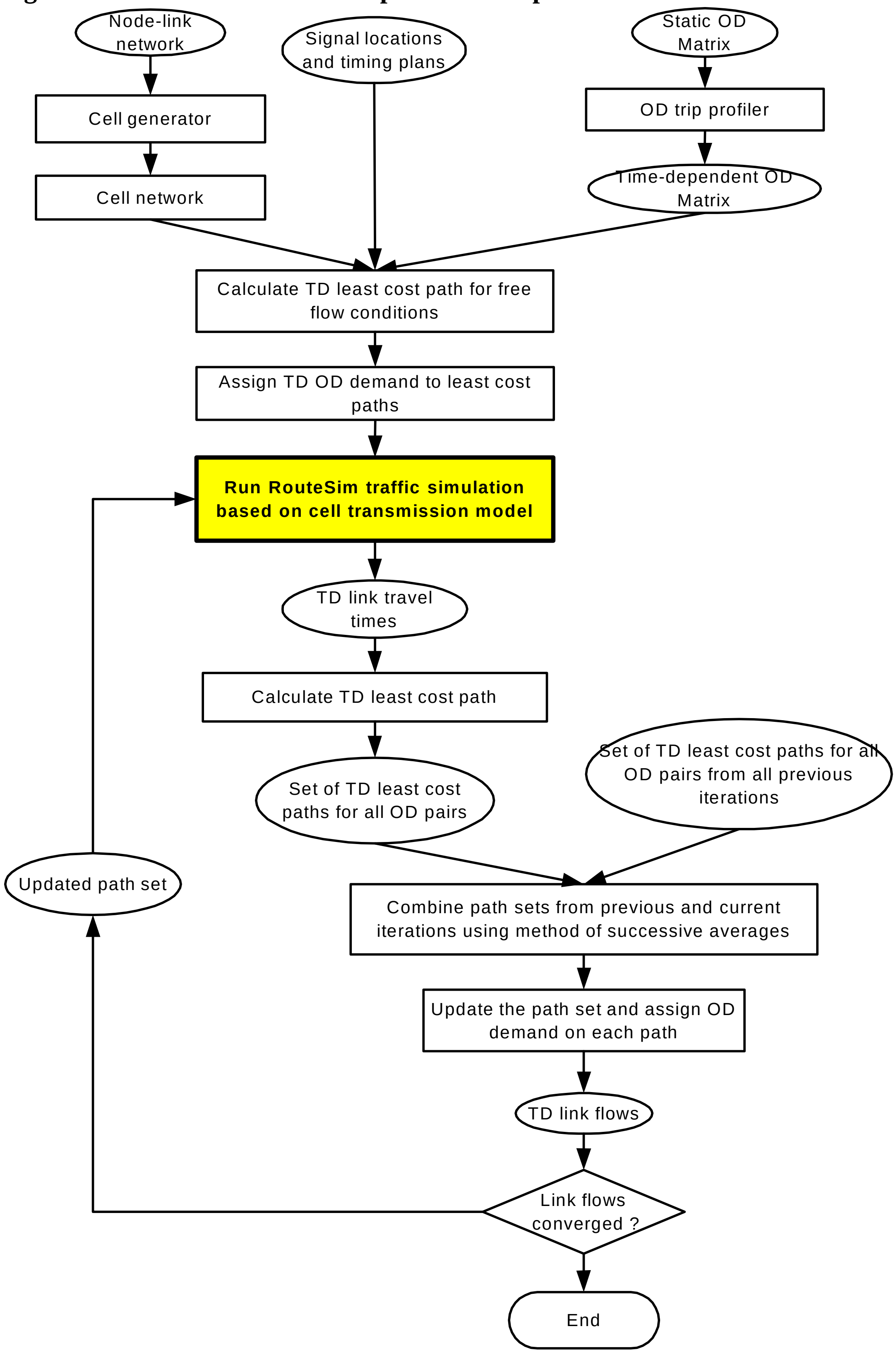
For this study, tests were performed with 6 iterations of DTA for the base case to create alternative paths for each vehicle for its OD pair and 5 iterations of DTA updates to optimize the assignments in reaching convergence – convergence was based on the relative difference of link traffic volumes between two consecutive iterations.

8.3.2 The ROUTESIM Mesoscopic Simulator

The cell transmission model can be considered to be a mesoscopic approach, because it moves vehicles based on average conditions in a cell, where the cell size can be sufficiently small to capture the state of individual vehicles. Mesoscopic simulation computes the cell location of each vehicle at every time step. This information is less detailed than the output provided by microscopic simulation (exact vehicle position, speed and acceleration at each time step) but is much more computationally efficient and allows mesoscopic simulators to solve large networks. The VISTA software takes advantage of this, and further is designed to run on Unix machines, which have much higher computational power than PCs, especially when run in parallel. VISTA has been successfully used to simulate street networks with as many as 40,000 nodes.

The VISTA system also includes a microscopic traffic simulator that has similar characteristics of car following and lane changing driver behavior with that of CORSIM. The analyst could also utilize the microscopic traffic simulator for a sub-network to conduct more detailed analyses. However, it is strongly recommended that traffic flow measurements should be conducted to calibrate the basic parameters of the car following and lane changing behavior for both passenger car and truck drivers. Furthermore, it is emphasized that the use of the microscopic simulator will require a substantially longer time to reach a DTA convergence.

Figure 23: Flowchart of the DTA procedure implemented in VISTA



8.3.2.1 Cell Transmission Model

The RouteSim simulator propagates vehicles through cells according to Daganzo's cell transmission model, such that link conditions are simulated by evaluating flow at a finite number of intermediate points along each link (Daganzo, 1994). Each road section is divided into homogeneous cells, such that the length of each cell is equal to the distance traveled by a typical vehicle under free flow traffic conditions in one time step. For this model, network input data, which is typically defined in terms of nodes and links, is defined by cells that are short segments of links. Jam density and maximum flow values are assigned to each cell based on the number of lanes available, other capacity modifications, and the speed limit on that roadway. These values will control the vehicle propagation into and out of each cell and along the roadway.

The state of the system at time t is given by the number of vehicles in each cell, $n_i(t)$. Two parameters are used: $N_i(t)$, the maximum number of vehicles that can be present in cell i at time t, and $Q_i(t)$, the maximum number of vehicles that can flow in cell i at time interval t. $N_i(t)$ is the product of the cell's length and its jam density, and $Q_i(t)$ is the capacity of cell i. The following variables are defined next:

$$S_{i-1}(t) = min\{ n_{i-1}(t),\ Q_{i-1}(t)\} \tag{1}$$

$$R_i(t) = min\{Q_i(t),\ N_i(t)-n_i(t)\} \tag{2}$$

where $S_{i-1}(t)$ is the maximum number of vehicles that can be sent by cell $i-1$ to cell i, and $R_i(t)$ is the maximum number of vehicles allowed in cell i. The number of vehicles that can flow from cell $i-1$ to cell i when the clock advances from t to $t+1$, $y_i(t)$ is defined as the minimum of the two variables:

$$y_i(t) = min\ \{ S_{i-1}(t),\ R_i(t) \} \tag{3}$$

Based on equations (1)-(3), the recursive relationship of the cell transmission model is expressed as follows:

$$\mathrm{n_i(t+1) = n_i(t) + y_i(t) - y_{i+1}(t)} \tag{4}$$

Thus, we can simulate traffic on a network by recursively computing the vehicle occupancy of every cell at each time step during the simulation period. Daganzo showed that the principles of the cell transmission model are consistent with the hydrodynamic theory of traffic flow, but can also capture microscopic effects, such as queuing. Merging and diverging junctions are explicitly modeled to maximize the flow on all the contributing components. The time step, which is user-specified, is selected as 30 seconds for this study.

8.3.2.2 Signalized Intersections

Modeling the flows at a signalized intersection is more complicated than freeway junctions, since several approaches converge and diverge at a single point and the flows are regulated by a traffic signal. At a four-legged signalized intersection, eight links are connected to a single point, where traffic arrives at and departs from the intersection to four directions. The traffic signal regulates the traffic flow so that conflicting flows are not simultaneously transmitted.

Approaching traffic at a four leg-intersection can move in three directions. We assume that each approach has an exclusive turning lane for each movement (this constraint is later relaxed), which means that we can divide the end cell of the approaching road into three sub-cells representing the three movements as depicted.

Phase sequence is the order that signal phases are displayed during the cycle. Phase sequences may consist of the combinations of the protected and permissive movements depending on the different left turn treatments. Two to six phases make up a typical signal cycle, depending on how the left turns need to be protected. The phases are generated from the combination of the eight basic NEMA phases, starting at the beginning of each barrier.

Gap acceptance in RouteSim is handled through the use of conflict definitions. A conflict defines a specific turning movement, the movement that conflicts with it, the priorities and gaps acceptable. This allows for flexible representation of gap acceptance and right turns on red. Driver gap acceptance decisions are mainly affected by the width of the facility to be crossed and the speed of the conflicting traffic. Various critical gap acceptance values for left and right turning vehicles are listed in the Highway Capacity Manual. The values range from 5.0 to 6.0 seconds for left turning and 5.5 to 6.5 seconds for right turning vehicles. Six seconds for both right turning and left turning vehicles were used for simplicity. The gap for turning vehicles can be identified by examining the occupancy of the cell transmitting the conflicting traffic. Since the time step for signalized intersections is two seconds, we consider the occupancy of the last three cells for both left and right turning vehicles.

8.3.2.3 Bus Movements

Buses differ from cars in size and travel behavior, and realistic simulation of a transportation network requires that buses and their impacts on the network be appropriately represented. First, buses are longer than cars, so they require more roadway capacity than cars. Further, the length of a bus not only affects the amount of space it requires, but also its maneuverability. Specifically, large vehicles require more space to turn and may take more time and cause more of a disruption to traffic when turning at intersections. Bus length is typically modeled using a bus-car equivalence factor, and this captures the added amount of roadway capacity required by buses; however, issues related to maneuverability are not typically captured as this would require data on bus vehicle turning capabilities and roadway geometries, and these are not readily available.

Another difference between buses and cars is that buses stop frequently, at both predefined bus stops and other locations as flag stops. The challenge in modeling bus stops is that buses do not stop at all stops, and the dwell time of each stop varies. Flag stops are even more challenging, as every node and mid-link location is a potential bus stop.

Ideally, dwell times would be determined by the number of boardings and alightings at a stop; however, since the automobile assignment-based approach does not assign person trips, the simulator does not track person movements, so the number of boardings and alightings is not known. Therefore, dwell times can be simulated deterministically or probabilistically. The deterministic approach assumes predetermined dwell times at predetermined bus stops throughout the network. If detailed bus stopping data were collected for each bus stop and route, this approach could approach reality. More often, however, detailed bus stop data is unavailable and an average dwell time is used for each stop. An alternative is to define a probability curve that describes the likelihood of a bus stopping, such that the simulation probabilistically selects the stops and dwells of a bus. This approach also requires stop and dwell time data for development of a probability curve.

The RouteSim cell transmission-based simulator has been enhanced to include bus movements. Buses are modeled as longer vehicles; however, the difficulties of turning movements have not yet been considered, since data on bus turning radii and intersection geometries have not been obtained. Bus dwells can be modeled either deterministically or probabilistically; however, since people movements are not captured in the simulation, dwells are not associated with boardings and alightings. Buses are held for the duration of the dwell, and the lane blockage resulting from a stopped bus is modeled by temporarily reducing the maximum flow and storage of the cell in which the bus stop is located. Acceleration is not captured in the cell transmission model, so the slower acceleration rate of buses is not simulated. On congested networks, where speeds are limited by capacity more so than by acceleration constraints, this approximation may be reasonable; however in other cases, bus travel times may appear slightly faster than in reality.

8.3.3 Time Dependent Shortest Path Algorithm

Ziliaskopoulos and Mahmassani introduced a time-dependent shortest path algorithm that computes the shortest path from every node and departure time to a destination node without assuming FIFO links (Mahmassani et al., 1993). It is built on Equation 5, which is a modified version of Cooke and Halsey's functional equation:

$$d_i(t) = \min\{d_i(t), c_{ij}(t) + d_j(t + c_{ij}(t))\} \qquad \forall i \in \Gamma^{-1}(j) \tag{5}$$

where

$d_i(t)$ = the minimum time path from node i to destination node D
$c_{ij}(t)$ = the travel time on arc (i,j) at time departing from node i at time t
N = set of all nodes
s = the destination node
T = set of discrete time steps

Initially, the destination node is entered into the scan eligible list. Further, distance labels for the destination node, $d_s(t)$, are set to 0 for all t, and the distance labels for each time step of the remaining nodes are set to ∞. The iterative process begins with removal of the destination node from the scan eligible list. For the node j being scanned, each upstream node i is examined for every time step, $t \in T$. If Equation 6 holds for nodes i and j at time t, then the distance label can be improved, so $d_i(t)$ is updated with the improved distance.

$$d_i(t) > c_{ij}(t) + d_j(t + c_{ij}(t)) \tag{6}$$

If $d_i(t)$ is changed for at least one time step, then node i is entered into the scan eligible list. The iterative process continues with selection of a new node from the scan eligible list. The process terminates when no nodes remain in the scan eligible list.

VIII.Preliminary Air Quality Analysis Vehicle Emissions Modeling

9.1 Automobile Emissions: An Overview

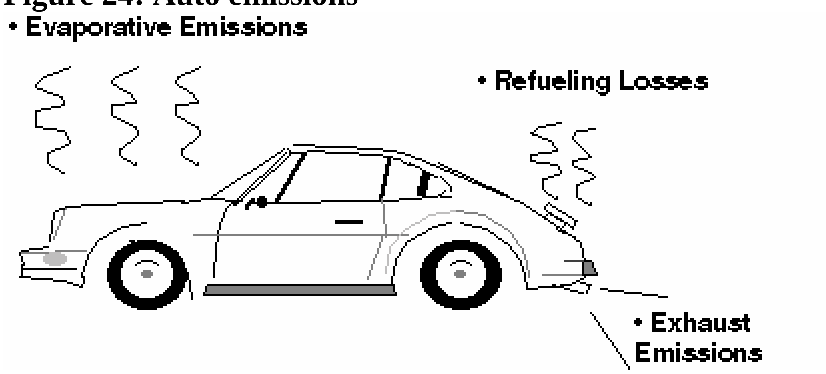
a. Cars and Pollution

Emissions from an individual car are generally low, relative to the smokestack image many people associate with air pollution. But in numerous cities across the country, the personal automobile is the single greatest polluter, as emissions from millions of vehicles on the road add up. Driving a private car is probably a typical citizen's most "polluting" daily activity.

b. Sources of Auto Emissions

The power to move a car comes from burning fuel in an engine. Pollution from cars comes from by-products of this combustion process (exhaust) and from evaporation of the fuel itself.

Figure 24: Auto emissions



c. The Combustible Process

Gasoline and diesel fuels are mixtures of hydrocarbons, compounds that contain hydrogen and carbon atoms. In a "perfect" engine, oxygen in the air would convert all the hydrogen in the fuel to water and all the carbon in the fuel to carbon dioxide. Nitrogen in the air would remain unaffected. In reality, the combustion process cannot be "perfect," and automotive engines emit several types of pollutants.

"Perfect" Combustion

FUEL (hydrocarbons) + AIR (oxygen and nitrogen) ==>>
CARBON DIOXIDE + water + unaffected nitrogen
Typical Engine Combustion

FUEL + AIR ==>> UNBURNED HYDROCARBONS +
NITROGEN OXIDES + CARBON

MONOXIDE + CARBON DIOXIDE + water

d. Exhaust Pollutants

Hydrocarbons (HC): Hydrocarbon emissions result when fuel molecules in the engine do not burn or burn only partially. Hydrocarbons react in the presence of nitrogen oxides and sunlight to form ground-level ozone, a major component of smog. Ozone irritates the eyes, damages the lungs, and aggravates respiratory problems. It is our most widespread and intractable urban air pollution problem. A number of exhaust hydrocarbons are also toxic, with the potential to cause cancer.

Nitrogen Oxides (NO_x): Under the high pressure and temperature conditions in an engine, nitrogen and oxygen atoms in the air react to form various nitrogen oxides, collectively known as NO_x. Nitrogen oxides, like hydrocarbons, are precursors to the formation of ozone. They also contribute to the formation of acid rain.

Carbon Monoxide: Carbon monoxide (CO) is a product of incomplete combustion and occurs when carbon in the fuel is partially oxidized rather than fully oxidized to carbon dioxide (CO_2). Carbon monoxide reduces the flow of oxygen in the bloodstream and is particularly dangerous to persons with heart disease.

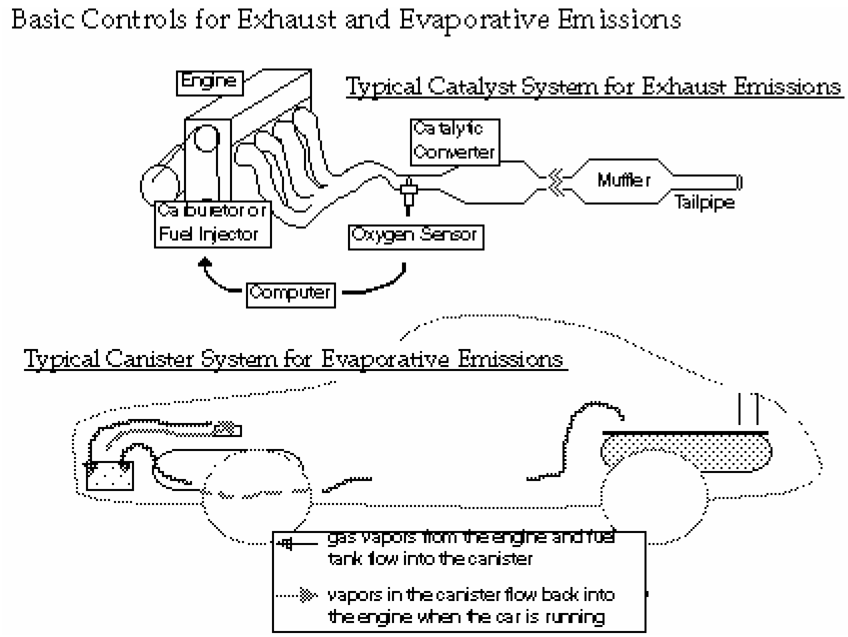
Carbon Dioxide: In recent years, the U.S. Environmental Protection Agency (EPA) has started to view carbon dioxide, a product of "perfect" combustion, as a pollution concern. Carbon dioxide does not directly impair human health, but it is a "greenhouse gas" that traps the earth's heat and contributes to the potential for global warming.

Evaporative Emissions: Hydrocarbon pollutants also escape into the air through fuel evaporation. With today's efficient exhaust emission controls and gasoline formulations, evaporative losses can account for a majority of the total hydrocarbon pollution from current model cars on hot days when ozone levels are highest. Evaporative emissions occur in several ways:

> **Diurnal**: Gasoline evaporation increases as the temperature rises during the day, heating the fuel tank and venting gasoline vapors.
>
> **Running Losses**: The hot engine and exhaust system can vaporize gasoline when the car is running.
> **Hot Soak**: The engine remains hot for a period of time after the car is turned off, and gasoline evaporation continues when the car is parked.
>
> **Refueling**: Gasoline vapors are always present in fuel tanks. These vapors are forced out when the tank is filled with liquid fuel.

9.2 Control of Automobile Emissions

The Clean Air Act of 1970 gave EPA broad authority to regulate motor vehicle pollution, and the Agency's emission control policies have become progressively more stringent since the early 1970s.



EPA standards dictate how much pollution autos may emit but automakers decide how to achieve the pollution limits. The emission reductions of the 1970s came about because of fundamental improvements in engine design, plus the addition of charcoal canisters to collect hydrocarbon vapors and exhaust gas recirculation valves to reduce nitrogen oxides.

The advent of "first generation" catalytic converters in 1975 significantly reduced hydrocarbon and carbon monoxide emissions. The use of converters provided a huge indirect benefit as well. Because lead inactivates the catalyst, 1975 saw the widespread introduction of unleaded gasoline. This resulted in dramatic reductions in ambient lead levels and alleviated many serious environmental and human health concerns associated with lead pollution.

The next major milestone in vehicle emission control technology came in 1980-81. In response to tighter standards, manufacturers equipped new cars with even more sophisticated emission control systems. These systems generally include a "three-way" catalyst (which converts carbon monoxide and hydrocarbons to carbon dioxide and water, and also helps reduce nitrogen oxides to elemental nitrogen and oxygen), plus an on-board computer and oxygen sensor. This equipment helps optimize the efficiency of the catalytic converter.

The 1990 Clean Air Act included provisions to further reduce vehicle emissions. Mobile source provisions include even tighter tailpipe standards, increased durability, improved control of evaporative emissions, and computerized diagnostic systems that identify malfunctioning emission controls.

9.3 Emissions Control and Air Quality

Efforts by government and industry since 1970 have greatly reduced typical vehicle emissions. In those same years, however, the number of miles we drive has more than doubled. The increase in travel has offset much of the emission control progress. The net result is a modest reduction in each automotive pollutant except lead, for which aggregate emissions have dropped by more than 95 percent. With ozone continuing to present a persistent urban air pollution problem, future vehicle emission control programs will emphasize hydrocarbon and nitrogen oxide reductions. Carbon monoxide control will remain critical in many cities, and limits on vehicle-generated carbon dioxide may become important in the future.

Before discussing the calculation of emissions rates by MOBILE6, some vital input parameters are presented in Tables 23 – 26.

Table 23: Vehicle Classifications

Number	*Abbreviation*	*Description*
1	LDGV	Light-Duty Gasoline Vehicles (Passenger Cars)
2	LDGT1	Light-Duty Gasoline Trucks 1 (0-6,000 lbs. GVWR, 0-3,750 lbs. LVW)
3	LDGT2	Light-Duty Gasoline Trucks 2 (0-6,000 lbs. GVWR, 3,751-5,750 lbs. LVW)
4	LDGT3	Light-Duty Gasoline Trucks 3 (6,001-8,500 lbs. GVWR, 0-5,750 lbs. ALVW)
5	LDGT4	Light-Duty Gasoline Trucks 4 (6,001-8,500 lbs. GVWR, greater than 5,751 lbs. ALVW)
6	HDGV2b	Class 2b Heavy-Duty Gasoline Vehicles (8,501-10,000 lbs. GVWR)
7	HDGV3	Class 3 Heavy-Duty Gasoline Vehicles (10,001-14,000 lbs. GVWR)
8	HDGV4	Class 4 Heavy-Duty Gasoline Vehicles (14,001-16,000 lbs. GVWR)
9	HDGV5	Class 5 Heavy-Duty Gasoline Vehicles (16,001-19,500 lbs. GVWR)
10	HDGV6	Class 6 Heavy-Duty Gasoline Vehicles (19,501-26,000 lbs. GVWR)
11	HDGV7	Class 7 Heavy-Duty Gasoline Vehicles (26,001-33,000 lbs. GVWR)
12	HDGV8a	Class 8a Heavy-Duty Gasoline Vehicles (33,001-60,000 lbs. GVWR)
13	HDGV8b	Class 8b Heavy-Duty Gasoline Vehicles (>60,000 lbs. GVWR)
14	LDDV	Light-Duty Diesel Vehicles (Passenger Cars)
15	LDDT12	Light-Duty Diesel Trucks 1and 2 (0-6,000 lbs. GVWR)
16	HDDV2b	Class 2b Heavy-Duty Diesel Vehicles (8,501-10,000 lbs. GVWR)
17	HDDV3	Class 3 Heavy-Duty Diesel Vehicles (10,001-14,000 lbs. GVWR)
18	HDDV4	Class 4 Heavy-Duty Diesel Vehicles (14,001-16,000 lbs. GVWR)
19	HDDV5	Class 5 Heavy-Duty Diesel Vehicles (16,001-19,500 lbs. GVWR)
20	HDDV6	Class 6 Heavy-Duty Diesel Vehicles (19,501-26,000 lbs. GVWR)
21	HDDV7	Class 7 Heavy-Duty Diesel Vehicles (26,001-33,000 lbs. GVWR)
22	HDDV8a	Class 8a Heavy-Duty Diesel Vehicles (33,001-60,000 lbs. GVWR)
23	HDDV8b	Class 8b Heavy-Duty Diesel Vehicles (>60,000 lbs. GVWR)
24	MC	Motorcycles (Gasoline)
25	HDGB	Gasoline Buses (School, Transit and Urban)
26	HDDBT	Diesel Transit and Urban Buses
27	HDDBS	Diesel School Buses
28	LDDT34	Light-Duty Diesel Trucks 3 and 4 (6,001-8,500 lbs. GVWR)

Table 24: Emission Type Classifications

Number	*Abbreviation*	*Description*	*Pollutants*	*Vehicle Classes*
1	Running	Exhaust Running Emissions	All except tire and brake wear.	All
2	Start	Exhaust Engine Start Emissions (trip start)	HC,CO,NO_x	LD plus MC
3	Hot Soak	Evaporative Hot Soak Emissions (trip end)	HC, BENZ, MTBE	Gas, inc. MC
4	Diurnal	Evaporative Diurnal Emissions (heat rise)	HC, BENZ , MTBE	Gas, inc. MC
5	Resting	Evaporative Resting Loss Emissions (leaks and seepage)	HC, BENZ, MTBE	Gas, inc. MC
6	Run Loss	Evaporative Running Loss Emissions	HC, BENZ, MTBE	Gas, less MC
7	Crankcase	Evaporative Crankcase Emissions (blow-by)	HC, BENZ, MTBE	Gas, inc. MC
8	Refueling	Evaporative Refueling Emissions (fuel displacement and spillage)	HC, BENZ, MTBE	Gas, less MC
9	Brake Wear	Particulate matter from brake component wear	Brake wear particulate	All
10	Tire Wear	Particulate matter from tire wear	Tire wear particulate	All

Table 25: Pollutant Categories

Number	Abbreviation	Description
1	HC	Hydrocarbons (gaseous)
2	CO	Carbon Monoxide (gaseous)
3	NOx	Oxides of Nitrogen (gaseous)
4	CO_2	Carbon Dioxide (gaseous)
5 thru 6	(reserved)	
7	SO_4	Sulfate Portion of Exhaust Particulate
8	OCARBON	Organic Carbon Portion of Diesel Exhaust Particulate
9	ECARBON	Elemental Carbon Portion of Diesel Exhaust Particulate
10	GASPM	Total Carbon Portion of Gasoline Exhaust Particulate
11	Lead	Lead Portion of Exhaust Particulate
12	SO_2	Sulfur Dioxide (gaseous)
13	NH_3	Ammonia (gaseous)
14	Brake	Brake Wear Particulate
15	Tire	Tire Wear Particulate
16	BENZ	Benzene
17	MTBE	Methyl Tertiary Butyl Ether
18	BUTA	1,3-Butadiene
19	FORM	Formaldehyde
20	ACET	Acetaldehyde
21	ACRO	Acrolein

Number	Abbreviation	Description
1	Freeway	High-Speed, Limited-Access Roadways
2	Arterial	Arterial and Collector Roadways
3	Local	Urban Local Roadways
4	Fwy Ramp	Freeway on and off ramps
5	None	Not Applicable (For start and some evaporative emissions)

Table 26: Hydrocarbon Categories

Number	Abbreviation	Description
1	THC	Total Hydrocarbons
2	NMHC	Non-Methane Hydrocarbons
3	VOC	Volatile Organic Compounds
4	TOG	Total Organic Gases
5	NMOG	Non-Methane Organic Gases

9.4 Basic Emissions Rates

MOBILE6 basic emission rates are derived from emissions tests conducted under standard conditions such as temperature, fuel, and driving cycle. Emission rates further assume a pattern of deterioration in emission performance over time, again based on results of standardized emission tests. MOBILE6 calculates adjustments to basic emission rates for conditions that differ from typical standard testing. Adjustments are used both to reflect how an in-use vehicle population is different from the tested samples and for conditions different from those used in the testing program. Adjustments are calculated for the effects of:

- Average speed by roadway type
- Temperature

- Air conditioning
- Humidity
- Gasoline volatility
- Gasoline oxygen content
- Gasoline and diesel fuel sulfur content
- Reformulated gasoline
- Detergent gasoline rule
- Other gasoline fuel properties (used to estimate HAPs only)
- Cold CO rule
- Off-cycle driving and Supplemental Federal Test Procedure (SFTP) rule
- Tampering
- Excess emissions (defeat device)
- Inspection and maintenance programs
- Anti-tampering programs
- Stage II refueling control programs
- Onboard diagnostics

Some adjustments do not affect all emission types or all emissions. Some adjustments, such as inspection and maintenance (I/M) programs, require detailed user-supplied information and complex calculation of the effect.

9.5 Methodology

This presents an overview the overall analysis process adopted for this study. The process is described in a stepwise process, each step corresponding to a task of the study.

Step 0 PREPARATION AND DATA INPUT

Network and Demand

Prepare the traffic network for the selected region.
Prepare the demand for the selected time periods.

Peak Period Scenarios

Prepare the peak period scenarios.
For both peak period scenarios (AM and PM):

Interpolate the demand data for the relevant period of simulation.
Profile the demand over the simulation period (demand varies over the peak period).

Step 1 SCENARIO RUNS

Required simulation

For both peak periods (Morning Peak, Evening Peak):

- Run simulations for the respective demands.
-- 1 iteration RouteSIM simulation
-- 10 iterations of DTA

Analysis of results

Import all the simulation results for further analyses:

Vehicle-based spatio-temporal routes with departure and arrival times.

Set of paths used by all the vehicles for every O-D pair.

Extract all the paths corresponding to all vehicles in the network along with their arrival times at each intersection:

Compute the total number of vehicles that traveled on each street segment during the entire simulation period.

Compute the total number of cars on each street segment.

Compute the total number of trucks on each street segment.

Compute the total fuel consumption for cars on each street segment.

Compute the total fuel consumption for trucks on each street segment.

Compute the travel times of each vehicle on each street segment.

Compute the total travel time of all the vehicles in the entire network.

Compute the length of all street segments.

Compute the total Vehicle Miles Traveled (VMT) in the entire network.

Compute the average speed of vehicles on each street segment.

Compute the average speed of cars on each street segment.

Compute the average speed of trucks on each street segment.

Tabulation of results

For both AM peak and PM peak determine the following measures

- Total measures of:
    - Number of VMT:
        - VMT for trucks.
        - VMT for cars.
    - Travel Time.
    - Fuel consumption by cars.
    - Fuel consumption by trucks.
- Averaged measures of top 100 street segments with:
    - Highest traffic volume:
        - Highest car volume.
        - Highest truck volume.
    - Lowest speed of vehicles:
        - Lowest speed of Cars.
        - Lowest speed of trucks.
    - Highest fuel consumption of cars.
    - Highest fuel consumption of trucks.

Step 2 DERIVED MEASURES

Determination of queue lengths and average delays:

For both AM and PM peak:

For every movement on every intersection.

For the entire simulation period.
For every time instant (every 6 seconds in our case):
- Compute the cumulative number of vehicles arriving.
- Compute the cumulative number of vehicles departing.
- Compute the average delay for each movement in all the intersection.
- Compute the maximum and average queue lengths for each movement in all intersections.

Tabulation of results
For both AM peak and PM peak determine the following measures:
- Averaged measures of top 100 movements with:
  - Highest queue lengths.
  - Highest average queue lengths.
  - Highest average delay.

Step 3 EMISSIONS COMPUTATION

Determination of CO, NOX, and TOG emission levels

For both AM and PM peak:
For each street segment:
- Compute fraction of vehicle types (in our case just car and truck).
- Total VMT.
- Average speed of all the vehicles.
- Compute/Procure other parameters:
  - Projected year for which emissions are computed
  - Average hourly temperature (day / night) for entire year
  - Time frame for which simulation is done
  - Weather conditions (cloud cover, sunshine) – *optional:*
    - Compute emissions for each street segment.
    - Compute emissions for the whole network.

Tabulation of results
For both AM peak and PM peak determine the following measures:
- Averaged measures of top 100 street segments with:
  - Highest CO levels.
  - Highest NOX levels
  - Highest TOG levels
- Total measures of:
  - CO levels.
  - NOX levels.
  - TOG levels.

9.6 Analysis Periods and Measures of Effectiveness (MOEs)

In this study, all the measures listed in Table 27 were computed for the morning peak period as well as evening peak period. For the purpose of efficient and speedy simulation the simulation was done for 2 hours for both the peak time periods. The time periods considered were:

- Morning Peak (6:00am – 10:00am)
- Evening Peak (3:00pm – 7:00pm)

In order to get a feel of the key areas that correspond to the critical values of these measures, we identified the 100 most critical street segments/movements/intersections in the network. In computing the MOEs *Fuel Consumption of Cars* and *Fuel Consumption of Trucks* the standard aggregated fuel consumption rates for trucks and cars were used:

- Trucks: 0.125 gallons/mile
- Cars: 0.054 gallons/mile

For the purpose of computing the emissions (CO, NOx, TOG) we made use of the software package developed by EPA known as MOBILE6. We linked this package with the VISTA software through a small routine interface. VISTA provided the inputs required by MOBILE6 to compute the emissions by running the simulation on the network. We were able to compute the emissions at the street level owing to the capability of VISTA to produce the parameters: VMT (Vehicle Miles Traveled) and Average Speed of Vehicles at the street level. Apart from these two parameters we have also facilitated the option of specifying a number of other criteria which might influence vehicular emissions.

Table 27: MOEs Computed

MOE	Units	Description
Average Speed of Vehicles	Miles/Hour	Top 100 street segments with the lowest average speeds for vehicles have been identified
Average Speed of Cars	Miles/Hour	Top 100 street segments with the lowest average speeds for cars in particular have been identified
Average Speed of Trucks	Miles/Hour	Top 100 street segments with the lowest average speeds for trucks in particular have been identified
Fuel Consumption of Cars	Gallons/Hour/Mile	Top 100 street segments with the highest fuel consumption for cars have been identified
Fuel Consumption of Trucks	Gallons/Hour/Mile	Top 100 street segments with the highest fuel consumption for trucks have been identified
Total Traffic Volume	Vehicles/Hour	Top 100 street segments with the highest traffic volume have been identified
Traffic Volume of Cars	Cars/Hour	Top 100 street segments with the highest traffic volume of cars in particular have been identified
Traffic Volume of Trucks	Trucks/Hour	Top 100 street segments with the highest traffic volume of trucks in particular have been identified
Average Queue Lengths	No. of Vehicles	Top 100 movements (and the corresponding intersections) with the longest average queue lengths have been identified
Average Movement Delays	Seconds	Top 100 movements (and the corresponding intersections) with the highest average movement delays have been identified
CO Emissions*	Grams/Mile/Hour	Top 100 street segments with the highest amount of CO emissions have been identified
NOX Emissions**	Grams/Mile/Hour	Top 100 street segments with the highest amount of NOX emissions have been identified
TOG Emissions***	Grams/Mile/Hour	Top 100 street segments with the highest amount of TOG emissions have been identified

* CO: Carbon Monoxide
** NOX: Nitrogen Oxides
*** TOG: Total Organic Gases

Table 28 lists the criteria which can be specified in VISTA while computing emissions using MOBILE6.

Table 28: Options Available For Computing Emissions

Options	**Description**
Link ID	Street segment on which emissions are desired
Year	Year in which emissions are desired
Time	Time duration for which emissions are to be computed
Hourly Temperatures During Day	Average hourly temperatures during the day in a year
Hourly Temperature During Night	Average hourly temperatures during the night in a year
Altitude	High/Low
Absolute Humidity	Absolute Humidity in (grains/lb)
Cloud Cover	High/Low
Peak Sun	Time duration of peak sun
Sunrise/Sunset	Times of sunrise and sunset
Month	Jan-June/July-Dec

IX. Presentation of results

Two major sets of runs were performed: one of the AM and another one for the PM peak periods. The overall statistics for each one of the runs are listed in Tables 29 and 30. As shown in Table 29, the total fuel consumption for the morning peak (6:00-10:00 AM) is 7,458 gallons for passenger cars or an average consumption rate of 18 miles/gallon and for trucks 1,365 gallons (or 4.79 miles/gallon). The passenger emissions for the morning peak are: TOG 61.6 kilograms, CO 262.1 kilograms and NO_X 22.3 kilograms; for trucks: TOG 3.2 kilograms, CO 13.3 kilograms and NO_X 4.2 kilograms, which are proportionally higher of the truck volume on the network. Similar quantities are produced in the afternoon peak, where the higher number of trucks in the network results in higher emissions, despite the lower overall volume; this is also reflected in the total fuel consumed.

Detailed MOEs as outlined are included in the Appendices A to E: Appendix A lists the 100 links with the highest observed traffic volumes during the analyses periods classified in truck and passenger car traffic. Appendix B provides an indication of the links with the lowest average speed; these would tend to be the most problematic in terms of traffic congestion. Appendix C lists the links that contribute the most to the fuel consumption on this network. Appendix D focuses on the movements that present the highest queue length and delay and average; this is an indication of intersections that are problematic on this network. Finally, Appendix E provides details on the links with the highest rate of pollutants emission.

Table 29: Overall Statistics for AM peak (6:00am – 10:00am)

Parameter	Cars	Trucks	Total
Total Vehicles	54,337	1,546	55,883
VMT (vehicle-miles)	134,246	6,539	140,785
Aggregate Travel Time (hours)	6,962	204	7,166
Average Travel Time (minutes)	7.68	7.92	7.69
Fuel Consumption in the whole network (gallons)	7,458	1,365	8,823
Average Consumption (miles/gallon)	18.00	4.79	15.95
	Emissions Networkwide (grams/mile)		
	TOG	**CO**	**NOX**
Total Emissions for Cars (Kilograms)	61.6	262.1	22.3
Total Emissions for Trucks (Kilograms)	3.2	13.3	4.2
Grand Total (Kilograms)	64.8	275.4	26.5

Table 30: Overall Statistics for PM peak

Parameter	Cars	Trucks	Total
Total Vehicles	47,738	3,239	50,977
VMT (vehicle-miles)	117,383	8,186	125,569
Aggregate Travel Time (hours)	5,285	419	5,704
Average Travel Time (minutes)	6.64	7.76	6.71
Fuel Consumption in the whole network (gallons)	6,994	1,877	8,871
Average Consumption (miles/gallon)	16.78	4.36	14.15
	Emissions Networkwide (grams/mile)		
	TOG	**CO**	**NOX**
Total Emissions for Cars(Kilograms)	58.3	250.8	20.9
Total Emissions for Trucks(Kilograms)	6.9	28.9	8.8
Grand Total(Kilograms)	65.2	279.7	29.7

X.Summary and conclusions

A simulation-based DTA model called VISTA was implemented for the South Bronx network for the morning (6:00am – 10:00am) and evening peak periods (3:00pm – 7:00pm). The VISTA DTA model was integrated with the FHWA's MOBILE6 air quality software in order to produce emission estimates of NO_x, CO, and TOG for all the roadway segments of the network.

A dynamic OD matrix for passenger cars and trucks was estimated using a static OD matrix provided by Urbitran Associates, AADT volumes from NYSDOT and limited 15-minute traffic counts for a small set of roadways using VISTA's proprietary algorithm. The available traffic counts were limited to the major arterials and freeways of the network. The GIS data were obtained from CALIPER Inc. Traffic control (e.g. signal timing, speed limit, and lane designation) data were obtained from the NYCDOT and from manual verification through visits to the site. The dynamic OD matrix, the traffic control data and the roadway geometry form the principal data required by the VISTA DTA model to be executed.

The main output of the DTA model is the path of each vehicle from its origin to its destination, including the corresponding origin departure time and the vehicle status along the path every six seconds of the simulation. The output allows the user to aggregate the results based on his/her specific needs such as 15-minute time intervals. It is recommended that the user aggregates the results based on the level of aggregation of the traffic counts that are used to produce the estimate of the dynamic OD matrix - the VISTA model has the capability to produce results at each 6 second time interval if it is desired, which is the current simulation step used within the mesoscopic traffic simulator. The user then has the capability to obtain traffic flow and air quality characteristics for each link of the network and for each specific time interval. A preliminary set of results that were produced under this phase of the project included the one hundred links of the network that produced the highest levels of air quality emissions, NO_x, CO, and TOG, respectively.

We emphasize that this phase of the project did not require any new traffic counts which would have produced much more updated and accurate results. In addition, the static OD matrix used is very sparse for that network as it is based on NYMTC's (NY MPO) transportation zones, which are very large to capture the details required in order to produce more accurate results.

The establishment of this first prototype model could now be used for various potential scenarios of interest such as:

Location and capacity of new waste transfer stations. The VISTA-DTA model would require the OD matrix for each of the new stations proposed and the roadway connections for ingress/egress of the trucks to/from the stations. Then the new model would produce the new dynamic traffic assignment pattern and the corresponding air quality MOEs.

Deletion of a Waste Transfer station. The DTA will simply be rerun without the corresponding OD of the existing waste transfer station and it will produce a new DTA pattern and the corresponding traffic flow and air quality MOEs.

Evaluation of new truck routes through the South Bronx. The VISTA model allows the user to designate specific truck routes and run the DTA. The DTA is executed as before where trucks are prohibited to use any paths that are note designated as truck routes. Similarly the VISTA DTA will produce the corresponding MOEs.

Evaluation of changes in demand for trucks and/or passenger cars. The user simply changes the OD demand for a specific OD pair or a set of OD pairs and executes the DTA model.

Establishment of a National Test Bed for Traffic Flow and Environmental Air Quality Measurements. This project provided the opportunity for the research team to establish a first prototype simulation-based DTA and air quality model (VISTA plus MOBILE6) for South Bronx. It is emphasized here that an important element of the VISTA system is that it allows the user to access the system from any computer that has Internet access. The South Bronx project could therefore become a national case study under which researchers can access it from various universities, the EPA, NYU, RPI and any other entity that is interested in environmental and transportation studies. This would require more funding that could be used to first collect more up to date traffic flow data and second to enhance the modules within the VISTA system according to the requirements of EPA in producing specific automated reports of relevance such that the users spend minimal time in running the model and summarizing the results.

It is further emphasized that the MOBILE6 EPA software bases its estimates for air quality measurements on the average speed. A more accurate model is needed which will take into consideration the more microscopic characteristics of traffic flow such as acceleration, deceleration, number of stops, vehicle type, and the prevailing weather conditions. As mentioned, the VISTA system has the capability to produce such estimates if the microscopic traffic simulator is activated. As an interim measure, the mesoscopic traffic simulator that is used for this project produces more accurate results that are based on the dynamics of traffic flow conditions as they unveil during the course of the time period of the day, providing a more discretized estimation of the average speed per time interval of the day (e.g. 15-minute time interval). Using the mesoscopic traffic simulator one could produce more accurate air quality estimates if a study is undertaken that will provide the distribution of the number of stops, acceleration/deceleration rates, vehicle types, and weather conditions for each time period of the day. A one-week study at a few characteristic locations will be sufficient to produce such estimates in the absence of a more costly implementation of a microscopic model.

The next step that could be followed by EPA that would further enhance the accuracy of the prototype VISTA plus MOBILE6 in South Bronx would be the installation of permanent air quality devices in the area such that the MOBILE6 software could be continuously enhanced using actual data. Furthermore, this prototype could be further expanded in other areas in the country that have air quality concerns and are willing to establish such a traffic/air quality simulator.

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APPENDIX A TRAFFIC VOLUMES

Table A-1: Top 100 Street Segments with Highest Traffic Volumes for AM Peak

Serial Number	Link ID	Street Name	Traffic Volume (vehicles/hour)
1	845	-	2318
2	507	-	2289
3	402	MAJOR DEEGAN MAIN S	2252
4	1125	-	2188
5	1126	CROSS BRONX MAIN W	2186
6	885	ALEX. HAMILTON BR W	2070
7	1095	-	2016
8	859	MAJOR DEEGAN MAIN N	2008
9	466	-	1994
10	954	-	1952
11	1218	-	1950
12	1292	-	1949
13	401	-	1944
14	468	-	1939
15	326	-	1906
16	1143	CROSS BRONX MAIN W	1906
17	474	CROSS BRONX EX	1906
18	317	-	1887
19	315	-	1839
20	259	CROSS BRONX MAIN W	1691
21	1168	-	1661
22	1173	-	1648
23	773	-	1607
24	541	-	1606
25	535	W145TH ST BR W	1605
26	786	-	1549
27	1402	-	1547
28	732	3RD AVE B	1528
29	261	-	1523
30	913	-	1468
31	805	-	1460
32	807	MAJOR DEEGAN MAIN N	1459
33	780	-	1449
34	387	-	1447
35	366	-	1446
36	649	-	1429
37	515	-	1423
38	367	-	1415
39	652	-	1414
40	461	-	1397
41	713	-	1396
42	2468	-	1378
43	926	-	1365
44	1104	-	1354

45	653	-	1324
46	893	-	1278
47	1160	-	1270
48	656	-	1269
49	1137	-	1269
50	655	-	1236
51	250	-	1233
52	901	-	1229
53	658	-	1217
54	764	-	1209
55	285	-	1207
56	354	-	1206
57	738	MAJOR DEEGAN MAIN N	1204
58	500	-	1203
59	659	-	1195
60	853	-	1193
61	1099	-	1188
62	753	-	1187
63	1132	-	1175
64	454	-	1171
65	751	MAJ DEEGAN EXP N	1171
66	397	-	1169
67	720	-	1168
68	977	-	1168
69	1179	-	1167
70	356	-	1167
71	1364	-	1166
72	342	-	1165
73	979	-	1164
74	833		1157
75	1246	SHERIDAN EX	1156
76	1413	-	1155
77	1111	-	1154
78	423		1154
79	431	SHERIDAN EX	1154
80	329	-	1153
81	407	-	1144
82	1177	-	1143
83	660	-	1142
84	1170	-	1142
85	459	-	1141
86	1171	-	1141
87	443	-	1139
88	1089	-	1138
89	657	-	1133
90	873	-	1120
91	295	-	1119
92	880	-	1118

93	1038	-	1118
94	835	-	1117
95	293	-	1116
96	294	MDE TO CBE W	1115
97	692	-	1103
98	834	-	1093
99	927	-	1067
100	410	-	1058

Table A-2: Top 100 Street Segments with Highest Traffic Volumes for PM Peak

Serial Number	Link ID	Street Name	Traffic Volume (vehicles/hour)
1	1638	-	2459
2	1855	E 170TH S	2330
3	2101	E 174TH S	2317
4	1784	E 175TH S	2302
5	2525	E 174TH S	2299
6	1125	-	2273
7	2433	3RD AV	2226
8	2098	E 174TH S	2155
9	1079	-	2031
10	1580	BROOK AV	1998
11	1209	-	1985
12	2000	E 175TH S	1980
13	1225	-	1968
14	2095	E 170TH S	1955
15	467	-	1944
16	758	-	1936
17	265	E 176TH S	1933
18	2469	-	1869
19	728	-	1863
20	457	-	1863
21	940	-	1855
22	757	-	1839
23	480	-	1828
24	781	-	1825
25	761	-	1770
26	1521	E 165TH S	1761
27	2490	E 170TH S	1718
28	1929	E 169TH S	1718
29	1983	-	1713
30	2043	E 170TH S	1643
31	1091		1638
32	1637	-	1615
33	2140		1596
34	2606	E 170TH S	1576
35	1527	E 168TH S	1562
36	477	-	1538
37	2002	E 176TH S	1519
38	1995	E 175TH S	1515
39	1533	E 168TH S	1514
40	2488	E 170TH S	1487
41	1998	E 175TH S	1484
42	1095	-	1477
43	2420	E 174TH S	1465
44	739	-	1462
45	2524		1447

46	548		1425
47	953	-	1407
48	2062	E 161ST S	1393
49	783	-	1378
50	2099		1354
51	1646	-	1346
52	1090		1328
53	2360	E 169TH S	1287
54	786	-	1265
55	1550	-	1261
56	862	-	1253
57	1787	E 176TH S	1246
58	1201	-	1233
59	1871	E 170TH S	1231
60	2254	-	1224
61	2543	E 170TH S	1215
62	1005	-	1212
63	1467	-	1209
64	1457		1204
65	1411	-	1199
66	1326	-	1198
67	1228	-	1195
68	1071	-	1189
69	780		1187
70	782		1181
71	1064	-	1180
72	1997	E 175TH S	1176
73	1643	-	1171
74	630		1167
75	1321		1167
76	2607		1166
77	1791	E 174TH S	1162
78	1479	E 168TH S	1161
79	1727	E 165TH S	1160
80	616		1156
81	2571		1154
82	1854	E 170TH S	1150
83	1860		1146
84	1812	E 174TH S	1145
85	784		1141
86	1124		1129
87	345		1103
88	281		1102
89	499	-	1086
90	283	-	1082
91	736		1077
92	492		1063
93	2018	E 144TH S	1059

94	762		1057
95	1049	-	1047
96	876		1037
97	849	-	1037
98	363		1027
99	1819		1022
100	2495		1013

Table A-3: Top 100 Street Segments with Highest Traffic Volumes of Cars for AM Peak

Serial Number	Link ID	Street Name	Traffic Volume (vehicles/hour)
1	845	-	2261
2	507	-	2233
3	402	MAJOR DEEGAN MAIN S	2197
4	1125	-	2038
5	1126	CROSS BRONX MAIN W	2037
6	859	MAJOR DEEGAN MAIN N	1988
7	885	ALEX. HAMILTON BR W	1956
8	401	-	1925
9	954	-	1901
10	1218	-	1899
11	1292	-	1898
12	1095	-	1854
13	466	-	1834
14	468	-	1781
15	317	-	1732
16	1143	CROSS BRONX MAIN W	1726
17	326	-	1726
18	474	CROSS BRONX EX	1726
19	315	-	1688
20	773	-	1596
21	541	-	1595
22	535	W145TH ST BR W	1594
23	259	CROSS BRONX MAIN W	1537
24	786	-	1520
25	1402	-	1518
26	1168	-	1507
27	732	3RD AVE B	1505
28	1173	-	1496
29	261	-	1471
30	913	-	1451
31	805	-	1433
32	807	MAJOR DEEGAN MAIN N	1432
33	780	-	1424
34	387	-	1422
35	366	-	1421
36	649	-	1412
37	515	-	1398
38	652	-	1398
39	367	-	1390
40	2468	-	1378
41	713	-	1372
42	461	-	1354
43	926	-	1349
44	653	-	1309

45	893	-	1263
46	656	-	1254
47	655	-	1221
48	1104	-	1210
49	901	-	1204
50	250	-	1204
51	658	-	1193
52	764	-	1185
53	285	-	1184
54	354	-	1183
55	738	MAJOR DEEGAN MAIN N	1181
56	1099	-	1181
57	659	-	1180
58	500	-	1174
59	753	-	1164
60	853	-	1160
61	1179	-	1152
62	751	MAJ DEEGAN EXP N	1149
63	397	-	1148
64	454	-	1148
65	720	-	1147
66	356	-	1145
67	977	-	1145
68	1364	-	1144
69	1160	-	1143
70	342	-	1142
71	1137	-	1142
72	979	-	1141
73	1177	-	1132
74	660	-	1131
75	423	-	1130
76	459	-	1129
77	833	MAJOR DEEGAN OFF-RAMP N	1129
78	443	-	1128
79	1089	-	1127
80	407	-	1118
81	1246	SHERIDAN EX	1114
82	1413	-	1113
83	431	SHERIDAN EX	1112
84	657	-	1110
85	1132	-	1106
86	1170	-	1102
87	1171	-	1101
88	1038	-	1096
89	1111	-	1096
90	873	-	1095
91	329	-	1094
92	295	-	1094

93	880	-	1092
94	835	-	1091
95	293	-	1090
96	294	MDE TO CBE W	1089
97	692	-	1088
98	834	-	1078
99	927	-	1046

Table A-4: Top 100 Street Segments with Highest Traffic Volumes of Cars for PM Peak

Serial Number	Link ID	Street Name	Traffic Volume (vehicles/hour)
1	1209	-	1891
2	2469	-	1864
3	2098	E 174TH S	1862
4	728	-	1861
5	457	-	1860
6	2000	E 175TH S	1857
7	1580	BROOK AV	1810
8	2101	E 174TH S	1807
9	1079	-	1804
10	467	-	1789
11	758	-	1781
12	265	E 176TH S	1779
13	1929	E 169TH S	1709
14	1062	-	1683
15	480	-	1681
16	757	-	1679
17	1521	E 165TH S	1632
18	1533	E 168TH S	1499
19	2043	E 170TH S	1497
20	2140	-	1465
21	1095	-	1462
22	2002	E 176TH S	1461
23	1062	-	1449
24	477	-	1448
25	1527	E 168TH S	1426
26	1638	-	1424
27	761	-	1379
28	2062	E 161ST S	1377
29	2490	E 170TH S	1376
30	1637	-	1374
31	1983	-	1291
32	2420	E 174TH S	1268
33	786	-	1254
34	862	-	1252
35	2360	E 169TH S	1252
36	1646	-	1212
37	1091	-	1196
38	2254	-	1195
39	1326	-	1193
40	2433	3RD AV	1190
41	2099	E 174TH S	1189
42	1071	-	1188
43	1871	E 170TH S	1187
44	940	-	1187

45	1855	E 170TH S	1185
46	1228	-	1183
47	2543	E 170TH S	1182
48	1995	E 175TH S	1181
49	953	-	1160
50	1643	-	1160
51	2606	E 170TH S	1155
52	1321	-	1154
53	1784	E 175TH S	1154
54	2607	E 170TH S	1153
55	2525	E 174TH S	1152
56	1005	-	1151
57	1125	-	1151
58	1998	E 175TH S	1150
59	1854	E 170TH S	1149
60	1791	E 174TH S	1149
61	1784	E 175TH S	1148
62	1727	E 165TH S	1148
63	1064	-	1147
64	2525	E 174TH S	1147
65	1550	-	1146
66	1855	E 170TH S	1145
67	1997	E 175TH S	1144
68	2488	E 170TH S	1143
69	1125	-	1122
70	1201	-	1121
71	1479	E 168TH S	1105
72	1467	-	1104
73	1411	-	1078
74	2095	E 170TH S	1077
75	1225	-	1040
76	783	-	1039
77	2018	E 144TH S	1037
78	1049	-	1036
79	739	-	1036
80	2433	3RD AV	1036
81	499	-	1035
82	1638	-	1035
83	849	-	1033
84	2571	E 161ST S	1032
85	363	-	1018
86	781	-	983
87	1812	E 174TH S	982
88	1819	E 170TH S	981
89	997	-	979
90	2524	E 174TH S	979
91	2495	E 170TH S	977
92	610	-	939

93	617	-	937
94	1787	E 176TH S	933
95	1090	-	932
96	782	-	931
97	839	CBE WB TO MDE N	930
98	1996	E 175TH S	929
99	1291	-	928
100	1225	-	928

Table A-5: Top 100 Street Segments with Highest Traffic Volumes of Trucks for AM Peak

Serial Number	Link ID	Street Name	Traffic Volume (trucks/hour)
1	1143	CROSS BRONX MAIN W	180
2	474	CROSS BRONX EX	180
3	326	-	180
4	1095	-	162
5	466	-	161
6	468	-	157
7	317	-	155
8	259	CROSS BRONX MAIN W	154
9	1168	-	153
10	1173	-	152
11	315	-	151
12	1126	CROSS BRONX MAIN W	149
13	1125	-	149
14	1104	-	145
15	1137	-	127
16	1160	-	127
17	885	ALEX. HAMILTON BR W	114
18	482	-	90
19	1112	-	90
20	1116	-	90
21	292	-	89
22	689	-	89
23	1132	-	69
24	1111	-	59
25	329	-	59
26	845	-	57
27	1151	-	57
28	507	-	56
29	402	MAJOR DEEGAN MAIN S	55
30	1148	-	54
31	1146	CROSS BRONX ON-RAMP W	54
32	2411	-	53
33	1144	-	53
34	2422	CLAREMONT PK	53
35	1921	CLAREMONT PK	53
36	1938	CLAREMONT PK	53
37	261	-	52
38	1218	-	51
39	954	-	51
40	1292	-	51
41	1801	WEBSTER AV	50
42	1363	-	46
43	706	CROSS BRONX OFF-RAMP W	46

44	697	-	44
45	839	CBE WB TO MDE N	44
46	305	-	44
47	427	-	43
48	461	-	43
49	1246	SHERIDAN EX	42
50	1413	-	42
51	431	SHERIDAN EX	42
52	1927	CLAREMONT PK	41
53	1170	-	40
54	1171	-	40
55	1941	CLAREMONT PK	38
56	1103	CROSS BRONX OFF-RAMP W	36
57	476	-	35
58	432	-	34
59	1403	-	34
60	1165	SHERIDAN EX	34
61	853	-	33
62	851	MAJOR DEEGAN ON-RAMP N	33
63	435	-	33
64	445	-	32
65	444	-	32
66	1234	-	32
67	1075	-	32
68	1087	-	32
69	1494	SOUTHERN BLV	31
70	264	-	31
71	1412	-	31
72	316	-	31
73	318	-	31
74	465	-	30
75	467	-	30
76	2283	SOUTHERN BLV	30
77	433	-	30
78	1180	-	30
79	1975	WILKINS AV	30
80	1495	WILKINS AV	30
81	1405	-	30
82	469	-	30
83	250	-	29
84	1162	-	29
85	786	-	29
86	1402	-	29
87	500	-	29
88	1105	-	29
89	1010	-	28
90	339	-	28

91	833	MAJOR DEEGAN OFF-RAMP N	28
92	1174	-	28
93	1094	-	28
94	1764	HALLECK S	28
95	1166	CROSS BRONX MAIN E	28
96	805	-	27
97	807	MAJOR DEEGAN MAIN N	27
98	909	-	27
99	407	-	27
100	388	-	27

Table A-6: Top 100 Street Segments with Highest Traffic Volumes of Trucks for PM Peak

Serial Number	Link ID	Street Name	Traffic Volume (trucks/hour)
1	763	-	346
2	1649	E 149TH S	346
3	2488	E 170TH S	345
4	1105	-	335
5	1561	-	334
6	1995	E 175TH S	334
7	1998	E 175TH S	334
8	2610	E 174TH S	334
9	2271	E 169TH S	328
10	609	-	315
11	618	-	314
12	1787	E 176TH S	313
13	1060	-	292
14	466	-	292
15	2091	E 170TH S	285
16	2086	E 169TH S	284
17	2208	3RD AV	275
18	281	-	196
19	345	-	196
20	348	-	196
21	283	-	194
22	358	-	192
23	1207	-	184
24	1741	-	165
25	2099	E 174TH S	165
26	362	-	164
27	726	-	164
28	2084	E 167TH S	163
29	1061	-	160
30	473	-	160
31	757	-	160
32	2386	E 174TH S	158
33	467	-	155
34	265	E 176TH S	154
35	758	-	154
36	1874	E 169TH S	151
37	2135	-	151
38	1531	E 168TH S	146
39	2043	E 170TH S	146
40	352	-	137
41	772	-	136
42	1003	-	136
43	1084	-	136
44	1089	-	134

45	1327	-	134
46	1646	-	134
47	1927	CLAREMONT PK	132
48	632	-	132
49	2385	E 174TH S	132
50	2000	E 175TH S	123
51	631	-	96
52	1290	-	96
53	350	-	95
54	344	-	92
55	741	-	91
56	1834	E 169TH S	91
57	1991	E 175TH S	91
58	2359	E 169TH S	91
59	2485	E 170TH S	91
60	477	-	90
61	472	-	89
62	749	-	89
63	627	-	89
64	1820	CLAY AV	82
65	1382	-	81
66	1329	-	78
67	1118	-	73
68	2405	-	73
69	2005	E 176TH S	73
70	871	-	71
71	941	-	71
72	2007	BOSTON R	71
73	501	-	69
74	536	-	69
75	577	-	69
76	872	-	69
77	2080	-	69
78	471	-	68
79	500	-	67
80	1116	-	67
81	2473	3RD AV	67
82	937	-	66
83	1416	-	65
84	632	-	63
85	742	-	62
86	1385	-	61
87	2100	E 174TH S	60
88	2362	E 170TH S	60
89	1023	-	59
90	1710	3RD AV	59
91	2002	E 176TH S	58
92	1463	-	56

93	1479	E 168TH S	56
94	370	-	52
95	2473	3RD AV	52
96	1672	E 161ST S	51
97	773	-	50
98	942	-	50
99	947	-	50
100	941	-	49

APPENDIX B AVERAGE SPEEDS

Table B-1: Top 100 Street Segments with Lowest Average Speeds of Vehicles for AM Peak

Serial Number	Link ID	Street Name	Average Speed (miles/hour)
1	349	-	6.55
2	358	-	6.75
3	388	-	5.02
4	394	-	6.00
5	401	-	5.60
6	402	MAJOR DEEGAN MAIN S	6.33
7	408	-	5.94
8	410	-	6.55
9	465	-	5.47
10	483	-	5.27
11	491	-	6.00
12	509	-	6.00
13	514	-	6.86
14	522	-	6.00
15	538	-	6.00
16	546	-	6.97
17	547	-	5.93
18	563	-	6.00
19	631	-	6.37
20	649	-	5.97
21	650	-	5.45
22	651	-	7.03
23	689	-	5.85
24	703	-	6.00
25	748	-	6.00
26	765	MAJOR DEEGAN ON-RAMP N	5.15
27	790	-	5.14
28	795	-	5.08
29	797	-	6.00
30	799	-	5.99
31	853	-	6.40
32	859	MAJOR DEEGAN MAIN N	5.91
33	865	-	5.15
34	880	-	5.99
35	913	-	5.55
36	930	-	6.00
37	956	-	6.72
38	959	-	5.91
39	968	-	5.35
40	1010	-	6.74
41	1011	-	5.16

42	1091	-	5.97
43	1107	-	5.97
44	1116	-	6.88
45	1119	-	6.02
46	1138	-	5.99
47	1144	-	5.85
48	1150	-	6.00
49	1157	-	6.00
50	1159	-	6.01
51	1169	-	6.00
52	1182	-	6.00
53	1187	-	5.94
54	1188	-	6.00
55	1215	-	6.00
56	1229	-	6.00
57	1260	-	5.23
58	1317	-	6.00
59	1372	-	6.00
60	1388	-	6.00
61	1393	-	6.00
62	1394	-	6.00
63	1475	GERARD AV	6.93
64	1522	WEBSTER AV	5.44
65	1524	E 165TH S	6.00
66	1569	JACKSON AV	5.83
67	1617	E 149TH S	6.00
68	1699	E 161ST S	5.45
69	1731	E 169TH S	6.00
70	1734	3RD AV	6.49
71	1795	MACOMBS R	6.00
72	1807	E 174TH S	5.95
73	1825	E 169TH S	6.00
74	1833	E 169TH S	6.00
75	1847	EDWARD L GRANT HW	6.00
76	1921	CLAREMONT PK	5.53
77	1966	BOSTON R	5.97
78	1968	CLAREMONT PK	6.59
79	1992	BOSTON R	6.27
80	2008	BOSTON R	5.97
81	2073	E 165TH S	6.00
82	2088	E 169TH S	6.00
83	2103	-	6.00
84	2112	-	6.00
85	2199	MELROSE AV	5.45
86	2208	3RD AV	6.57
87	2244	PROSPECT AV	6.81
88	2270	E 167TH S	6.23
89	2336	CONCOURSE VILLAGE	6.12

90	2385	E 174TH S	7.04
91	2391	BOSTON R	5.78
92	2402	CLAREMONT PK	5.80
93	2475	3RD AV	6.00
94	2485	E 170TH S	5.90
95	2502	E 167TH S	5.97
96	2514	WOODYCREST AV	5.20
97	2537	GRAND CONCOURS	6.00
98	2539	E 167TH S	5.97
99	2549	E 149TH S	5.90
100	2580	E 163RD S	6.69

Table B-2: Top 100 Street Segments with Lowest Average Speeds of Vehicles for PM Peak

Serial Number	Link ID	Street Name	Average Speed (miles/hour)
1	2005	E 176TH S	5.10
2	2189	MORRIS AV	5.34
3	1729	E 163RD S	5.43
4	2182	E 149TH S	5.45
5	689	-	5.49
6	2385	E 174TH S	5.72
7	1212	-	5.73
8	748	-	5.87
9	1110	-	5.92
10	1144	-	5.93
11	1182	-	5.93
12	1404	-	5.94
13	795	-	5.94
14	1187	-	5.94
15	1450	EDWARD L GRANT HW	5.97
16	2569	E 161ST S	5.98
17	1847	EDWARD L GRANT HW	5.98
18	1776	BOSTON R	5.98
19	2073	E 165TH S	5.99
20	1107	-	5.99
21	799	-	5.99
22	1138	-	5.99
23	757	-	5.99
24	1393	-	5.99
25	2008	BOSTON R	5.99
26	1195	-	6.00
27	1256	-	6.00
28	1898	MACOMBS R	6.00
29	1188	-	6.00
30	1807	E 174TH S	6.00
31	522	-	6.00
32	1229	-	6.00
33	2088	E 169TH S	6.00
34	2488	E 170TH S	6.00
35	2098	E 174TH S	6.00
36	2544	GRAND CONCOURS	6.00
37	2543	E 170TH S	6.00
38	1966	BOSTON R	6.00
39	1351	-	6.00
40	509	-	6.00
41	547	-	6.00
42	1123	-	6.00
43	2539	E 167TH S	6.00
44	2591	SOUTHERN BLV	6.00
45	2502	E 167TH S	6.00

46	1825	E 169TH S	6.00
47	395	-	6.00
48	1388	-	6.00
49	1394	-	6.00
50	419	-	6.00
51	420	-	6.00
52	1731	E 169TH S	6.00
53	2579	E 169TH S	6.00
54	924	-	6.00
55	882	-	6.00
56	1017	-	6.00
57	1021	-	6.00
58	1091	-	6.00
59	1727	E 165TH S	6.00
60	1150	-	6.00
61	491	-	6.00
62	2475	3RD AV	6.00
63	563	-	6.00
64	575	-	6.00
65	1157	-	6.00
66	1211	-	6.00
67	1317	-	6.00
68	1617	E 149TH S	6.00
69	1833	E 169TH S	6.00
70	2493	GRAND CONCOURS	6.00
71	2515	PROSPECT AV	6.00
72	2495	E 170TH S	6.00
73	343	-	6.00
74	790	-	6.00
75	775	-	6.00
76	538	-	6.00
77	2034	E 165TH S	6.00
78	477	-	6.00
79	1221	-	6.00
80	1321	-	6.00
81	2045	RAM	6.00
82	930	-	6.00
83	1524	E 165TH S	6.00
84	2492	E 170TH S	6.00
85	842	-	6.00
86	884	-	6.00
87	394	-	6.00
88	797	-	6.00
89	1018	-	6.00
90	497	-	6.00
91	2573	ELTON AV	6.00
92	2103	-	6.00
93	1215	-	6.00

94	1169	-	6.00
95	1372	-	6.00
96	2534	E 167TH S	6.00
97	2112	-	6.00
98	1834	E 169TH S	6.00
99	1119	-	6.00
100	1795	MACOMBS R	6.00

Table B-3: Top 100 Street Segments with Lowest Average Speeds of Cars for AM Peak

Serial Number	Link ID	Street Name	Average Speed (miles/hour)
1	849	-	5.01
2	388	-	5.08
3	1011	-	5.09
4	2514	WOODYCREST AV	5.09
5	795	-	5.09
6	790	-	5.14
7	765	MAJOR DEEGAN ON-RAMP N	5.14
8	865	-	5.15
9	483	-	5.26
10	968	-	5.37
11	1921	CLAREMONT PK	5.38
12	1699	E 161ST S	5.41
13	2199	MELROSE AV	5.43
14	1522	WEBSTER AV	5.43
15	650	-	5.51
16	913	-	5.51
17	401	-	5.57
18	465	-	5.61
19	2402	CLAREMONT PK	5.63
20	2391	BOSTON R	5.78
21	1144	-	5.85
22	689	-	5.85
23	859	MAJOR DEEGAN MAIN N	5.90
24	2485	E 170TH S	5.91
25	959	-	5.91
26	2549	E 149TH S	5.92
27	547	-	5.93
28	649	-	5.94
29	1187	-	5.94
30	408	-	5.95
31	1807	E 174TH S	5.95
32	1260	-	5.96
33	1159	-	5.96
34	1569	JACKSON AV	5.96
35	1107	-	5.97
36	2539	E 167TH S	5.97
37	1091	-	5.97
38	2502	E 167TH S	5.97
39	1966	BOSTON R	5.97
40	2008	BOSTON R	5.97
41	1138	-	5.99
42	880	-	5.99
43	799	-	5.99
44	1825	E 169TH S	6.00

45	2088	E 169TH S	6.00
46	1188	-	6.00
47	1388	-	6.00
48	1317	-	6.00
49	538	-	6.00
50	509	-	6.00
51	1617	E 149TH S	6.00
52	2475	3RD AV	6.00
53	491	-	6.00
54	1372	-	6.00
55	1731	E 169TH S	6.00
56	748	-	6.00
57	930	-	6.00
58	2112	-	6.00
59	2073	E 165TH S	6.00
60	1833	E 169TH S	6.00
61	2537	GRAND CONCOURS	6.00
62	563	-	6.00
63	1157	-	6.00
64	394	-	6.00
65	797	-	6.00
66	1215	-	6.00
67	703	-	6.00
68	1394	-	6.00
69	2103	-	6.00
70	1524	E 165TH S	6.00
71	522	-	6.00
72	1229	-	6.00
73	1847	EDWARD L GRANT HW	6.00
74	1150	-	6.00
75	1182	-	6.00
76	1169	-	6.00
77	1393	-	6.00
78	1795	MACOMBS R	6.01
79	1119	-	6.02
80	2336	CONCOURSE VILLAGE	6.12
81	1992	BOSTON R	6.24
82	631	-	6.31
83	402	MAJOR DEEGAN MAIN S	6.37
84	349	-	6.48
85	853	-	6.48
86	1734	3RD AV	6.49
87	410	-	6.55
88	2208	3RD AV	6.57
89	956	-	6.60
90	1116	-	6.67
91	1010	-	6.73
92	358	-	6.74

93	2580	E 163RD S	6.76
94	2217	TINTON AV	6.81
95	514	-	6.81
96	1968	CLAREMONT PK	6.90
97	1475	GERARD AV	6.93
98	546	-	6.97
99	2385	E 174TH S	6.99
100	651	-	7.05

Table B-4: Top 100 Street Segments with Lowest Average Speeds of Cars for PM Peak

Serial Number	Link ID	Street Name	Average Speed (miles/hour)
1	1654	3RD AV	5.06
2	2005	E 176TH S	5.11
3	2189	MORRIS AV	5.37
4	2182	E 149TH S	5.40
5	1729	E 163RD S	5.49
6	689	-	5.49
7	1212	-	5.72
8	2385	E 174TH S	5.73
9	748	-	5.87
10	1110	-	5.92
11	1144	-	5.93
12	1404	-	5.93
13	1182	-	5.93
14	1187	-	5.94
15	795	-	5.94
16	1847	EDWARD L GRANT HW	5.98
17	1776	BOSTON R	5.98
18	1450	EDWARD L GRANT HW	5.98
19	2569	E 161ST S	5.99
20	2073	E 165TH S	5.99
21	1107	-	5.99
22	799	-	5.99
23	1138	-	5.99
24	757	-	5.99
25	2008	BOSTON R	5.99
26	1195	-	6.00
27	1256	-	6.00
28	1898	MACOMBS R	6.00
29	1188	-	6.00
30	522	-	6.00
31	1229	-	6.00
32	1807	E 174TH S	6.00
33	2088	E 169TH S	6.00
34	2488	E 170TH S	6.00
35	2098	E 174TH S	6.00
36	2544	GRAND CONCOURS	6.00
37	2543	E 170TH S	6.00
38	1966	BOSTON R	6.00
39	1351	-	6.00
40	509	-	6.00
41	547	-	6.00
42	2539	E 167TH S	6.00
43	2591	SOUTHERN BLV	6.00
44	2502	E 167TH S	6.00

45	1123	-	6.00
46	1388	-	6.00
47	1394	-	6.00
48	395	-	6.00
49	1731	E 169TH S	6.00
50	1825	E 169TH S	6.00
51	419	-	6.00
52	420	-	6.00
53	2579	E 169TH S	6.00
54	924	-	6.00
55	575	-	6.00
56	790	-	6.00
57	882	-	6.00
58	1017	-	6.00
59	1021	-	6.00
60	1150	-	6.00
61	2034	E 165TH S	6.00
62	343	-	6.00
63	491	-	6.00
64	538	-	6.00
65	563	-	6.00
66	775	-	6.00
67	1091	-	6.00
68	1211	-	6.00
69	1317	-	6.00
70	1617	E 149TH S	6.00
71	1833	E 169TH S	6.00
72	2495	E 170TH S	6.00
73	2493	GRAND CONCOURS	6.00
74	2515	PROSPECT AV	6.00
75	1157	-	6.00
76	2475	3RD AV	6.00
77	1727	E 165TH S	6.00
78	1221	-	6.00
79	1321	-	6.00
80	2045	RAM	6.00
81	477	-	6.00
82	930	-	6.00
83	842	-	6.00
84	2492	E 170TH S	6.00
85	394	-	6.00
86	797	-	6.00
87	1524	E 165TH S	6.00
88	884	-	6.00
89	1018	-	6.00
90	497	-	6.00
91	2573	ELTON AV	6.00
92	2103	-	6.00

93	1215	-	6.00
94	2534	E 167TH S	6.00
95	1169	-	6.00
96	1372	-	6.00
97	2112	-	6.00
98	1834	E 169TH S	6.00
99	1393	-	6.00
100	1795	MACOMBS R	6.00

Table B-5: Top 100 Street Segments with Lowest Average Speeds of Trucks for AM Peak

Serial Number	Link ID	Street Name	Average Speed (miles/hour)
1	1852	JEROME AV	5.00
2	2406	3RD AV	5.08
3	2549	E 149TH S	5.09
4	1882	E 165TH S	5.14
5	402	MAJOR DEEGAN MAIN S	5.15
6	865	-	5.16
7	283	-	5.25
8	1187	-	5.25
9	1637	-	5.31
10	1990	SOUTHERN BLV	5.31
11	2569	E 161ST S	5.32
12	1288	-	5.33
13	2562	BROOK AV	5.35
14	1878	E 165TH S	5.40
15	2651	TIFFANY S	5.42
16	655	-	5.44
17	1590	ST ANNS AV	5.45
18	1848	EDWARD L GRANT HW	5.50
19	1989	SOUTHERN BLV	5.62
20	1104	-	5.63
21	2306	E 161ST S	5.65
22	765	MAJOR DEEGAN ON-RAMP N	5.67
23	2580	E 163RD S	5.71
24	408	-	5.76
25	1424	MORRIS AV	5.77
26	2299	3RD AV	5.79
27	2336	CONCOURSE VILLAGE	5.79
28	959	-	5.81
29	689	-	5.91
30	880	-	5.92
31	1795	MACOMBS R	5.94
32	1144	-	5.96
33	656	-	5.97
34	1091	-	5.97
35	369	-	5.97
36	1012	-	5.99
37	1182	-	6.00
38	748	-	6.00
39	884	-	6.00
40	1195	-	6.00
41	1524	E 165TH S	6.00
42	1731	E 169TH S	6.00
43	1388	-	6.00
44	1394	-	6.00

45	842	-	6.00
46	1966	BOSTON R	6.00
47	522	-	6.00
48	1229	-	6.00
49	1188	-	6.00
50	496	-	6.00
51	703	-	6.00
52	760	-	6.00
53	790	-	6.00
54	1123	-	6.00
55	2103	-	6.00
56	2534	E 167TH S	6.00
57	1393	-	6.00
58	1506	MORRIS AV	6.00
59	491	-	6.00
60	563	-	6.00
61	799	-	6.00
62	1018	-	6.00
63	1107	-	6.00
64	1169	-	6.00
65	1215	-	6.00
66	1256	-	6.00
67	2008	BOSTON R	6.00
68	1807	E 174TH S	6.00
69	1847	EDWARD L GRANT HW	6.00
70	2199	MELROSE AV	6.00
71	2574	WASHINGTON AV	6.00
72	1150	-	6.00
73	343	-	6.00
74	509	-	6.00
75	775	-	6.00
76	2475	3RD AV	6.00
77	1727	E 165TH S	6.00
78	2073	E 165TH S	6.00
79	2492	E 170TH S	6.00
80	538	-	6.00
81	486	-	6.00
82	547	-	6.00
83	924	-	6.00
84	1372	-	6.00
85	1825	E 169TH S	6.00
86	1138	-	6.00
87	845	-	6.05
88	713	-	6.07
89	1522	WEBSTER AV	6.16
90	651	-	6.26
91	2170	3RD AV	6.27
92	2415	CLAY AV	6.40

93	367	-	6.49
94	1695	3RD AV	6.55
95	859	MAJOR DEEGAN MAIN N	6.61
96	653	-	6.61
97	1492	SOUTHERN BLV	6.69
98	1498	E 167TH S	6.74
99	410	-	6.76
100	292	-	6.81

Table B-6: Top 100 Street Segments with Lowest Average Speeds of Trucks for PM Peak

Serial Number	Link ID	Street Name	Average Speed
1	2005	E 176TH S	5.06
2	2385	E 174TH S	5.38
3	1450	EDWARD L GRANT HW	5.45
4	689	-	5.49
5	2569	E 161ST S	5.61
6	1212	-	5.75
7	748	-	5.80
8	469	-	5.82
9	795	-	5.89
10	1182	-	5.91
11	1110	-	5.92
12	1393	-	5.95
13	1144	-	5.98
14	757	-	6.00
15	547	-	6.00
16	1825	E 169TH S	6.00
17	1187	-	6.00
18	2098	E 174TH S	6.00
19	1169	-	6.00
20	882	-	6.00
21	1017	-	6.00
22	1021	-	6.00
23	1091	-	6.00
24	1727	E 165TH S	6.00
25	2579	E 169TH S	6.00
26	477	-	6.00
27	2073	E 165TH S	6.00
28	1898	MACOMBS R	6.00
29	1590	ST ANNS AV	6.00
30	1807	E 174TH S	6.00
31	1847	EDWARD L GRANT HW	6.00
32	395	-	6.00
33	491	-	6.00
34	2475	3RD AV	6.00
35	563	-	6.00
36	1138	-	6.00
37	1388	-	6.00
38	1394	-	6.00
39	575	-	6.00
40	1150	-	6.00
41	1195	-	6.00
42	760	-	6.00
43	799	-	6.00
44	884	-	6.00

45	1211	-	6.00
46	1776	BOSTON R	6.00
47	2008	BOSTON R	6.00
48	1524	E 165TH S	6.00
49	2515	PROSPECT AV	6.00
50	1188	-	6.00
51	1372	-	6.00
52	1256	-	6.00
53	1966	BOSTON R	6.00
54	2488	E 170TH S	6.00
55	2543	E 170TH S	6.00
56	1404	-	6.00
57	522	-	6.00
58	1229	-	6.00
59	1731	E 169TH S	6.00
60	343	-	6.00
61	394	-	6.00
62	496	-	6.00
63	703	-	6.00
64	775	-	6.00
65	790	-	6.00
66	797	-	6.00
67	924	-	6.00
68	1119	-	6.00
69	1351	-	6.00
70	2103	-	6.00
71	1834	E 169TH S	6.00
72	2085	E 169TH S	6.00
73	2492	E 170TH S	6.00
74	2495	E 170TH S	6.00
75	1795	MACOMBS R	6.00
76	538	-	6.00
77	842	-	6.00
78	1018	-	6.00
79	1215	-	6.00
80	2034	E 165TH S	6.00
81	2502	E 167TH S	6.00
82	2534	E 167TH S	6.00
83	2539	E 167TH S	6.00
84	2591	SOUTHERN BLV	6.00
85	1107	-	6.00
86	282	MORRIS AV	6.45
87	1747	PROSPECT AV	6.46
88	2580	E 163RD S	6.49
89	1878	E 165TH S	6.55
90	2182	E 149TH S	6.60
91	2244	PROSPECT AV	6.67
92	1675	E 161ST S	6.75

93	337	-	6.94
94	2186	MORRIS AV	7.00
95	1665	E 156TH S	7.16
96	258	-	7.32
97	904	-	7.33
98	1126	CROSS BRONX MAIN W	7.37
99	1094	-	7.38
100	808	-	7.87

APPENDIX C FUEL CONSUMPTION

Table C-1: Top 100 Street Segments with the Highest Fuel Consumption of Cars for AM Peak

Serial Number	Link ID	Street Name	Fuel Consumption (gallons/mile/hour)
1	845	-	122.08
2	507	-	120.58
3	402	MAJOR DEEGAN MAIN S	118.66
4	1125	-	110.07
5	1126	CROSS BRONX MAIN W	109.98
6	859	MAJOR DEEGAN MAIN N	107.35
7	885	ALEX. HAMILTON BR W	105.61
8	401	-	103.93
9	954	-	102.64
10	1218	-	102.56
11	1292	-	102.49
12	1095	-	100.10
13	466	-	99.02
14	468	-	96.19
15	317	-	93.55
16	1143	CROSS BRONX MAIN W	93.20
17	326	-	93.20
18	474	CROSS BRONX EX	93.19
19	315	-	91.17
20	773	-	86.18
21	541	-	86.15
22	535	W145TH ST BR W	86.08
23	259	CROSS BRONX MAIN W	83.02
24	786	-	82.06
25	1402	-	81.99
26	1168	-	81.40
27	732	3RD AVE B	81.29
28	1173	-	80.77
29	261	-	79.43
30	913	-	78.35
31	805	-	77.38
32	807	MAJOR DEEGAN MAIN N	77.31
33	780	-	76.88
34	387	-	76.81
35	366	-	76.73
36	649	-	76.27
37	515	-	75.51
38	652	-	75.49
39	367	-	75.08
40	2468	-	74.39
41	713	-	74.07
42	461	-	73.12
43	926	-	72.86

44	653	-	70.69
45	893	-	68.18
46	656	-	67.70
47	655	-	65.93
48	1104	-	65.32
49	901	-	65.02
50	250	-	65.00
51	658	-	64.42
52	764	-	64.01
53	285	-	63.94
54	354	-	63.86
55	738	MAJOR DEEGAN MAIN N	63.77
56	1099	-	63.76
57	659	-	63.72
58	500	-	63.41
59	753	-	62.86
60	853	-	62.64
61	1179	-	62.23
62	751	MAJ DEEGAN EXP N	62.06
63	397	-	61.99
64	454	-	61.97
65	720	-	61.92
66	356	-	61.85
67	977	-	61.83
68	1364	-	61.76
69	1160	-	61.72
70	342	-	61.69
71	1137	-	61.67
72	979	-	61.63
73	1177	-	61.13
74	660	-	61.06
75	423	-	61.02
76	459	-	60.98
77	833	MAJOR DEEGAN OFF-RAMP N	60.97
78	443	-	60.91
79	1089	-	60.84
80	407	-	60.35
81	1246	SHERIDAN EX	60.17
82	1413	-	60.10
83	431	SHERIDAN EX	60.03
84	657	-	59.94
85	1132	-	59.74
86	1170	-	59.51
87	1171	-	59.45
88	1038	-	59.18
89	1111	-	59.17
90	873	-	59.13

91	329	-	59.09
92	295	-	59.06
93	880	-	58.99
94	835	-	58.91
95	293	-	58.88
96	294	MDE TO CBE W	58.81
97	692	-	58.77
98	834	-	58.23
99	927	-	56.48
100	845	-	56.38

Table C-2: Top 100 Street Segments with the Highest Fuel Consumption of Cars for PM Peak

Serial Number	Link ID	Street Name	Fuel Consumption (gallons/hour)
1	1209	-	102.11
2	2469	-	100.67
3	2098	E 174TH S	100.57
4	728	-	100.48
5	457	-	100.42
6	2000	E 175TH S	100.26
7	1580	BROOK AV	97.72
8	2101	E 174TH S	97.60
9	1079	-	97.42
10	467	-	96.62
11	758	-	96.19
12	265	E 176TH S	96.07
13	1929	E 169TH S	92.29
14	1062	-	90.86
15	480	-	90.79
16	757	-	90.68
17	1521	E 165TH S	88.15
18	1533	E 168TH S	80.96
19	2043	E 170TH S	80.86
20	2140	-	79.09
21	1095	-	78.97
22	2002	E 176TH S	78.89
23	1062	-	78.26
24	477	-	78.19
25	1527	E 168TH S	77.00
26	1638	-	76.90
27	761	-	74.48
28	2062	E 161ST S	74.38
29	2490	E 170TH S	74.29
30	1637	-	74.20
31	1983	E 174TH S	69.71
32	2420	E 174TH S	68.47
33	786	-	67.72
34	862	-	67.63
35	2360	E 169TH S	67.59
36	1646	-	65.45
37	1091	-	64.58
38	2254	-	64.53
39	1326	-	64.44
40	2433	3RD AV	64.26
41	2099	E 174TH S	64.22
42	1071	-	64.15
43	1871	E 170TH S	64.10
44	940	-	64.08

45	1855	E 170TH S	63.99
46	1228	-	63.90
47	2543	E 170TH S	63.85
48	1995	E 175TH S	63.77
49	953	-	62.66
50	1643	-	62.62
51	2606	E 170TH S	62.35
52	1321	-	62.33
53	1784	E 175TH S	62.30
54	2607	E 170TH S	62.24
55	2525	E 174TH S	62.21
56	1005	-	62.14
57	1125	-	62.14
58	1998	E 175TH S	62.12
59	1854	E 170TH S	62.06
60	1791	E 174TH S	62.03
61	1784	E 175TH S	62.01
62	1727	E 165TH S	61.97
63	1064	-	61.94
64	2525	E 174TH S	61.94
65	1550	-	61.90
66	1855	E 170TH S	61.85
67	1997	E 175TH S	61.76
68	2488	E 170TH S	61.70
69	1125	-	60.59
70	1201	-	60.52
71	1479	E 168TH S	59.67
72	1467	-	59.62
73	1411	-	58.21
74	2095	E 170TH S	58.14
75	1225	-	56.18
76	783	-	56.11
77	2018	E 144TH S	56.02
78	1049	-	55.96
79	739	-	55.93
80	2433	3RD AV	55.93
81	499	-	55.91
82	1638	-	55.87
83	849	-	55.80
84	2571	E 161ST S	55.71
85	363	-	54.99
86	781	-	53.08
87	1812	E 174TH S	53.03
88	1819	E 170TH S	52.96
89	997	-	52.88
90	2524	E 174TH S	52.85
91	2495	E 170TH S	52.78

92	610	-	50.72
93	617	-	50.62
94	1787	E 176TH S	50.38
95	1090	-	50.35
96	782	-	50.29
97	839	CBE WB TO MDE N	50.22
98	1996	E 175TH S	50.15
99	1291	-	50.11

Table C-3: Top 100 Street Segments with the Highest Fuel Consumption of Trucks for AM Peak

Serial Number	Link ID	Street Name	Fuel Consumption (gallons/hour)
1	1143	CROSS BRONX MAIN W	22.54
2	474	CROSS BRONX EX	22.54
3	326	-	22.54
4	1095	-	20.29
5	466	-	20.08
6	468	-	19.67
7	317	-	19.33
8	259	CROSS BRONX MAIN W	19.21
9	1168	-	19.17
10	1173	-	19.00
11	315	-	18.83
12	1126	CROSS BRONX MAIN W	18.67
13	1125	-	18.67
14	1104	-	18.08
15	1137	-	15.83
16	1160	-	15.83
17	885	ALEX. HAMILTON BR W	14.29
18	482	-	11.25
19	1112	-	11.25
20	1116	-	11.21
21	292	-	11.17
22	689	-	11.13
23	1132	-	8.58
24	1111	-	7.33
25	329	-	7.33
26	845	-	7.17
27	1151	-	7.13
28	507	-	7.00
29	402	MAJOR DEEGAN MAIN S	6.88
30	1148	-	6.71
31	1146	CROSS BRONX ON-RAMP W	6.71
32	2411	-	6.67
33	1144	-	6.67
34	2422	CLAREMONT PK	6.63
35	1921	CLAREMONT PK	6.63
36	1938	CLAREMONT PK	6.58
37	261	-	6.46
38	1218	-	6.38
39	954	-	6.38
40	1292	-	6.38
41	1801	WEBSTER AV	6.25
42	1363	-	5.79
43	706	CROSS BRONX OFF-RAMP	5.79

		W	
44	697	-	5.46
45	839	CBE WB TO MDE N	5.46
46	305	-	5.46
47	427	-	5.42
48	461	-	5.38
49	1246	SHERIDAN EX	5.25
50	1413	-	5.25
51	431	SHERIDAN EX	5.25
52	1927	CLAREMONT PK	5.13
53	1170	-	5.00
54	1171	-	4.96
55	1941	CLAREMONT PK	4.79
56	1103	CROSS BRONX OFF-RAMP W	4.46
57	476	-	4.42
58	432	-	4.29
59	1403	-	4.29
60	1165	SHERIDAN EX	4.29
61	853	-	4.08
62	851	MAJOR DEEGAN ON-RAMP N	4.08
63	435	-	4.08
64	445	-	4.04
65	444	-	4.04
66	1234	-	4.04
67	1075	-	4.04
68	1087	-	3.96
69	1494	SOUTHERN BLV	3.92
70	264	-	3.88
71	1412	-	3.83
72	316	-	3.83
73	318	-	3.83
74	465	-	3.79
75	467	-	3.79
76	2283	SOUTHERN BLV	3.79
77	433	-	3.79
78	1180	-	3.79
79	1975	WILKINS AV	3.75
80	1495	WILKINS AV	3.75
81	1405	-	3.75
82	469	-	3.75
83	250	-	3.63
84	1162	-	3.63
85	786	-	3.63
86	1402	-	3.63
87	500	-	3.58
88	1105	-	3.58

89	1010	-	3.54
90	339	-	3.54
91	833	MAJOR DEEGAN OFF-RAMP N	3.50
92	1174	-	3.46
93	1094	-	3.46
94	1764	HALLECK S	3.46
95	1166	CROSS BRONX MAIN E	3.46
96	805	-	3.42
97	807	MAJOR DEEGAN MAIN N	3.42
98	909	-	3.38
99	407	-	3.33
100	388	-	3.33

Table C-4: Top 100 Street Segments with the Highest Fuel Consumption of Trucks for PM Peak

Serial Number	Link ID	Street Name	Fuel Consumption (gallons/hour)
1	763	-	43.21
2	1649	E 149TH S	43.21
3	2488	E 170TH S	43.08
4	1105	-	41.88
5	1561	-	41.75
6	1995	E 175TH S	41.75
7	1998	E 175TH S	41.75
8	2610	E 174TH S	41.75
9	2271	E 169TH S	40.96
10	609	-	39.42
11	618	-	39.29
12	1787	E 176TH S	39.13
13	1060	-	36.54
14	466	-	36.50
15	2091	E 170TH S	35.63
16	2086	E 169TH S	35.54
17	2208	3RD AV	34.38
18	281	-	24.54
19	345	-	24.54
20	348	-	24.54
21	283	-	24.21
22	358	-	24.04
23	1207	-	22.96
24	1741	-	20.58
25	2099	E 174TH S	20.58
26	362	-	20.54
27	726	-	20.54
28	2084	E 167TH S	20.42
29	1061	-	20.04
30	473	-	20.00
31	757	-	20.00
32	2386	E 174TH S	19.79
33	467	-	19.38
34	265	E 176TH S	19.29
35	758	-	19.29
36	1874	E 169TH S	18.88
37	2135	-	18.88
38	1531	E 168TH S	18.29
39	2043	E 170TH S	18.25
40	352	-	17.08
41	772	-	17.00
42	1003	-	17.00
43	1084	-	17.00

44	1089	-	16.75
45	1327	-	16.71
46	1646	-	16.71
47	1927	CLAREMONT PK	16.54
48	632	-	16.50
49	2385	E 174TH S	16.50
50	2000	E 175TH S	15.38
51	631	-	11.96
52	1290	-	11.96
53	350	-	11.88
54	344	-	11.54
55	741	-	11.33
56	1834	E 169TH S	11.33
57	1991	E 175TH S	11.33
58	2359	E 169TH S	11.33
59	2485	E 170TH S	11.33
60	477	-	11.25
61	472	-	11.17
62	749	-	11.13
63	627	-	11.08
64	1820	CLAY AV	10.21
65	1382	-	10.17
66	1329	-	9.79
67	1118	-	9.13
68	2405	-	9.13
69	2005	E 176TH S	9.08
70	871	-	8.92
71	941	-	8.92
72	2007	BOSTON R	8.92
73	501	-	8.67
74	536	-	8.67
75	577	-	8.67
76	872	-	8.67
77	2080	-	8.67
78	471	-	8.46
79	500	-	8.42
80	1116	-	8.33
81	2473	3RD AV	8.33
82	937	-	8.21
83	1416	-	8.08
84	632	-	7.92
85	742	-	7.71
86	1385	-	7.67
87	2100	E 174TH S	7.50
88	2362	E 170TH S	7.50
89	1023	-	7.42
90	1710	3RD AV	7.42

91	2002	E 176TH S	7.25
92	1463	-	6.96
93	1479	E 168TH S	6.96
94	370	-	6.54
95	2473	3RD AV	6.54
96	1672	E 161ST S	6.33
97	773	-	6.21
98	942	-	6.21
99	947	-	6.21
100	941	-	6.17

APPENDIX D DELAY AND QUEUE LENGTHS

Table D-1: Top 100 Movements with the Maximum Average Delay for AM Peak

Serial Number	Intersection ID	From Link ID	From Street Name	To Link ID	To Street Name	Average Delay (seconds)
1	1846	1673	E 161ST S	1691	E 161ST S	936.00
2	1833	1709	3RD AV	1653	MELROSE AV	934.36
3	1823	1743	WESTCHESTER AV	1621	WESTCHESTER AV	852.77
4	1844	1686	MELROSE AV	1685	MELROSE AV	678.06
5	1855	1513	MORRIS AV	1715	E 161ST S	593.06
6	1977	1712	E 153RD S	2047	MORRIS AV	591.23
7	1846	2315	MELROSE AV	1688	E 161ST S	584.44
8	1868	1744	E 163RD S	1751	PROSPECT AV	574.85
9	1966	2184	GRAND CONCOURS	2020	E 149TH S	566.61
10	1760	2186	MORRIS AV	1428	MORRIS AV	532.67
11	1844	1665	E 156TH S	1683	MELROSE AV	500.76
12	1788	1881	E 165TH S	1506	MORRIS AV	439.37
13	1866	2248	E 163RD S	1746	WESTCHESTER AV	410.62
14	1833	2548	E 149TH S	1651	3RD AV	393.68
15	1823	1747	PROSPECT AV	1619	WESTCHESTER AV	392.81
16	1846	2301	MELROSE AV	1690	MELROSE AV	372.00
17	2140	1595	E 163RD S	2475	3RD AV	371.28
18	1987	2458	GRAND CONCOURS	2072	E 165TH S	351.44
19	2179	1710	3RD AV	2552	3RD AV	349.18
20	1805	2166	WILLIS AV	1564	WILLIS AV	344.72
21	2140	1595	E 163RD S	2477	E 163RD S	325.77
22	1760	1706	E 149TH S	1428	MORRIS AV	279.72
23	1834	2196	3RD AV	1657	E 150TH S	277.41
24	1833	1709	3RD AV	1649	E 149TH S	269.49
25	1890	2385	E 174TH S	1810	MORRIS AV	238.33
26	1855	1700	E 161ST S	1716	CONCOURSE VILLAGE	215.10
27	1836	1720	3 RD AV	1663	3RD AV	210.76
28	1762	2339	RIVER AV	1435	E 165TH S	208.17
29	1762	2339	RIVER AV	1434	RIVER AV	199.70
30	2140	1595	E 163RD S	2476	3RD AV	198.53
31	2185	1734	3RD AV	2571	E 161ST S	191.90
32	1849	1675	E 161ST S	1700	E 161ST S	189.11
33	2185	2476	3RD AV	2570	3RD AV	173.53
34	1977	1712	E 153RD S	2046	MORRIS AV	164.21
35	1840	154	Willis Ave	1673	E 161ST S	150.46
36	1844	2314	MELROSE AV	1683	MELROSE AV	137.46
37	1966	2184	GRAND CONCOURS	2021	E 149TH S	133.82
38	1967	2174	E 149TH S	2023	GRAND CONCOURS	133.45
39	1760	2173	E 149TH S	1427	MORRIS AV	129.13

40	1834	1659	WESTCHESTER AV	1654	3RD AV	127.50
41	1858	1725	BROOK AV	1723	E 163RD S	119.22
42	1855	2331	CONCOURSE VILLAGE	1713	E 161ST S	115.05
43	1784	1498	E 167TH S	1494	SOUTHERN BLV	113.82
44	1823	1747	PROSPECT AV	1623	LONGWOOD AV	112.39
45	1760	2186	MORRIS AV	1425	E 149TH S	110.50
46	1823	2614	LONGWOOD AV	1622	PROSPECT AV	108.63
47	1989	2064	GRAND CONCOURS	2080		108.00
48	1788	1512	MORRIS AV	1507	E 165TH S	93.37
49	1966	2184	GRAND CONCOURS	2019	GRAND CONCOURS	91.22
50	1890	1914	MORRIS AV	1812	E 174TH S	86.72
51	1987	2034	E 165TH S	2074	GRAND CONCOURS	85.80
52	2140	2572	3RD AV	2474	E 163RD S	85.13
53	1784	1551	SOUTHERN BLV	1491	E 167TH S	81.14
54	1760	2189	MORRIS AV	1426	E 149TH S	79.22
55	1841	1699	E 161ST S	1674	E 161ST S	77.43
56	1788	1827	MORRIS AV	1509	E 165TH S	77.25
57	1849	1715	E 161ST S	1699	E 161ST S	72.23
58	1866	2273	WESTCHESTER AV	1745	E 163RD S	72.00
59	1834	1659	WESTCHESTER AV	1657	E 150TH S	70.91
60	1784	2282	SOUTHERN BLV	1493	E 167TH S	67.50
61	1840	2317	COURTLANDT AV	1673	E 161ST S	66.24
62	1962	2005	E 176TH S	2008	BOSTON R	66.10
63	1882	2394	SOUTHERN BLV	1791	E 174TH S	57.00
64	1933	1942	CROTONA AV	1934	PROSPECT AV	54.00
65	1833	1577	E 149TH S	1651	3RD AV	51.60
66	2185	1734	3RD AV	2572	3RD AV	51.24
67	1866	2248	E 163RD S	1744	E 163RD S	48.00
68	1833	2550	MELROSE AV	1650	3RD AV	47.00
69	1882	2394	SOUTHERN BLV	1792	BOSTON R	46.85
70	1933	1967	BOSTON R	1935	BOSTON R	46.64
71	1933	1942	CROTONA AV	1935	BOSTON R	45.82
72	1866	2248	E 163RD S	1743	WESTCHESTER AV	45.00
73	1882	1989	SOUTHERN BLV	1792	BOSTON R	44.60
74	1855	1429	E 161ST S	1714	MORRIS AV	44.05
75	2185	2306	E 161ST S	2572	3RD AV	43.07
76	1833	2550	MELROSE AV	1649	E 149TH S	42.45
77	1960	1990	SOUTHERN BLV	2005	E 176TH S	41.88
78	1882	2524	E 174TH S	1792	BOSTON R	41.63
79	1833	2548	E 149TH S	1653	MELROSE AV	40.58
80	1960	275	SOUTHERN BLV	2005	E 176TH S	39.86
81	2185	1590	ST ANNS AV	2571	E 161ST S	38.07
82	2187	2569	E 161ST S	2578	WASHINGTON AV	38.00
83	1952	2009	BOSTON R	1986	CROSS BRONX EXPWY SRV R	38.00
84	1866	2273	WESTCHESTER AV	1743	WESTCHESTER AV	37.55
85	2140	2473	3RD AV	2477	E 163RD S	37.15
86	2140	2473	3RD AV	2476	3RD AV	36.91

87	1762	1878	E 165TH S	1436	RIVER AV	36.00
88	1784	1498	E 167TH S	1493	E 167TH S	36.00
89	1882	2392	BOSTON R	1791	E 174TH S	35.83
90	1960	2002	E 176TH S	2005	E 176TH S	33.71
91	1966	2022	E 149TH S	2021	E 149TH S	32.40
92	1823	2214	WESTCHESTER AV	1623	LONGWOOD AV	32.09
93	1866	1619	WESTCHESTER AV	1744	E 163RD S	31.07
94	1833	2548	E 149TH S	1650	3RD AV	31.01
95	1882	1989	SOUTHERN BLV	1791	E 174TH S	30.83
96	1882	1989	SOUTHERN BLV	1790	SOUTHERN BLV	30.62
97	1882	2524	E 174TH S	1789	BOSTON R	30.26
98	1784	1498	E 167TH S	1492	SOUTHERN BLV	30.00
99	1882	2392	BOSTON R	1790	SOUTHERN BLV	30.00
100	1823	2214	WESTCHESTER AV	1622	PROSPECT AV	29.81

Table D-2: Top 100 Movements with the Maximum Average Delay for PM Peak

Serial Number	Intersection ID	From Link ID	From Street Name	To Link ID	To Street Name	Average Delay (seconds)
1	1823	1747	PROSPECT AV	1623	LONGWOOD AV	1174.57
2	1823	2614	LONGWOOD AV	1622	PROSPECT AV	1122.00
3	1866	1750	E 163RD S	1743	WESTCHESTER AV	1102.48
4	1823	1743	WESTCHESTER AV	1621	WESTCHESTER AV	964.14
5	1840	2317	COURTLANDT AV	1673	E 161ST S	893.97
6	1855	1429	E 161ST S	1714	MORRIS AV	823.84
7	1844	2314	MELROSE AV	1683	MELROSE AV	823.07
8	1849	1675	E 161ST S	1700	E 161ST S	770.20
9	1868	1744	E 163RD S	1751	PROSPECT AV	731.39
10	1855	1700	E 161ST S	1713	E 161ST S	730.91
11	1866	2248	E 163RD S	1746	WESTCHESTER AV	638.59
12	1823	1747	PROSPECT AV	1619	WESTCHESTER AV	621.98
13	1855	1700	E 161ST S	1716	CONCOURSE VILLAGE	544.79
14	1760	1706	E 149TH S	1426	E 149TH S	530.14
15	1836	1720	3 RD AV	1663	3RD AV	511.93
16	1840	2317	COURTLANDT AV	1672	E 161ST S	509.22
17	1855	2331	CONCOURSE VILLAGE	1713	E 161ST S	456.20
18	1760	2186	MORRIS AV	1425	E 149TH S	446.67
19	1855	1513	MORRIS AV	1715	E 161ST S	443.28
20	1833	2548	E 149TH S	1651	3RD AV	442.25
21	1882	2394	SOUTHERN BLV	1792	BOSTON R	435.25
22	2179	1710	3RD AV	2552	3RD AV	426.55
23	2185	2476	3RD AV	2570	3RD AV	414.92
24	1882	2527	BOSTON R	1790	SOUTHERN BLV	412.00
25	1833	1709	3RD AV	1649	E 149TH S	397.48
26	1760	1706	E 149TH S	1428	MORRIS AV	392.22
27	1977	1712	E 153RD S	2046	MORRIS AV	390.39
28	1937	1153		1946	CROTONA PARK	379.09
29	1784	1498	E 167TH S	1494	SOUTHERN BLV	349.22
30	1784	2282	SOUTHERN BLV	1493	E 167TH S	327.00
31	1788	1881	E 165TH S	1506	MORRIS AV	302.87
32	1788	1516	E 165TH S	1508	MORRIS AV	278.09
33	1788	1512	MORRIS AV	1508	MORRIS AV	270.00
34	1784	1551	SOUTHERN BLV	1491	E 167TH S	264.05
35	1844	1686	MELROSE AV	1685	MELROSE AV	261.92
36	2187	2308	E 161ST S	2577	E 161ST S	260.28
37	1882	2392	BOSTON R	1790	SOUTHERN BLV	259.20
38	1890	282	MORRIS AV	1813	E 174TH S	250.67
39	2140	2572	3RD AV	2474	E 163RD S	229.96
40	1760	2189	MORRIS AV	1426	E 149TH S	213.98
41	1868	1755	E 163RD S	1749	PROSPECT AV	202.80
42	1849	1715	E 161ST S	1699	E 161ST S	194.92

43	1841	1699	E 161ST S	1674	E 161ST S	192.90
44	1890	2385	E 174TH S	1810	MORRIS AV	189.53
45	2187	2574	WASHINGTON AV	2576	E 161ST S	182.60
46	1788	1827	MORRIS AV	1509	E 165TH S	180.51
47	2185	2306	E 161ST S	2572	3RD AV	176.44
48	1833	2550	MELROSE AV	1649	E 149TH S	158.94
49	1788	1512	MORRIS AV	1507	E 165TH S	153.58
50	1834	1659	WESTCHESTER AV	1657	E 150TH S	128.96
51	1833	1709	3RD AV	1652	E 149TH S	109.36
52	1933	1942	CROTONA AV	1935	BOSTON R	107.47
53	1890	2385	E 174TH S	1813	E 174TH S	101.96
54	1967	2020	E 149TH S	2023	GRAND CONCOURS	101.06
55	1833	2548	E 149TH S	1650	3RD AV	96.32
56	1855	2331	CONCOURSE VILLAGE	1714	MORRIS AV	96.00
57	1882	2524	E 174TH S	1792	BOSTON R	90.54
58	1833	2548	E 149TH S	1653	MELROSE AV	90.43
59	1882	2392	BOSTON R	1788	SOUTHERN BLV	74.44
60	1937	1978	CROTONA AV	1945	CROTONA AV	69.32
61	1760	2173	E 149TH S	1427	MORRIS AV	66.60
62	1890	1914	MORRIS AV	1812	E 174TH S	61.62
63	2185	1590	ST ANNS AV	2571	E 161ST S	56.79
64	1933	1972	PROSPECT AV	1933	BOSTON R	54.67
65	2140	2580	E 163RD S	2475	3RD AV	53.99
66	2179	1705	3RD AV	2553	3RD AV	53.04
67	1882	1989	SOUTHERN BLV	1792	BOSTON R	52.29
68	1967	2020	E 149TH S	2024	E 149TH S	51.00
69	1866	2248	E 163RD S	1744	E 163RD S	46.50
70	2140	1595	E 163RD S	2477	E 163RD S	46.29
71	1760	2186	MORRIS AV	1428	MORRIS AV	45.75
72	1962	2005	E 176TH S	2008	BOSTON R	44.83
73	1866	2248	E 163RD S	1743	WESTCHESTER AV	42.00
74	1960	1990	SOUTHERN BLV	2005	E 176TH S	41.25
75	1933	1967	BOSTON R	1935	BOSTON R	40.10
76	1960	2002	E 176TH S	2005	E 176TH S	40.00
77	1866	1619	WESTCHESTER AV	1744	E 163RD S	39.97
78	1966	2184	GRAND CONCOURS	2021	E 149TH S	39.47
79	2140	2473	3RD AV	2477	E 163RD S	39.26
80	1952	273	BOSTON R	1986	CROSS BRONX EXPWY SRV R	39.14
81	1833	1577	E 149TH S	1652	E 149TH S	38.74
82	1960	275	SOUTHERN BLV	2005	E 176TH S	38.14
83	1988	2127	GRAND CONCOURS	2077	GRAND CONCOURS	38.00
84	1890	1914	MORRIS AV	1813	E 174TH S	37.78
85	1988	2127	GRAND CONCOURS	2076	E 165TH S	37.60
86	1866	2273	WESTCHESTER AV	1743	WESTCHESTER AV	37.03
87	1866	1750	E 163RD S	1745	E 163RD S	36.92
88	1988	1885	E 165TH S	2076	E 165TH S	36.55
89	1866	1750	E 163RD S	1746	WESTCHESTER AV	36.24

90	1866	2273	WESTCHESTER AV	1744	E 163RD S	36.23
91	2185	2306	E 161ST S	2570	3RD AV	34.50
92	1988	2035	E 165TH S	2077	GRAND CONCOURS	34.14
93	1882	2392	BOSTON R	1791	E 174TH S	33.90
94	1882	1989	SOUTHERN BLV	1790	SOUTHERN BLV	33.32
95	1882	2394	SOUTHERN BLV	1791	E 174TH S	33.00
96	1823	2214	WESTCHESTER AV	1623	LONGWOOD AV	32.92
97	1933	2320	BOSTON R	1934	PROSPECT AV	32.85
98	1882	2527	BOSTON R	1791	E 174TH S	32.62
99	1846	2568	E 161ST S	1690	MELROSE AV	32.45
100	1966	2182	E 149TH S	2020	E 149TH S	32.26

Table D-3: Top 100 Movements with the Maximum Queue Lengths for AM Peak

Serial Number	Intersection ID	From Link ID	From Street Name	To Link ID	To Street Name	Maximum Queue Length (Number of vehicles)
1	1868	1744	E 163RD S	1751	PROSPECT AV	36
2	1805	1567	WILLIS AV	1563	E 143RD S	35
3	1846	2315	MELROSE AV	1688	E 161ST S	34
4	1849	1675	E 161ST S	1700	E 161ST S	31
5	1805	1567	WILLIS AV	1565	WILLIS AV	30
6	1760	2189	MORRIS AV	1426	E 149TH S	30
7	1866	2248	E 163RD S	1746	WESTCHESTER AV	29
8	1823	1747	PROSPECT AV	1619	WESTCHESTER AV	29
9	1977	1712	E 153RD S	2047	MORRIS AV	29
10	2140	1595	E 163RD S	2477	E 163RD S	29
11	1833	1709	3RD AV	1649	E 149TH S	28
12	1866	1750	E 163RD S	1743	WESTCHESTER AV	26
13	1855	2331	CONCOURSE VILLAGE	1713	E 161ST S	26
14	1855	1700	E 161ST S	1713	E 161ST S	26
15	1966	2184	GRAND CONCOURS	2019	GRAND CONCOURS	25
16	1855	2331	CONCOURSE VILLAGE	1714	MORRIS AV	23
17	1933	1942	CROTONA AV	1935	BOSTON R	22
18	2185	2476	3RD AV	2570	3RD AV	21
19	1762	2339	RIVER AV	1434	RIVER AV	18
20	2140	1595	E 163RD S	2476	3RD AV	18
21	1784	2270	E 167TH S	1492	SOUTHERN BLV	18
22	1855	1700	E 161ST S	1716	CONCOURSE VILLAGE	18
23	1823	1743	WESTCHESTER AV	1621	WESTCHESTER AV	18
24	1844	1665	E 156TH S	1683	MELROSE AV	18
25	1855	1513	MORRIS AV	1715	E 161ST S	17
26	1987	2458	GRAND CONCOURS	2072	E 165TH S	15
27	1784	1551	SOUTHERN BLV	1491	E 167TH S	15
28	2140	1595	E 163RD S	2475	3RD AV	15
29	1890	1914	MORRIS AV	1812	E 174TH S	15
30	1855	1429	E 161ST S	1715	E 161ST S	15
31	1788	1881	E 165TH S	1506	MORRIS AV	15
32	1967	2174	E 149TH S	2023	GRAND CONCOURS	15
33	1788	1512	MORRIS AV	1508	MORRIS AV	14
34	1844	1686	MELROSE AV	1685	MELROSE AV	14
35	1844	2314	MELROSE AV	1683	MELROSE AV	13
36	1833	2548	E 149TH S	1651	3RD AV	13
37	1788	1512	MORRIS AV	1507	E 165TH S	13
38	1966	2184	GRAND CONCOURS	2021	E 149TH S	13
39	2185	1734	3RD AV	2572	3RD AV	12

40	1967	2174	E 149TH S	2022	E 149TH S	12
41	1788	1827	MORRIS AV	1509	E 165TH S	11
42	1788	1827	MORRIS AV	1507	E 165TH S	11
43	1855	1700	E 161ST S	1714	MORRIS AV	11
44	1868	1544	PROSPECT AV	1752	E 163RD S	11
45	2185	1734	3RD AV	2571	E 161ST S	11
46	1788	1516	E 165TH S	1509	E 165TH S	11
47	1784	1498	E 167TH S	1494	SOUTHERN BLV	10
48	1823	2214	WESTCHESTER AV	1623	LONGWOOD AV	10
49	1846	2301	MELROSE AV	1690	MELROSE AV	10
50	1834	2196	3RD AV	1657	E 150TH S	10
51	1882	2394	SOUTHERN BLV	1789	BOSTON R	10
52	1890	2385	E 174TH S	1810	MORRIS AV	10
53	1836	1720	3 RD AV	1663	3RD AV	10
54	1966	2182	E 149TH S	2020	E 149TH S	10
55	1882	2394	SOUTHERN BLV	1792	BOSTON R	10
56	1977	1712	E 153RD S	2046	MORRIS AV	10
57	1805	2166	WILLIS AV	1564	WILLIS AV	10
58	1966	2184	GRAND CONCOURS	2020	E 149TH S	10
59	1760	1706	E 149TH S	1428	MORRIS AV	10
60	1987	1882	E 165TH S	2073	E 165TH S	10
61	2179	1710	3RD AV	2552	3RD AV	10
62	1858	1725	BROOK AV	1723	E 163RD S	10
63	1849	1715	E 161ST S	1699	E 161ST S	10
64	2140	2572	3RD AV	2474	E 163RD S	10
65	1841	1699	E 161ST S	1674	E 161ST S	10
66	1823	2244	PROSPECT AV	1620	PROSPECT AV	9
67	1834	1659	WESTCHESTER AV	1657	E 150TH S	9
68	2140	2580	E 163RD S	2475	3RD AV	9
69	2140	2572	3RD AV	2475	3RD AV	9
70	1760	2173	E 149TH S	1427	MORRIS AV	9
71	1840	2317	COURTLANDT AV	1673	E 161ST S	8
72	1866	2273	WESTCHESTER AV	1743	WESTCHESTER AV	8
73	1890	1914	MORRIS AV	1810	MORRIS AV	8
74	1882	2392	BOSTON R	1788	SOUTHERN BLV	8
75	1882	1989	SOUTHERN BLV	1789	BOSTON R	8
76	1833	2550	MELROSE AV	1649	E 149TH S	8
77	1937	1943	CROTONA AV	1946	CROTONA PARK	8
78	1823	2614	LONGWOOD AV	1620	PROSPECT AV	7
79	1960	2002	E 176TH S	2004	SOUTHERN BLV	7
80	1846	1673	E 161ST S	1690	MELROSE AV	7
81	1834	1659	WESTCHESTER AV	1654	3RD AV	7
82	1882	1989	SOUTHERN BLV	1790	SOUTHERN BLV	7
83	1962	2010	BOSTON R	2007	BOSTON R	7
84	1962	2005	E 176TH S	2007	BOSTON R	7
85	1846	2568	E 161ST S	1690	MELROSE AV	7
86	2187	2574	WASHINGTON AV	2576	E 161ST S	7

87	1833	1709	3RD AV	1653	MELROSE AV	7
88	1952	2009	BOSTON R	1984	BOSTON R	7
89	1803	1762	HUNTS POINT AV	1559	HUNTS POINT AV	7
90	1866	2273	WESTCHESTER AV	1744	E 163RD S	7
91	2187	2308	E 161ST S	2577	E 161ST S	6
92	1868	1744	E 163RD S	1752	E 163RD S	6
93	1882	2524	E 174TH S	1789	BOSTON R	6
94	1868	1744	E 163RD S	1749	PROSPECT AV	6
95	1868	1544	PROSPECT AV	1750	E 163RD S	6
96	1855	1429	E 161ST S	1714	MORRIS AV	6
97	1823	1747	PROSPECT AV	1622	PROSPECT AV	6
98	1840	1688	E 161ST S	1671	3rd Ave	6
99	1784	1551	SOUTHERN BLV	1494	SOUTHERN BLV	6
100	2185	1590	ST ANNS AV	2571	E 161ST S	6

Table D-4: Top 100 Movements with the Maximum Queue Lengths for PM Peak

Serial Number	Intersection ID	From Link ID	From Street Name	To Link ID	To Street Name	Maximum Queue Length (Number of Vehicles)
1	1868	1744	E 163RD S	1751	PROSPECT AV	36
2	1840	2317	COURTLANDT AV	1673	E 161ST S	33
3	1849	1675	E 161ST S	1700	E 161ST S	32
4	1760	2189	MORRIS AV	1426	E 149TH S	31
5	1977	1712	E 153RD S	2047	MORRIS AV	29
6	1855	1429	E 161ST S	1714	MORRIS AV	29
7	2140	1595	E 163RD S	2476	3RD AV	29
8	1823	1747	PROSPECT AV	1619	WESTCHESTER AV	29
9	1866	2248	E 163RD S	1746	WESTCHESTER AV	29
10	1933	1942	CROTONA AV	1935	BOSTON R	29
11	1833	2550	MELROSE AV	1649	E 149TH S	28
12	1833	1709	3RD AV	1649	E 149TH S	28
13	1855	2331	CONCOURSE VILLAGE	1713	E 161ST S	26
14	1855	1700	E 161ST S	1713	E 161ST S	25
15	1866	1750	E 163RD S	1743	WESTCHESTER AV	24
16	1846	2568	E 161ST S	1688	E 161ST S	23
17	1823	2244	PROSPECT AV	1620	PROSPECT AV	22
18	1846	1673	E 161ST S	1691	E 161ST S	22
19	2140	2580	E 163RD S	2475	3RD AV	21
20	2185	2476	3RD AV	2570	3RD AV	21
21	1866	1619	WESTCHESTER AV	1744	E 163RD S	19
22	1844	2314	MELROSE AV	1683	MELROSE AV	18
23	1823	1743	WESTCHESTER AV	1621	WESTCHESTER AV	18
24	1855	1700	E 161ST S	1716	CONCOURSE	18

					VILLAGE	
25	1855	1513	MORRIS AV	1715	E 161ST S	17
26	2140	1595	E 163RD S	2477	E 163RD S	17
27	1966	2182	E 149TH S	2019	GRAND CONCOURS	16
28	1760	2189	MORRIS AV	1425	E 149TH S	16
29	1882	2392	BOSTON R	1788	SOUTHERN BLV	15
30	1784	1551	SOUTHERN BLV	1491	E 167TH S	15
31	2179	1705	3RD AV	2553	3RD AV	15
32	1788	1881	E 165TH S	1506	MORRIS AV	15
33	1784	2270	E 167TH S	1492	SOUTHERN BLV	15
34	1890	1914	MORRIS AV	1812	E 174TH S	15
35	1967	2020	E 149TH S	2023	GRAND CONCOURS	15
36	1788	1516	E 165TH S	1508	MORRIS AV	14
37	1933	1972	PROSPECT AV	1933	BOSTON R	14
38	1844	1686	MELROSE AV	1685	MELROSE AV	14
39	2187	2308	E 161ST S	2577	E 161ST S	13
40	2185	1590	ST ANNS AV	2570	3RD AV	13
41	1788	1512	MORRIS AV	1507	E 165TH S	13
42	2185	2306	E 161ST S	2572	3RD AV	13
43	1833	2548	E 149TH S	1651	3RD AV	13
44	1784	1498	E 167TH S	1494	SOUTHERN BLV	12
45	1788	1827	MORRIS AV	1509	E 165TH S	11
46	1868	1544	PROSPECT AV	1752	E 163RD S	11
47	1866	2273	WESTCHESTER AV	1744	E 163RD S	10
48	1833	1709	3RD AV	1653	MELROSE AV	10
49	1858	1725	BROOK AV	1723	E 163RD S	10
50	1800	2238	LAFAYETTE AV	1547	HUNTS POINT AV	10
51	1890	2385	E 174TH S	1810	MORRIS AV	10
52	1882	2394	SOUTHERN BLV	1792	BOSTON R	10
53	1823	2214	WESTCHESTER AV	1623	LONGWOOD AV	10
54	1836	1720	3 RD AV	1663	3RD AV	10
55	1977	1712	E 153RD S	2046	MORRIS AV	10
56	1760	1706	E 149TH S	1428	MORRIS AV	10
57	1841	1699	E 161ST S	1674	E 161ST S	10
58	1834	1659	WESTCHESTER AV	1657	E 150TH S	10
59	1849	1715	E 161ST S	1699	E 161ST S	10
60	2140	2572	3RD AV	2474	E 163RD S	10
61	2179	1710	3RD AV	2552	3RD AV	10
62	1833	2548	E 149TH S	1653	MELROSE AV	10
63	1937	1978	CROTONA AV	1945	CROTONA AV	10
64	1890	1914	MORRIS AV	1813	E 174TH S	10
65	1833	1577	E 149TH S	1652	E 149TH S	10
66	1966	2184	GRAND CONCOURS	2021	E 149TH S	10
67	1833	2548	E 149TH S	1650	3RD AV	10
68	2187	2574	WASHINGTON AV	2576	E 161ST S	10
69	1882	1989	SOUTHERN BLV	1791	E 174TH S	9
70	1882	1989	SOUTHERN BLV	1790	SOUTHERN BLV	9

71	1988	2035	E 165TH S	2075	E 165TH S	9
72	1840	2317	COURTLANDT AV	1672	E 161ST S	9
73	1967	2174	E 149TH S	2022	E 149TH S	9
74	1866	2273	WESTCHESTER AV	1743	WESTCHESTER AV	9
75	1803	1762	HUNTS POINT AV	1559	HUNTS POINT AV	9
76	1890	2385	E 174TH S	1813	E 174TH S	9
77	1868	1544	PROSPECT AV	1750	E 163RD S	8
78	1882	2394	SOUTHERN BLV	1789	BOSTON R	8
79	1882	1989	SOUTHERN BLV	1789	BOSTON R	8
80	1784	1551	SOUTHERN BLV	1494	SOUTHERN BLV	8
81	1952	273	BOSTON R	1985	BOSTON R	8
82	1966	2182	E 149TH S	2020	E 149TH S	8
83	1868	1744	E 163RD S	1749	PROSPECT AV	7
84	2140	1595	E 163RD S	2475	3RD AV	7
85	1966	2184	GRAND CONCOURS	2020	E 149TH S	7
86	2185	1734	3RD AV	2572	3RD AV	7
87	1866	1750	E 163RD S	1746	WESTCHESTER AV	7
88	1855	1700	E 161ST S	1714	MORRIS AV	7
89	1823	1747	PROSPECT AV	1623	LONGWOOD AV	7
90	1937	1943	CROTONA AV	1946	CROTONA PARK	7
91	1866	1619	WESTCHESTER AV	1745	E 163RD S	7
92	1823	2614	LONGWOOD AV	1622	PROSPECT AV	6
93	1866	1750	E 163RD S	1745	E 163RD S	6
94	1823	2614	LONGWOOD AV	1620	PROSPECT AV	6
95	1962	2005	E 176TH S	2007	BOSTON R	6
96	1988	2035	E 165TH S	2077	GRAND CONCOURS	6
97	1868	1744	E 163RD S	1752	E 163^{RD} S	6
98	1868	1748	PROSPECT AV	1752	E 163^{RD} S	6
99	1988	1885	E 165TH S	2076	E 165^{TH} S	6
100	1960	1990	SOUTHERN BLV	2003	SOUTHERN BLV	6

Table D-5: Top 100 Movements with the Maximum Average Queue Lengths for AM Peak

Serial Number	Intersection ID	From Link ID	From Street Name	To Link ID	To Street Name	Average Queue Length (number of vehicles)
1	1977	1712	E 153RD S	2047	MORRIS AV	4
2	1833	1709	3RD AV	1649	E 149TH S	4
3	1866	2248	E 163RD S	1746	WESTCHESTER AV	4
4	1823	1747	PROSPECT AV	1619	WESTCHESTER AV	4
5	1846	2315	MELROSE AV	1688	E 161ST S	3
6	1866	1750	E 163RD S	1743	WESTCHESTER AV	3
7	1805	1567	WILLIS AV	1563	E 143RD S	3
8	2185	2476	3RD AV	2570	3RD AV	3
9	1855	1700	E 161ST S	1716	CONCOURSE VILLAGE	3
10	1855	1700	E 161ST S	1713	E 161ST S	3
11	1868	1744	E 163RD S	1751	PROSPECT AV	3
12	1855	1513	MORRIS AV	1715	E 161ST S	2
13	1823	1743	WESTCHESTER AV	1621	WESTCHESTER AV	2
14	1849	1675	E 161ST S	1700	E 161ST S	2
15	1855	2331	CONCOURSE VILLAGE	1714	MORRIS AV	2
16	1788	1881	E 165TH S	1506	MORRIS AV	2
17	1844	1686	MELROSE AV	1685	MELROSE AV	2
18	1967	2174	E 149TH S	2023	GRAND CONCOURS	2
19	2140	1595	E 163RD S	2477	E 163RD S	2
20	1805	1567	WILLIS AV	1565	WILLIS AV	2
21	1844	1665	E 156TH S	1683	MELROSE AV	2
22	1890	1914	MORRIS AV	1812	E 174TH S	2
23	1833	2548	E 149TH S	1651	3RD AV	2
24	1987	2458	GRAND CONCOURS	2072	E 165TH S	2
25	1836	1720	3 RD AV	1663	3RD AV	2
26	1977	1712	E 153RD S	2046	MORRIS AV	1
27	1788	1512	MORRIS AV	1507	E 165TH S	1
28	1805	2166	WILLIS AV	1564	WILLIS AV	1
29	1760	1706	E 149TH S	1428	MORRIS AV	1
30	1966	2184	GRAND CONCOURS	2019	GRAND CONCOURS	1
31	1788	1512	MORRIS AV	1508	MORRIS AV	1
32	2179	1710	3RD AV	2552	3RD AV	1
33	1855	2331	CONCOURSE VILLAGE	1713	E 161ST S	1
34	2140	2572	3RD AV	2474	E 163RD S	1
35	1760	2189	MORRIS AV	1426	E 149TH S	1
36	1966	2184	GRAND CONCOURS	2021	E 149TH S	1
37	1841	1699	E 161ST S	1674	E 161ST S	1
38	1788	1516	E 165TH S	1509	E 165TH S	1
39	1849	1715	E 161ST S	1699	E 161ST S	1

40	1788	1827	MORRIS AV	1509	E 165TH S	1
41	1858	1725	BROOK AV	1723	E 163RD S	1
42	1987	1882	E 165TH S	2073	E 165TH S	1
43	1762	2339	RIVER AV	1434	RIVER AV	1
44	2140	1595	E 163RD S	2476	3RD AV	1
45	1966	2184	GRAND CONCOURS	2020	E 149TH S	1
46	1882	2394	SOUTHERN BLV	1792	BOSTON R	0

Table D-6: Top 100 Movements with the Maximum Average Queue Lengths for PM Peak

Serial Number	Intersection ID	From Link ID	From Street Name	To Link ID	To Street Name	Average Queue Length (number of vehicles)
1	1840	2317	COURTLANDT AV	1673	E 161ST S	5
2	1849	1675	E 161ST S	1700	E 161ST S	5
3	1977	1712	E 153RD S	2047	MORRIS AV	5
4	1760	2189	MORRIS AV	1426	E 149TH S	4
5	1855	1429	E 161ST S	1714	MORRIS AV	4
6	1833	1709	3RD AV	1649	E 149TH S	4
7	2140	1595	E 163RD S	2476	3RD AV	4
8	1823	1747	PROSPECT AV	1619	WESTCHESTER AV	4
9	1866	2248	E 163RD S	1746	WESTCHESTER AV	3
10	1855	1700	E 161ST S	1716	CONCOURSE VILLAGE	3
11	2185	2476	3RD AV	2570	3RD AV	3
12	1868	1744	E 163RD S	1751	PROSPECT AV	3
13	1866	1750	E 163RD S	1743	WESTCHESTER AV	3
14	1844	2314	MELROSE AV	1683	MELROSE AV	2
15	1855	2331	CONCOURSE VILLAGE	1713	E 161ST S	2
16	1855	1513	MORRIS AV	1715	E 161ST S	2
17	1844	1686	MELROSE AV	1685	MELROSE AV	2
18	1967	2020	E 149TH S	2023	GRAND CONCOURS	2
19	1823	1743	WESTCHESTER AV	1621	WESTCHESTER AV	2
20	2187	2308	E 161ST S	2577	E 161ST S	2
21	1788	1881	E 165TH S	1506	MORRIS AV	2
22	1788	1512	MORRIS AV	1507	E 165TH S	2
23	1846	2568	E 161ST S	1688	E 161ST S	2
24	1890	1914	MORRIS AV	1812	E 174TH S	2
25	1846	1673	E 161ST S	1691	E 161ST S	2
26	1855	1700	E 161ST S	1713	E 161ST S	2
27	1836	1720	3 RD AV	1663	3RD AV	2
28	1977	1712	E 153RD S	2046	MORRIS AV	2
29	1760	1706	E 149TH S	1428	MORRIS AV	2
30	1841	1699	E 161ST S	1674	E 161ST S	2
31	1834	1659	WESTCHESTER AV	1657	E 150TH S	2
32	1833	2548	E 149TH S	1651	3RD AV	1
33	1849	1715	E 161ST S	1699	E 161ST S	1
34	2140	2572	3RD AV	2474	E 163RD S	1
35	1788	1516	E 165TH S	1508	MORRIS AV	1
36	2179	1710	3RD AV	2552	3RD AV	1
37	2179	1705	3RD AV	2553	3RD AV	1
38	1788	1827	MORRIS AV	1509	E 165TH S	1
39	1833	2548	E 149TH S	1653	MELROSE AV	1

40	1784	1551	SOUTHERN BLV	1491	E 167TH S	1
41	1890	1914	MORRIS AV	1813	E 174TH S	1
42	1833	1577	E 149TH S	1652	E 149TH S	1
43	1966	2184	GRAND CONCOURS	2021	E 149TH S	1
44	1784	1498	E 167TH S	1494	SOUTHERN BLV	1
45	2140	2580	E 163RD S	2475	3RD AV	1
46	1866	1619	WESTCHESTER AV	1744	E 163RD S	1
47	1933	1942	CROTONA AV	1935	BOSTON R	1
48	1833	2548	E 149TH S	1650	3RD AV	1
49	2187	2574	WASHINGTON AV	2576	E 161ST S	1
50	1823	2244	PROSPECT AV	1620	PROSPECT AV	1
51	1937	1978	CROTONA AV	1945	CROTONA AV	1
52	1882	2392	BOSTON R	1788	SOUTHERN BLV	0

APPENDIX E EMISSION LEVELS

Table E-1: Top 100 Street Segments with the Maximum CO Emission Levels for AM Peak

Serial Number	Link ID	Street Name	CO Emission (gm/mile)
1	1985	BOSTON R	1094.31
2	2059	GRAND CONCOURS	1094.31
3	2064	GRAND CONCOURS	1094.31
4	2623	PROSPECT AV	1094.31
5	1472	E 144TH S	1088.98
6	2017	E 144TH S	1076.19
7	1190		1075.13
8	922		1055.1
9	931		1055.1
10	1036		1055.1
11	1181		1055.1
12	1203		1055.1
13	1206		1055.1
14	1359		1055.1
15	1720	3 RD AV	1055.1
16	1896	JEROME AV	1055.1
17	2042	E 170TH S	1055.1
18	2070	GERARD AV	1055.1
19	2078	GRAND CONCOURS	1055.1
20	2080		1055.1
21	2092		1055.1
22	2093	E 170TH S	1055.1
23	2132		1055.1
24	2486	GRAND CONCOURS	1055.1
25	2530	E 161ST S	1055.1
26	2535		1055.1
27	2606	E 170TH S	1055.1
28	2608		1055.1
29	2611	GRAND CONCOURS	1055.1
30	2612	E 161ST S	1055.1
31	869		1053.05
32	666		1052.73
33	571		1051
34	2627	PROSPECT AV	1048.49
35	2536	E 167TH S	1047.92
36	1277		1047.92
37	1131		1045.86
38	1437	GERARD AV	1045.86
39	670		1044.84
40	2009	BOSTON R	1045.29
41	1930	BOSTON R	1043.81
42	2503		1043.81
43	1207		1042.79

44	360		1041.76
45	828		1041.76
46	679		1040.73
47	1106		1040.73
48	1163		1040.73
49	1201		1040.73
50	2066	E 161ST S	1038.68
51	1652	E 149TH S	1037.65
52	2076	E 165TH S	1035.6
53	1961	BOSTON R	1032.52
54	352		1031.49
55	1651	3RD AV	1030.47
56	2035	E 165TH S	1028.41
57	1032		1025.33
58	940		1024.31
59	2022	E 149TH S	1024.31
60	2063	E 161ST S	1021.23
61	1045		1017.12
62	1062		1017.12
63	2010	BOSTON R	1012.61
64	775		1012.22
65	1321		1012.2
66	2502	E 167TH S	1012.32
67	2539	E 167TH S	1012.32
68	1317		1011.83
69	394		1011.83
70	797		1011.83
71	930		1011.83
72	1157		1011.83
73	1617	E 149TH S	1011.83
74	1833	E 169TH S	1011.83
75	2088	E 169TH S	1011.83
76	2112		1011.83
77	2537	GRAND CONCOURS	1011.83
78	1119		1011.82
79	790		1011.09
80	1107		1009.89
81	1351		1010.46
82	1221		1010.46
83	1834	E 169TH S	1010.46
84	2085	E 169TH S	1010.46
85	2493	GRAND CONCOURS	1010.46
86	2544	GRAND CONCOURS	1010.46
87	1709	3RD AV	1010.97
88	1898	MACOMBS R	1008.49
89	343		1008.49
90	419		1008.49

91	420		1008.49
92	2492	E 170TH S	1008.49
93	2475	3RD AV	1006.95
94	1123		1007.51
95	1256		1007.51
96	1727	E 165TH S	1007.51
97	2543	E 170TH S	1007.51
98	1187		1005.99
99	395		1006.53
100	924		1006.53

Table E-2: Top 100 Street Segments with the Maximum CO Emission Levels for PM Peak

Serial Number	Link ID	Street Name	CO Emission (gm/mile)
1	1985	BOSTON R	1094.31
2	1124		1077.27
3	1472	E 144TH S	1075.13
4	2627	PROSPECT AV	1069.8
5	1190		1057.01
6	869		1055.33
7	2535		1055.1
8	2606	E 170TH S	1055.1
9	2608		1055.1
10	2486	GRAND CONCOURS	1055.1
11	2042	E 170TH S	1055.1
12	2078	GRAND CONCOURS	1055.1
13	2093	E 170TH S	1055.1
14	1896	JEROME AV	1055.1
15	1359		1055.1
16	1033		1055.1
17	1036		1055.1
18	1181		1055.1
19	848		1055.1
20	922		1055.1
21	931		1055.1
22	936		1055.1
23	679		1055.1
24	704		1055.1
25	715		1055.1
26	571		1055.1
27	1206		1052.02
28	1207		1052.02
29	1203		1051
30	828		1035.6
31	2623	PROSPECT AV	1035.7
32	352		1034.65
33	2070	GERARD AV	1032.52
34	1437	GERARD AV	1032.52
35	1201		1032.52
36	2009	BOSTON R	1031.44
37	1888	JEROME AV	1027.39
38	1032		1026.36
39	940		1026.36
40	2066	E 161ST S	1025.33
41	472		1024.31
42	1652	E 149TH S	1023.51
43	666		1022.26
44	2022	E 149TH S	1020.2

45	2503		1019.18
46	1651	3RD AV	1018.15
47	1961	BOSTON R	1016.1
48	2010	BOSTON R	1012.43
49	670		1015.17
50	1277		1014.04
51	1045		1014.04
52	1062		1014.04
53	2112		1011.91
54	2544	GRAND CONCOURS	1011.83
55	2573	ELTON AV	1011.83
56	2493	GRAND CONCOURS	1011.83
57	2045	RAM	1011.83
58	2088	E 169TH S	1011.83
59	1833	E 169TH S	1011.83
60	1617	E 149TH S	1011.83
61	1221		1011.83
62	1317		1011.83
63	1321		1011.83
64	1123		1011.83
65	1157		1011.83
66	930		1011.83
67	497		1011.83
68	509		1011.83
69	419		1011.83
70	420		1011.83
71	432		1012.08
72	2035	E 165TH S	1011.99
73	1164		1010.96
74	2085	E 169TH S	1008.9
75	2495	E 170TH S	1007.92
76	2492	E 170TH S	1006.95
77	2548	E 149TH S	1004.8
78	1186		1004.8
79	498		1004.81
80	2103		1002.06
81	1131		1001.83
82	2020	E 149TH S	1001.73
83	1351		999.136
84	1450	EDWARD L GRANT HW	997.446
85	1898	MACOMBS R	996.331
86	2536	E 167TH S	997.621
87	563		995.295
88	2475	3RD AV	995.005
89	2027	E 153RD S	994.542
90	1930	BOSTON R	994.541
91	575		992.42

92	1834	E 169TH S	992.302
93	1709	3RD AV	993.515
94	757		990.377
95	2076	E 165TH S	991.462
96	1195		989.375
97	1018		988.397
98	1212		986.62
99	703		986.445
100	496		986.445

Table E-3: Top 100 Street Segments with the Maximum NOX Emission Levels for AM Peak

Serial Number	Link ID	*Street Name*	NOx Emission (gm/mile)
1	1985	BOSTON R	77.689
2	2059	GRAND CONCOURS	77.689
3	2064	GRAND CONCOURS	77.689
4	2623	PROSPECT AV	77.689
5	1472	E 144TH S	77.306
6	2017	E 144TH S	76.388
7	1190		76.311
8	922		74.91
9	931		74.91
10	1036		74.91
11	1181		74.91
12	1203		74.91
13	1206		74.91
14	1359		74.91
15	1720	3 RD AV	74.91
16	1896	JEROME AV	74.91
17	2042	E 170TH S	74.91
18	2070	GERARD AV	74.91
19	2078	GRAND CONCOURS	74.91
20	2080		74.91
21	2092		74.91
22	2093	E 170TH S	74.91
23	2132		74.91
24	2486	GRAND CONCOURS	74.91
25	2530	E 161ST S	74.91
26	2535		74.91
27	2606	E 170TH S	74.91
28	2608		74.91
29	2611	GRAND CONCOURS	74.91
30	2612	E 161ST S	74.91
31	869		74.762
32	666		74.738
33	571		74.615
34	2627	PROSPECT AV	74.397
35	2536	E 167TH S	74.393
36	1277		74.393
37	1131		74.246
38	1437	GERARD AV	74.246
39	670		74.172
40	2009	BOSTON R	74.168
41	1930	BOSTON R	74.098
42	2503		74.098
43	1207		74.024

44	360		73.951
45	828		73.951
46	679		73.877
47	1106		73.877
48	1163		73.877
49	1201		73.877
50	2066	E 161ST S	73.729
51	1652	E 149TH S	73.656
52	2076	E 165TH S	73.508
53	1961	BOSTON R	73.287
54	352		73.213
55	1651	3RD AV	73.139
56	2035	E 165TH S	72.992
57	1032		72.77
58	940		72.696
59	2022	E 149TH S	72.696
60	2063	E 161ST S	72.475
61	1045		72.18
62	1062		72.18
63	2010	BOSTON R	73.053
64	775		72.962
65	1321		72.956
66	2502	E 167TH S	72.888
67	2539	E 167TH S	72.888
68	1317		72.849
69	394		72.849
70	797		72.849
71	930		72.849
72	1157		72.849
73	1617	E 149TH S	72.849
74	1833	E 169TH S	72.849
75	2088	E 169TH S	72.849
76	2112		72.849
77	2537	GRAND CONCOURS	72.849
78	1119		72.847
79	790		72.853
80	1107		72.712
81	1351		71.745
82	1221		71.745
83	1834	E 169TH S	71.745
84	2085	E 169TH S	71.745
85	2493	GRAND CONCOURS	71.745
86	2544	GRAND CONCOURS	71.745
87	1709	3RD AV	71.737
88	1898	MACOMBS R	71.604
89	343		71.604
90	419		71.604

91	420		71.604
92	2492	E 170TH S	71.604
93	2475	3RD AV	72.494
94	1123		71.533
95	1256		71.533
96	1727	E 165TH S	71.533
97	2543	E 170TH S	71.533
98	1187		72.431
99	395		71.463
100	924		71.463

Table E-1: Top 100 Street Segments with the Maximum NOX Emission Levels for PM Peak

Serial Number	Link ID	Street Name	NOx Emission (gm/mile)
1	1985	BOSTON R	77.689
2	1124		76.465
3	1472	E 144TH S	76.311
4	2627	PROSPECT AV	75.928
5	1190		75.01
6	869		74.926
7	2535		74.91
8	2606	E 170TH S	74.91
9	2608		74.91
10	2486	GRAND CONCOURS	74.91
11	2042	E 170TH S	74.91
12	2078	GRAND CONCOURS	74.91
13	2093	E 170TH S	74.91
14	1896	JEROME AV	74.91
15	1359		74.91
16	1033		74.91
17	1036		74.91
18	1181		74.91
19	848		74.91
20	922		74.91
21	931		74.91
22	936		74.91
23	679		74.91
24	704		74.91
25	715		74.91
26	571		74.91
27	1206		74.688
28	1207		74.688
29	1203		74.615
30	828		73.508
31	2623	PROSPECT AV	73.479
32	352		73.44
33	2070	GERARD AV	73.287
34	1437	GERARD AV	73.287
35	1201		73.287
36	2009	BOSTON R	73.172
37	1888	JEROME AV	72.918
38	1032		72.844
39	940		72.844
40	2066	E 161ST S	72.77
41	472		72.696
42	1652	E 149TH S	72.639

43	666		72.549
44	2022	E 149TH S	72.401
45	2503		72.328
46	1651	3RD AV	72.254
47	1961	BOSTON R	72.106
48	2010	BOSTON R	73.011
49	670		72.039
50	1277		71.959
51	1045		71.959
52	1062		71.959
53	2112		72.855
54	2544	GRAND CONCOURS	72.849
55	2573	ELTON AV	72.849
56	2493	GRAND CONCOURS	72.849
57	2045	RAM	72.849
58	2088	E 169TH S	72.849
59	1833	E 169TH S	72.849
60	1617	E 149TH S	72.849
61	1221		72.849
62	1317		72.849
63	1321		72.849
64	1123		72.849
65	1157		72.849
66	930		72.849
67	497		72.849
68	509		72.849
69	419		72.849
70	420		72.849
71	432		71.818
72	2035	E 165TH S	71.811
73	1164		71.737
74	2085	E 169TH S	72.636
75	2495	E 170TH S	72.565
76	2492	E 170TH S	72.494
77	2548	E 149TH S	71.295
78	1186		71.295
79	498		71.295
80	2103		72.14
81	1131		71.08
82	2020	E 149TH S	71.073
83	1351		71.927
84	1450	EDWARD L GRANT HW	71.806
85	1898	MACOMBS R	71.723
86	2536	E 167TH S	70.778
87	563		71.647
88	2475	3RD AV	71.626

89	2027	E 153RD S	70.557
90	1930	BOSTON R	70.557
91	575		71.438
92	1834	E 169TH S	71.43
93	1709	3RD AV	70.483
94	757		71.291
95	2076	E 165TH S	70.336
96	1195		71.218
97	1018		71.146
98	1212		71.034
99	703		71.004
100	496		71.004

Table E-2: Top 100 Street Segments with the Maximum TOG Emission Levels for AM Peak

Serial Number	Link ID	Street Name	TOG Emission (gm/mile)
1	1985	BOSTON R	200.999
2	2059	GRAND CONCOURS	200.999
3	2064	GRAND CONCOURS	200.999
4	2623	PROSPECT AV	200.999
5	1472	E 144TH S	200.016
6	2017	E 144TH S	197.655
7	1190		197.459
8	922		193.847
9	931		193.847
10	1036		193.847
11	1181		193.847
12	1203		193.847
13	1206		193.847
14	1359		193.847
15	1720	3 RD AV	193.847
16	1896	JEROME AV	193.847
17	2042	E 170TH S	193.847
18	2070	GERARD AV	193.847
19	2078	GRAND CONCOURS	193.847
20	2080		193.847
21	2092		193.847
22	2093	E 170TH S	193.847
23	2132		193.847
24	2486	GRAND CONCOURS	193.847
25	2530	E 161ST S	193.847
26	2535		193.847
27	2606	E 170TH S	193.847
28	2608		193.847
29	2611	GRAND CONCOURS	193.847
30	2612	E 161ST S	193.847
31	869		193.468
32	666		193.407
33	571		193.089
34	2627	PROSPECT AV	192.541
35	2536	E 167TH S	192.521
36	1277		192.52
37	1131		192.142
38	1437	GERARD AV	192.141
39	670		191.952
40	2009	BOSTON R	191.951
41	1930	BOSTON R	191.762
42	2503		191.762
43	1207		191.573
44	360		191.383

45	828		191.383
46	679		191.194
47	1106		191.194
48	1163		191.194
49	1201		191.194
50	2066	E 161ST S	190.815
51	1652	E 149TH S	190.625
52	2076	E 165TH S	190.246
53	1961	BOSTON R	189.677
54	352		189.488
55	1651	3RD AV	189.298
56	2035	E 165TH S	188.919
57	1032		188.35
58	940		188.161
59	2022	E 149TH S	188.161
60	2063	E 161ST S	187.592
61	1045		186.834
62	1062		186.834
63	2010	BOSTON R	186.601
64	775		186.394
65	1321		186.381
66	2502	E 167TH S	186.308
67	2539	E 167TH S	186.308
68	1317		186.216
69	394		186.215
70	797		186.215
71	930		186.215
72	1157		186.215
73	1617	E 149TH S	186.215
74	1833	E 169TH S	186.215
75	2088	E 169TH S	186.215
76	2112		186.215
77	2537	GRAND CONCOURS	186.215
78	1119		186.213
79	790		186.131
80	1107		185.857
81	1351		185.705
82	1221		185.704
83	1834	E 169TH S	185.704
84	2085	E 169TH S	185.704
85	2493	GRAND CONCOURS	185.704
86	2544	GRAND CONCOURS	185.704
87	1709	3RD AV	185.697
88	1898	MACOMBS R	185.342
89	343		185.341
90	419		185.341
91	420		185.341

92	2492	E 170TH S	185.341
93	2475	3RD AV	185.308
94	1123		185.16
95	1256		185.16
96	1727	E 165TH S	185.16
97	2543	E 170TH S	185.16
98	1187		185.134
99	395		184.979
100	924		184.978

Table E-3: Top 100 Street Segments with the Maximum TOG Emission Levels for PM Peak

Serial Number	Link ID	Street Name	TOG Emission (gm/mile)
1	1985	BOSTON R	200.999
2	1124		197.854
3	1472	E 144TH S	197.459
4	2627	PROSPECT AV	196.475
5	1190		194.115
6	869		193.889
7	2535		193.847
8	2606	E 170TH S	193.847
9	2608		193.847
10	2486	GRAND CONCOURS	193.847
11	2042	E 170TH S	193.847
12	2078	GRAND CONCOURS	193.847
13	2093	E 170TH S	193.847
14	1896	JEROME AV	193.847
15	1359		193.847
16	1033		193.847
17	1036		193.847
18	1181		193.847
19	848		193.847
20	922		193.847
21	931		193.847
22	936		193.847
23	679		193.847
24	704		193.847
25	715		193.847
26	571		193.847
27	1206		193.279
28	1207		193.279
29	1203		193.089
30	828		190.246
31	2623	PROSPECT AV	190.181
32	352		190.071
33	2070	GERARD AV	189.677
34	1437	GERARD AV	189.677
35	1201		189.677
36	2009	BOSTON R	189.394
37	1888	JEROME AV	188.729
38	1032		188.54
39	940		188.54
40	2066	E 161ST S	188.35
41	472		188.161
42	1652	E 149TH S	188.012
43	666		187.782
44	2022	E 149TH S	187.403

45	2503		187.213
46	1651	3RD AV	187.023
47	1961	BOSTON R	186.644
48	2010	BOSTON R	186.506
49	670		186.472
50	1277		186.265
51	1045		186.265
52	1062		186.265
53	2112		186.23
54	2544	GRAND CONCOURS	186.215
55	2573	ELTON AV	186.215
56	2493	GRAND CONCOURS	186.215
57	2045	RAM	186.215
58	2088	E 169TH S	186.215
59	1833	E 169TH S	186.215
60	1617	E 149TH S	186.215
61	1221		186.215
62	1317		186.215
63	1321		186.215
64	1123		186.215
65	1157		186.215
66	930		186.215
67	497		186.215
68	509		186.215
69	419		186.215
70	420		186.215
71	432		185.903
72	2035	E 165TH S	185.886
73	1164		185.697
74	2085	E 169TH S	185.671
75	2495	E 170TH S	185.489
76	2492	E 170TH S	185.308
77	2548	E 149TH S	184.559
78	1186		184.559
79	498		184.559
80	2103		184.4
81	1131		184.009
82	2020	E 149TH S	183.991
83	1351		183.856
84	1450	EDWARD L GRANT HW	183.542
85	1898	MACOMBS R	183.334
86	2536	E 167TH S	183.232
87	563		183.141
88	2475	3RD AV	183.085
89	2027	E 153RD S	182.664
90	1930	BOSTON R	182.664
91	575		182.606

92	1834	E 169TH S	182.585
93	1709	3RD AV	182.474
94	757		182.227
95	2076	E 165TH S	182.095
96	1195		182.041
97	1018		181.859
98	1212		181.542
99	703		181.496
100	496		181.496

APPENDIX F REVIEW OF SOFTWARE TOOLS

The CORridor SIMulator (CORSIM) [1] is an interval-based microscopic simulation model that was developed by the Federal Highway Administration (FHWA) to emulate the behavior of traffic for signalized and freeway systems. In CORSIM, each individual vehicle is treated as a distinct object whose kinematic properties (speed, acceleration, and jerk) as well as status (queued, moving, lane changing) are taken into consideration. Individual vehicles (including carpools, trucks and buses) are moved based on vehicle performance characteristics, driver aggressiveness, car following/lane-changing logic, and traffic control signals. Thus, driving behavior on roadways reflecting traffic operations can be simulated.

CORSIM combines an urban street traffic simulator (NETSIM) and a freeway traffic simulator (FRESIM) into an integrated package. It provides capabilities of not only simulating traffic behavior on integrated urban transportation networks of freeways and surface streets, but also evaluating geometric design and traffic control strategies. FRESIM [2, 3] is a microscopic freeway simulator that has been tested, validated and used in various research studies [4, 5, 6]. It is extensively used to evaluate freeway operations [7] and reconstruction alternatives [8, 9]. Besides its wide application and use, it has some limitations [10].

CORSIM generates 10 different driver types, ranging from the most passive (i.e., driver type 1) to the most aggressive (i.e. driver type 10), to represent driving behavioral characteristics. The desired speed of each driver is fixed and linearly increases from the passive to the aggressive type. In addition, the driver type for each emitted vehicle is randomly selected from the embedded discrete distribution rather than a distribution that can be calibrated by users. More recently, a new model to better reflect the speed distribution for the driver population has been proposed [11].

WATSIM [12, 13] is also a microscopic simulation model that has similar characteristics with CORSIM. It has a user friendly windows based graphical interface and has its own network generator that makes it easy to input a transportation network and the associated geometric and traffic flow data. The simulation model for signalized networks is practically the same with NETSIM and it can accept input for CORSIM. The freeway simulation module has similar characteristics with FRESIM. A researcher or practitioner will find very few differences between CORSIM or WATSIM in terms of its functionality.

SYNCHRO [14] is a signal simulation/optimization software that is capable to model isolated intersections, arterials and networks. It also has a microscopic simulation model, SimTraffic that compares favorably with CORSIM and WATSIM. SYNCHRO has a very user friendly graphical interface that makes it rather easy to input geometric, traffic flow and signal data. One of its advantages is that it can interface with CORSIM, the Highway Capacity Software (HCS) and TRANSYT-7F. HCS is the officially sponsored software by the Federal Highway Administration (FHWA) that follows the Highway Capacity Manual [15] procedures for capacity analyses of various transportation facilities (freeways, multilane and two lane highways, arterials, intersections, pedestrians, transit facilities). A user can generate the transportation network under investigation in SYNCHRO and automatically create the input for CORSIM. Thereafter, the user can use CORSIM for further analysis with minor editing. The ability of SYNCHRO to optimize signal timing can aid in sensitivity analyses of the impact of various policies such as signal timing and geometric changes. The results of each policy can then be verified with CORSIM.

DYNASMART and DYNAMIT are two products of a FHWA project that are available via Oak Ridge National Labs. While they are good research tools they are still not commercial quality and are hard to use unless the initial developers are involved in the study; the cost of this proposition would be prohibitive within this project's resources. In addition, they both seem to rely on problematic Method of Successive Average procedure to equilibrate traffic which can produce questionable results.

INTEGRATION is probably the first Dynamic Traffic Assignment/Simulation tool introduced in the early 1990's and while it was quite advanced at the time, it appears that have been abandoned and no support is provided.

VISTA is a networked system, accessible through the public Internet or a private Intranet. The models represent traditional and cutting-edge transportation algorithms capable of handling large-scale real-time needs (as will be discussed). The client is a machine-independent Java application. CORBA used to bridge the client with the modules and data, allowing the modules to be developed in languages other than Java. Other distributed-object technologies (RMI and DCOM for example) limit the languages or operating systems available for developing and deploying VISTA modules.

The VISTA system as used in this study includes:

- A Data Warehouse containing all the data needed by the models.
- Existing and new transportation models and tools (planning, engineering, control, monitoring, evaluation and operational).
- User interfaces for the various stakeholders (planners, engineers, policy makers, and operators) that enable access to the data and models from any computer hardware, at any location, at any time.
- The system uses CORBA to facilitate communication between the client application and the application server.
- Support capabilities for all relevant transportation applications.
- Functionality for interaction among users.
- Reporting tools.
- Security features providing access control and fine-grained permissions on data and models.
- Some basic administrative capabilities.

The system is intended for deployment at the state or regional level. The State Department of Transportation (DOT), the Metropolitan Planning Organizations (MPO's), County Engineers, City Engineers, Transit Agencies, Freight Agencies, and other stakeholders will have access to the system at various authorization levels to obtain/maintain data, run models and perform analysis. Policy makers at the Federal, State and Local governments will be able to monitor projects, obtain data, evaluate impacts of policies and make decisions. The overall structure of VISTA is outlined below.

VISTA employs a large scale traffic simulator called RouteSim. RouteSim is a mesoscopic simulator based on an extension of Daganzo's (1994) cell transmission model introduced by Ziliaskopoulos and Lee (1996). RouteSim is one of the fundamental modules, since it is used for simulation, dynamic traffic assignment and evaluation. The main enhancements over the basic cell transmission model are (i) the concept of adjustable size cells that improves the flexibility, accuracy and computational requirements of the model, and (ii) a modeling approach to represent signalized intersections. The basic cell transmission model along with the enhancements yield a model that can simulate integrated freeway/surface street networks with varying degree of detail. RouteSim requires as inputs network geometry and path flow data. The path flow data can be generated from time-dependent or static origin-destination matrices or input directly by the user. RouteSim assigns every generated vehicle to a path, similar to the DYNASMART model introduced by Mahmassani et al (1993). An advantage of RouteSim is that the simulation step and the representational detail are adjustable to the geometry of the network. Lengthy freeway segments that do not need to be modeled in detail are simulated as aggregate long cells and their state is updated infrequently-e.g. a two-mile freeway segment without on- and off-ramps could be modeled as a single cell and be updated every two minutes. On the other hand, close to intersections or problematic points where the evolution of queues, spatio-temporal traffic dynamics and signalization phases need to be captured in detail, the simulation step can be as small as two seconds. Simulation steps of this magnitude allow detail representation of signalized intersections--i.e., signal control strategies, phasing, start-up/lost times and gap acceptance behavior. Note that while detail data (e.g., geometry, timing plans, turning movements) are required for accurately simulating a network with signalized intersections, RouteSim will run even if no such data are provided, by assuming (and prompting the user), geometry, control and traffic data.

Chapter 4
Air Quality Modeling

Bruce Egan and John Purdum

Estimating Ambient Air Quality Impacts of Emissions Scenarios

This chapter of the report describes the use of atmospheric dispersion modeling techniques to estimate the ambient air quality impacts of fine particulate emissions associated with traffic patterns in the South Bronx. Due to data limitations the modeling effort concentrates on the area bounded by the Cross Bronx Expressway in the north, the Deegan Expressway in the west and the Bruckner and Sheridan Expressways in the east. In chapter 6 the same techniques are used to model air quality associated with different routing scenarios of motor vehicles handling waste transfer within the South Bronx.

Atmospheric dispersion models are based upon mathematical simulations of air flow patterns and turbulent mixing rates in the atmosphere. These models require, as input data, estimates of emission rates of pollutants, the locations of the emissions and meteorological data representative of the area being studied. The standard dispersion model recommended by the US EPA for multi source applications is the Industrial Source Complex model (ISC). This model can be run for different types of sources (point, roadway, and area types) and utilizes meteorological data routinely collected at National Weather Service stations at airports. The dispersion model calculates estimates of ambient air concentrations within the study area. This report describes the methodology employed and presents results for the base case scenario, representing present traffic conditions.

The next sections of this report discuss the ISC model, the estimation of vehicular emissions for the study area and the use of meteorological data to estimate ambient air quality impacts, and the predicted concentration patterns.

The Industrial Source Complex Model (ISC)

ISC is based upon the gaussian plume formulation for estimating atmospheric dispersion rates. The parameters used in the model are based upon observational data taken under a variety of meteorological conditions. The specific version of the model we have utilized is the Industrial Source Complex Short Term model, version 3.0, known as ISC3ST, and is routinely run with meteorological data from nearby National Weather Stations or with site-specific meteorological measurements.[3] In this application, urban diffusion coefficients were used to simulate the increased dispersion rates experienced in urban settings. For regulatory applications the model is typically run with sequentially meteorological input data for each hour of a year and for emissions for each hour of the day and for each of the sources of interest. Calculations are made for a set of locations (receptors) which are spaced closely enough to adequately resolve spatial variations in the study area.

[3] The interested reader is referred to www.epa.gov/scram for descriptions of the model and its applications.

Particulate Matter Vehicular Emissions Estimates

Overview

The air quality modeling has the purpose of estimating the implications of alternative transportation planning alternatives on the ambient air quality concentrations of fine particulate matter (PM) (PM_{10} and $PM_{2.5}$). The ISC model requires inputs of combustion generated emission rates for vehicles on each of the traffic links and for each of the proposed scenarios. The model uses this information in conjunction with appropriate meteorological data for the area to predict the patterns of ground level PM concentrations. Emission rate input information is required for each roadway link in units of grams per link for each hour of meteorological data used. Each roadway link is modeled as an area source having a length equal to the length of the link and a width equal to the road. The emission rates for each link depend upon the traffic volumes provided and the mix of vehicle types assumed for the roadway links. This section discusses the different steps and assumptions made to develop these emission rates.

Vehicle emission rates

The emission rates of PM per vehicle depend primarily upon the vehicle engine type, vehicle weight, and the year of manufacture. The US EPA uses an emissions model PART 5, now incorporated into the model MOBIL6, for their estimates of the implications of various vehicular emissions related studies. The table below shows the vehicle type categorization scheme used by EPA.

Number	*Abbreviation*	*Description*
1	LDGV	Light-Duty Gasoline Vehicles (Passenger Cars)
2	LDGT1	Light-Duty Gasoline Trucks 1 (0-6,000 lbs. GVWR, 0-3,750 lbs. LVW)
3	LDGT2	Light-Duty Gasoline Trucks 2 (0-6,000 lbs. GVWR, 3,751-5,750 lbs. LVW)
4	LDGT3	Light-Duty Gasoline Trucks 3 (6,001-8,500 lbs. GVWR, 0-5,750 lbs. ALVW)
5	LDGT4	Light-Duty Gasoline Trucks 4 (6,001-8,500 lbs. GVWR, greater than 5,751 lbs. ALVW)
6	HDGV2b	Class 2b Heavy-Duty Gasoline Vehicles (8,501-10,000 lbs. GVWR)
7	HDGV3	Class 3 Heavy-Duty Gasoline Vehicles (10,001-14,000 lbs. GVWR)
8	HDGV4	Class 4 Heavy-Duty Gasoline Vehicles (14,001-16,000 lbs. GVWR)
9	HDGV5	Class 5 Heavy-Duty Gasoline Vehicles (16,001-19,500 lbs. GVWR)
10	HDGV6	Class 6 Heavy-Duty Gasoline Vehicles (19,501-26,000 lbs. GVWR)
11	HDGV7	Class 7 Heavy-Duty Gasoline Vehicles (26,001-33,000 lbs. GVWR)
12	HDGV8a	Class 8a Heavy-Duty Gasoline Vehicles (33,001-60,000 lbs. GVWR)
13	HDGV8b	Class 8b Heavy-Duty Gasoline Vehicles (>60,000 lbs. GVWR)
14	LDDV	Light-Duty Diesel Vehicles (Passenger Cars)
15	LDDT12	Light-Duty Diesel Trucks 1and 2 (0-6,000 lbs. GVWR)
16	HDDV2b	Class 2b Heavy-Duty Diesel Vehicles (8,501-10,000 lbs. GVWR)
17	HDDV3	Class 3 Heavy-Duty Diesel Vehicles (10,001-14,000 lbs. GVWR)
18	HDDV4	Class 4 Heavy-Duty Diesel Vehicles (14,001-16,000 lbs. GVWR)
19	HDDV5	Class 5 Heavy-Duty Diesel Vehicles (16,001-19,500 lbs. GVWR)
20	HDDV6	Class 6 Heavy-Duty Diesel Vehicles (19,501-26,000 lbs. GVWR)
21	HDDV7	Class 7 Heavy-Duty Diesel Vehicles (26,001-33,000 lbs. GVWR)
22	HDDV8a	Class 8a Heavy-Duty Diesel Vehicles (33,001-60,000 lbs. GVWR)
23	HDDV8b	Class 8b Heavy-Duty Diesel Vehicles (>60,000 lbs. GVWR)
24	MC	Motorcycles (Gasoline)
25	HDGB	Gasoline Buses (School, Transit and Urban)
26	HDDBT	Diesel Transit and Urban Buses
27	HDDBS	Diesel School Buses
28	LDDT34	Light-Duty Diesel Trucks 3 and 4 (6,001-8,500 lbs. GVWR)

EPA has developed tables of unit emission rates (grams per vehicle- mile traveled (VMT)) as a function of the fuel burned (gasoline, diesel or natural gas), for each of the above different vehicle size categories, the year of manufacture of the vehicle and the assumed emissions control equipment employed. We have adopted the EPA tabulations for the purposes of this study. The spreadsheets that are integral to the MOBIL6 model were obtained from EPA and are provided in Appendix 1. Because we do not have detailed information on the mix of the year of manufacture or the control technologies employed by the vehicles in our study, and to not overly complicate the interpretation of our results, we decided to assume that all the vehicles were relatively new and that they would employ appropriate control technologies. Because our study has the purpose of examining the effects of alternative traffic flow scenarios on PM concentrations, we would further recommend that the emission rates per VMT for the alternative scenarios also be the same as used in the base case depicted here.

The table below shows the set of these values that we have selected for our analyses. These correspond to the emission rates for zero accumulated mileage, for vehicles manufactured or to be manufactured in the years 1987 through 2020 for gasoline powered vehicles that employ catalyst and air pump control technologies and for the years 1998 through 2003 for diesel powered vehicles.

Selected Emission rates by Vehicle Classification

Vehicle Classification Number	Abbreviation	PM Emission rate g/VMT
1	LDGV	0.0043
2	LDGT1	0.0043
3	LDGT2	0.0043
4	LDGT3	0.0043
5-13	LDGT4, all HDGVs	0.054
14	LDDV	0.1
15	LDDT12	0.109
16-19	HDDV2b-HDDV5	0.1103
20	HDDV6	0.23745
21	HDDV7	0.17965
22	HDDV8a	0.23745
23	HDDV8b	0.23745
24	MC	NA
25	HDGB	0.054
26	HDDBT	0.237
27	HDDBS	0.187
28	LDDT34	0.1103

The next step is to estimate what percent of the vehicles fall into the above different classifications. Statistical information on the distribution of vehicles into different categories based on data from a survey in New York involving 2,713651 trucks was used to estimate the breakout of these vehicles by type. The statistics allow the break out of the numbers of vehicles by different fuel type categories and also provides a distribution of weight sizes by fuel type. Table 1 provides this breakout.

To match classifications with the EPA MOBILE6 classifications these statistics were further allocated into a more detailed breakout as seen in Table 2 (a). Finally, automobile traffic was assumed to be composed of 99.5% gasoline and 0.005 % diesel powered engines[4]. This is shown in Table 2 (b).

The emission rates for the mix of vehicle types were then coupled to the traffic volumes predicted in by the traffic model presented in the previous chapter as outputs from the transportation analysis. These outputs were provided as predicted truck and automobile traffic volumes (in vehicles per hour) for each of the 2670 roadway links simulated in the traffic model. Volumes were provided for both am and pm peak time periods. The am peak period was defined as the four hours from 6 am to 10 in the morning and the peak pm period was defined as from 3

[4] For Bronx county from: www.epa.gov/otag/hdmodels.htm. Sec5.pdf : Table V-1 .1996 County-level annual and Average Daily VMT by vehicle Type.

pm to 7 pm (15:00 through 19:00) in the evening. The traffic volumes were divided into two categories: automobiles and trucks. For each roadway link, the product of the vehicles per hour times the roadway link length gives the VMT for that road and for that hour. We multiply the VMT for cars and trucks separately by the appropriate emission factors and add them to estimate the total emissions per hour for the roadway link.

Table 3, for am traffic, shows a sample of the combined information on the road way locations and dimensions, EPA emission rates per vehicle classification type, the fraction of vehicles in any specific classification, and the volume of truck or car traffic for the first ten links. For ease of viewing, the values for only the first two vehicle classifications are shown. However, the summaries of statistics for all the links and vehicle classes are presented. Note that at the top of the page, the maximum, minimum and average values of the parameters are presented in a column among all the roadway links.

Summaries of the emissions statistics are shown in Table 4. On the basis of Table 4, the following observations about the traffic data and its effect on PM emission rates were made. First, the total emissions from cars are much larger than those from the trucks. Secondly, because most of the cars are assumed to be gasoline powered, the emissions are primarily attributed to gasoline engines. Thirdly, morning PM emissions from cars are greater than afternoon emissions. The opposite is true for trucks.

The final step to develop inputs to the dispersion model is to calculate emission rates for every hour of the day. To estimate traffic volumes for all the other hours of the day, the traffic model provided the data. Table 5 summarizes the counts by hour and the Average Daily Traffic (ADT) provided. To calculate the traffic flow rate for any hour of the day from the traffic model predictions of am and pm peak hour volumes, a ratio of the hourly rate to the average of the rates for the four peak traffic hours was calculated. These fractions range from .05 to over 1.0. They were then multiplied by the predicted am or peak volumes to calculate a rate for any hour of the day in the am or pm.

Meteorological Input Data

Wind speed, wind direction and estimates of the turbulence rates in the atmosphere are required as input data to dispersion models to simulate the transport and mixing of contaminants emitted into the atmosphere. For the ISC model, this information is typically obtained from measurements made at nearby NWS airports, provided that the data from that location is deemed representative for the particular study purposes. Turbulence rates are determined by estimating the atmospheric stability class for a particular hour. In this study, meteorological data from LaGuardia airport for the 5-year period 1991 through 1995 was used. Upper level wind and temperature data was obtained from the NWS site at Albany, NY for the same time period. The data is used to define, for each hour of the study period, the following parameters: wind speed and wind direction, atmospheric stability classification, wind speed profile and mixing depth. The ISC3ST model uses the hour-by- hour wind data to compute both short term (e.g. 24 hour averages) and also long term (e.g. annual averages) at each receptor location.
Wind Roses provide a visual summary of the frequency of occurrence of winds and associated wind speeds of winds from different directions. Figures 1 and 2 show the wind rose patterns for

the years 1991 and the 5 year period 1991-1995 at LaGuardia Airport. For 1991, the patterns show predominant wind directions from the northeast, the northwest and the southwest. For all five years, the most frequently occurring winds come from the northeast, the northwest or the south.

Computational Source and Receptor Arrays

Roadways sources.

Roadways and highways are treated as area type sources each having a length and a width. The lengths and widths of each link provided by the traffic model were used for these purposes. The ISC model breaks each area sources into a series of smaller point sources for computational purposes. Figure 3 shows all the roadway links as input into ISC. For purposes of visualizing the source configurations, an enlargement of the northwestern-most section of the source array is shown in Figure 4.

Receptor Array

For each hour of the study period, ISC uses the meteorological input data in combination with the emissions rate estimates for that time period to estimate the ambient air concentration at different preset receptor locations within the study area. We used a computational grid with receptors spaced every 250 meters in a Universal Transverse Mercator (UTM) coordinate system along the north-south and east-west directions. A total of 667 receptors were used.

Predicted Concentrations

Annual average concentrations were predicted for each of the years of meteorological data and then averaged to provide the pattern for the 5-year period. Figure 5 shows the resulting isopleths of concentrations. The highest concentrations are seen to occur in the areas of high density of roadway links and high traffic volumes near the major expressways. The maximum predicted PM_{10} concentration is 0.103 micrograms per cubic meter ($\mu g/m^3$). In calculating emission rates of particulate matter from motor vehicles, EPA utilizes a factor of 0.89 to multiply PM_{10} values by to estimate $PM_{2.0}$ emissions for gasoline engines with catalytic converters, and a factor of 0.92 to multiply PM_{10} values by to estimate $PM_{2.5}$ emissions for diesel engines. Using a factor of 0.9 the estimate of the maximum annual average $PM_{2.5}$ concentration would be 0.09 $\mu g/m^3$.

Figure 6 shows the maximum daily 24- hour average PM_{10} concentrations predicted for the 5 year time period. The peak 24-hour averages are seen to be nearly a factor of five larger than the annual average values.

Discussion

The results shown are for the base case, the situation using our understanding of the present traffic volumes and available vehicle mix data. The modeling considers only the emission associated with vehicular traffic in the South Bronx area. Future work will involve looking at the differences in the air quality impacts associated with proposed changes to traffic volumes and routing for alternative future scenarios involving waste transfer operations. Because of the study's focus on the differences of the air quality impacts of different traffic pattern scenarios, no other sources of PM_{10} in the study area or sources in the surrounding area have been included in the emissions inventory. In reality, PM_{10} concentrations in any urban area consist of a large component associated with transport by the wind from surrounding areas. Had external sources been included, the overall predicted concentrations would be much higher but the effects of differences in traffic patterns in our future analyses would be masked by the contributions from the other sources.

The predicted concentrations are also based on vehicular emission rates data projected by EPA for recent and the next several future years. This is probably an optimistic assumption regarding actual emission rates. Present measurements of ambient air quality in the area reflect the fact that older vehicles without modern control technologies emit more pollution than newer vehicles. As older vehicles are phased out, overall emission rates should be lower and ambient air PM levels should be correspondingly lower.

Sensitivity of model results to input data changes

Predictions from dispersion models depend to varying degrees on the accuracy of the input data. We have not performed a full analysis of the sensitivity of the predicted results to changes in all input parameters. However, we can quantify the sensitivity of the maximum predicted concentrations results to the choice of different years of meteorological data. Table 6 shows the annual averages and the highest and second highest 24-hour averages for each of the years 1991-1995 and for all 5 years. It may be seen that the year-to-year variability is relatively small.

Table 4 provides us with some further insight regarding the sensitivity of the predicted concentrations to changes in the motor vehicle mix assumed. Because gasoline cars constitute the largest single source category for PM emissions with the present traffic patterns, we should expect that these emissions would dominate over emissions from other vehicle types in the future scenarios. However, we note that on a per vehicle basis, trucks contribute over four times as much PM to the atmosphere.

2. Comparisons of the ambient air quality levels for nitrogen oxide emissions - all roadway links

The previous sections of the chapter provided modeling results for PM_{10} and $PM_{2.5}$ emissions associated with all the vehicular traffic modeled in the South Bronx. This section presents the modeling results for Nitrogen Oxides (NO_x) emissions for the same traffic flow assumptions.

The NO_x emission rates that we used for each of the EPA vehicle classifications are from MOBILE6 for late model vehicles and are provided in Table 7. Table 8 summarizes the overall emissions statistics generated.

On the basis of Table 8, the following observations about the traffic data and its effect on NO_x emission rates were made. First, on a per vehicle basis, NO_x emissions from trucks are about seven times those from cars. Second, for the entire study area, the total emissions from cars are about a factor of three on average larger than the truck emissions. This ratio of car emissions to truck emissions was about 4.2 for PM_{10}. Third, because most of the cars are assumed to be gasoline powered, the NO_x emissions are primarily attributed to gasoline engines, as was also found with PM_{10}. Fourth, the morning NO_x emissions from cars are greater than afternoon emissions. For trucks, the afternoon NO_x emissions are greater than those during the morning.

Figure 7 shows the pattern of annual average concentrations developed for the modeling year of 1993. 1993 was the year that produced the largest maximum annual average concentrations for PM_{10} in our prior modeling.

Summary and Conclusions

The work performed to date suggests the following findings from the base case study:

(1) Traffic volume estimates from the traffic model were used with US EPA emission factors to generate PM emission rates for base case conditions from roadway links in the South Bronx. The model is capable of showing detailed variations in the ground level patterns of ambient air concentrations.

(2) Traffic volume and VMT of trucks are about 5% of the total.

(3) PM emissions from trucks are about 18% of the total.

(4) PM emissions from diesel engines are 4 to 20 times greater than those from gasoline engines for similar sized vehicles per VMT.

(5) The EPA ISC3ST dispersion model was set up and run for the base case emissions scenario and also for the scenarios described in chapter 6.

(6) Predicted concentrations are highest along the main traffic arteries. Maximum annual average concentrations are consistently in the range of 0.1 $\mu g/m^3$.

(7) Maximum 24-hour average concentrations are in similar areas and range from 0.3 to 0.5 $\mu g/m^3$.

(8) Wind data from LaGuardia show consistent year-to-year patterns and is reasonable for use with predicting the relative impacts of alternative future vehicular traffic scenarios.

(9) NO_x emissions from trucks are about seven times those from cars. Second, for the entire study area, the total emissions from cars are about a factor of three on average larger than the truck emissions.

(10) This ratio of car emissions to truck emissions is lower than that found for PM which suggests that diesel trucks are a larger contributing source to NO_x concentrations than to PM concentrations relative to gasoline powered vehicles.

(11) Since most of the cars are assumed to be gasoline powered, the NO_x emissions are primarily attributed to gasoline engines, as was also found with PM_{10}.

(12) The morning NO_x emissions from cars are greater than afternoon emissions. For trucks, the afternoon NO_x emissions are greater than those during the morning.

Tables

Table 1. NEW YORK STATE NUMBER OF VEHICLES BY EPA PART 5 CLASSIFICATIONS

EPA PART 5 Vehicle Classification Name	Gross Vehicle Weight (LBS)	Gasoline	Diesel	Liq Gas & Other	Total	Light	Medium	Light-Heavy	Heavy-heavy
LDGV (Light-duty gasoline vehicle)					0	0			
LDGT1 (Light-duty gasoline truck,I)	< 6000	1752139			1752139	1752139			
LDGT2 (Light-duty gasoline truck,II)	6001-8500	451819			451819	451819			
HDGV (Heavy-duty gasoline truck,I)	> 8500	329078			329078	309533	19545		
MC (Motor-cycle)									
LDDV (Light-duty diesel vehicle)	< 6000		4298		4298	4298			
LDDT (Light-duty diesel truck)	6001-8500		34130		34130	34130			
2BHDDV (Class 2B heavy-duty diesel vehicle)	8501-10000		20478		20478		20478		
LHDDV (Light heavy-duty diesel vehicle)	10001-19500		9115		9115		9115		
MHDDV (Medium heavy-duty diesel vehicle)	19501-33000		48502		48502		7727	26986	13789
HHDDV (Heavy heavy-duty diesel vehicle)	33000+		53312		53312				53312
BUSES (Buses)					0				
Lig gas, other, non reported -light				9928	9928	9928			
Lig gas, other, non reported -heavy				854	854				854
TOTAL NUMBER OF VEHICLES		2533036	169835	10782	2713653	2561847	56865	26986	67955
Percent in Column		93.34%	6.26%	0.40%	100.00%	94.41%	2.10%	0.99%	2.50%

Diesel and Other				Classification			14	15	28	16	17	18	19	20	21	22	
							light	light	light	light	medium	medium	medium	light heavy	heavy-heav	heavy-heavy	
				Weight Range lower limit (lbs)			<6000	<6000	8500	10000	14000	16000	19500	26000	33000	>33001	
Weight Range (lbs)		diesel	Tot Gasoline	Liq gas	Other/not reported	Total reported	LDDV	LDDT12	LDDT34	HDDV2b	HDDV3	HDDV4	HDDV5	HDDV6	HDDV7	HDDV8a-b	Liq GAS
0	6000	4298	1752139	4298		1760735		4298									4298
6001	10000	54604	722911	362	4544	777877			34122.38	20481.62							362
10001	14000	4047	17113	362	362	21522					4047						362
14001	16000	3620	3620			7240						3620					
16001	19500	1448	4771			6219							1448				
19501	26000	41929	28245	724		70898								41929			724
26001	33000	6573	1506			8079									6573		
33001	+	53312	2731		130	56043										53312	
total		169831	2533036	5746	5036	2708613		4298	34122.38	20481.62	4047	3620	1448	41929	6573	53312	5746
Fraction of traffic volume for trucks								**0.001587**	**0.012598**	**0.007562**	**0.001494**	**0.001336**	**0.000535**	**0.01548**	**0.002427**	**0.019682**	**0.002121**
g/VMT							0.1	0.109	0.109	0.110316	0.110316	0.110316	0.110316	0.179652	0.179652	0.237452	0.00043

Table 2 (a) Refined Break out of Truck Traffic Survey by MOBIL6 Classifications																
Gasoline				Classification			1	2,3	4,5	6	7	8	9	10	11	12,13
							light	light	light	light	medium	medium	medium	light heavy	heavy-heav	heavy-heav
				Weight Range lower limit (lbs)			<6000	<6000	8500	10000	14000	16000	19500	26000	33000	>33001
Weight Range (lbs)		diesel	Tot Gasoline	Liq gas	Other/not reported	Total reported	LDGV	LDGT1-2	LDGT3-4	HDGV2b	HDGV3	HDGV4	HDGV5	HDGV6	HDGV7	HDGV8a-b
0	6000	4298	1752139	4298		1760735		1752139								
6001	10000	54604	722911	362	4544	777877			451751.6	271159.4						
10001	14000	4047	17113	362	362	21522					17113					
14001	16000	3620	3620			7240						3620				
16001	19500	1448	4771			6219							4771			
19501	26000	41929	28245	724		70898								28245		
26001	33000	6573	1506			8079									1506	
33001	+	53312	2731		130	56043										2731
total		169831	2533036	5746	5036	2708613		1752139	451751.6	271159.4	17113	3620	4771	28245	1506	2731
Fraction of traffic volume for trucks								**0.646877**	**0.166783**	**0.10011**	**0.006318**	**0.001336**	**0.001761**	**0.010428**	**0.000556**	**0.001008**
g/VMT							0.0043	0.0043	0.0043	0.054	0.054	0.054	0.054	0.054	0.054	0.054

Table 3. Sample calculation of emissions per roadway link.

Link ID	Link Name	x1 (m)	y1 (m)	x2 (m)	y2 (m)	Length (Meters)	Length (Miles)	Width (feet)	car volume (veh/hour)	truck volume (veh/hour)	total volume (veh/hour)	car speed (mph)	truck speed (mph)	car volume (VMT/hour)	truck volume (VMT/hour)
		UTM Zone 18: Longitudes 78W to 72W, WGS 1984													
	MAX Value-all links	594786.1	4523050	594786.1	4523048		0.47	72	2260.667	180.3333	2318	147.4344	147.2728	593.28	50.666667
	MIN Value -all links	589826.4	4516846	589816.8	4516914		0	12	0	0	0	0	0	0	0
	AVERAGE Value-all link	591733.1	4519886	591734.2	4519886		0.087582	19.72744	193.152	5.177337	198.3293	11.09514	10.41662	18.547498	0.5451133
Total all links							233.9304		515909	13828.67	529737.7	29635.13	27822.79	49540.367	1455.9975
1	Centroid Connector	591222.5	4517373	591063.3	4517515	213.3992	0.12	12	227.3333	1.666667	229	5.351643	44.08167	27.28	0.2
2	Centroid Connector	591222.5	4517373	591370.5	4517349	149.8428	0.12	12	89.66667	0.333333	90	42.88117	36.00004	10.76	0.04
3	Centroid Connector	590932.6	4517923	590716.5	4517982	224.1197	0.13	12	58.66667	1.333333	60	0.335968	0.736718	7.6266667	0.1733333
4	Centroid Connector	590932.6	4517923	591213.1	4517795	308.3982	0.19	12	61.33333	0.666667	62	68.03026	65.14289	11.653333	0.1266667
5	Centroid Connector	590932.6	4517923	591067.9	4517874	143.8337	0.09	12	0	0	0	0	0	0	0
6	Centroid Connector	591332.8	4517695	591213.1	4517795	155.7431	0.1	12	45.66667	0.666667	46.33333	9.175787	35.99997	4.5666667	0.0666667
7	Centroid Connector	591332.8	4517695	591506.9	4517736	178.8181	0.11	12	9.666667	0	9.666667	34.69488	0	1.0633333	0
8	Centroid Connector	591482.6	4517897	591681.2	4517734	257.2438	0.16	12	35.33333	0.333333	35.66667	16.10132	57.59995	5.6533333	0.0533333
9	Centroid Connector	591482.6	4517897	591308.7	4517980	192.7278	0.12	12	16	1	17	1.030976	43.20002	1.92	0.12
10	Centroid Connector	591989	4517459	591814.7	4517560	201.7701	0.13	12	1190.667	4	1194.667	0.302017	0.484764	154.78667	0.52
11	Centroid Connector	591989	4517459	592168.7	4517636	252.1419	0.16	12	0	0	0	0	0	0	0
12	Centroid Connector	590540.6	4518696	590488.1	4518444	257.1988	0.16	12	28.66667	6	34.66667	1.171872	1.845172	4.5866667	0.96
13	Centroid Connector	590471.6	4519892	590653	4519716	252.9492	0.16	12	11.33333	1.333333	12.66667	59.70732	62.27014	1.8133333	0.2133333
14	Centroid Connector	590471.6	4519892	590584.2	4519912	114.3853	0.07	12	14.66667	0.333333	15	22.95646	36.00008	1.0266667	0.0233333
15	Centroid Connector	590471.6	4519892	590409.2	4519676	224.3612	0.14	12	25.33333	1.333333	26.66667	51.14008	51.69247	3.5466667	0.1866667
16	Centroid Connector	591384.1	4520084	591239.6	4520136	153.3416	0.1	12	496.3333	0	496.3333	0.051099	0	49.633333	0
17	Centroid Connector	591384.1	4520084	591472.4	4520306	238.6213	0.15	12	531.6667	1	532.6667	0.082959	0.128023	79.75	0.15
18	Centroid Connector	590836.6	4520399	590761.5	4520464	99.41072	0.06	12	13.66667	1	14.66667	4.241379	19.63636	0.82	0.06
19	Centroid Connector	590836.6	4520399	590891.2	4520581	190.3348	0.12	12	16.66667	0.666667	17.33333	42.27019	45.47367	2	0.08
20	Centroid Connector	590708	4521662	590813	4521757	141.5238	0.09	12	8	0.333333	8.333333	32.94913	27.00003	0.72	0.03
21	Centroid Connector	590708	4521662	590573.6	4521572	161.5297	0.1	12	45	0.333333	45.33333	34.4437	32.72723	4.5	0.0333333
22	Centroid Connector	591544.8	4520492	591472.4	4520306	199.0641	0.12	12	133	1	134	0.304828	56.34782	15.96	0.12
23	Centroid Connector	591544.8	4520492	591587.6	4520580	98.15399	0.06	12	15.66667	2.333333	18	21.78548	22.90913	0.94	0.14
24	Centroid Connector	591142.5	4521082	591086.9	4521004	95.85738	0.06	12	130.6667	1.333333	132	0.397211	23.3513	7.84	0.08
25	Centroid Connector	591010.3	4521460	591147.5	4521446	137.9533	0.09	12	993	1.666667	994.6667	0.154058	0.281789	89.37	0.15
26	Centroid Connector	591293.9	4521376	591147.5	4521446	162.0925	0.1	12	73	1.666667	74.66667	29.73972	27.69224	7.3	0.1666667
27	Centroid Connector	591293.9	4521376	591430.8	4521300	156.8039	0.1	12	363.3333	0.333333	363.6667	0.286118	0.352596	36.333333	0.0333333
28	Centroid Connector	591729	4518394	591878.9	4518602	256.4341	0.16	12	18.33333	0.666667	19	7.957824	11.87631	2.9333333	0.1066667
29	Centroid Connector	591904.3	4518788	591878.9	4518602	187.7938	0.12	12	50.66667	1	51.66667	0.395078	1.741933	6.08	0.12
30	Centroid Connector	591904.3	4518788	591917.6	4518885	97.54634	0.06	12	33.66667	0.333333	34	5.595258	27.00003	2.02	0.02
31	Centroid Connector	591992.3	4518292	592121.2	4518218	148.9818	0.09	12	0	0	0	0	0	0	0
32	Centroid Connector	591992.3	4518292	592069.1	4518551	269.9248	0.17	12	11.33333	0.666667	12	4.78564	6.408372	1.9266667	0.1133333
33	Centroid Connector	591992.3	4518292	591917.9	4518081	224.0311	0.14	12	3.666667	0.333333	4	2.75	72.00016	0.5133333	0.0466667
34	Centroid Connector	592290.3	4518223	592442	4518401	234.2973	0.15	12	69	1.333333	70.33333	53.68879	54.00005	10.35	0.2
35	Centroid Connector	592290.3	4518223	592231.5	4518336	128.2254	0.08	12	77.66667	1.666667	79.33333	18.12648	28.79998	6.2133333	0.1333333
36	Centroid Connector	592466	4519334	592423.4	4519193	146.6171	0.09	12	13	1.333333	14.33333	15.91433	29.4546	1.17	0.12
37	Centroid Connector	592466	4519334	592359	4519337	107.0483	0.07	12	3.666667	0	3.666667	22.35487	0	0.2566667	0
38	Centroid Connector	592386.2	4519789	592497.7	4519758	115.64	0.07	12	47.66667	1.333333	49	14.44907	25.84623	3.3366667	0.0933333
39	Centroid Connector	592957.4	4519291	593069.5	4519461	203.3871	0.13	12	41.66667	4.333333	46	3.398003	1.578215	5.4166667	0.5633333

Table 4. Statistics of Peak Hour Traffic Volumes and Particulate Emissions

	Units	AM Cars	AM Trucks	Total	PM Cars	PM Trucks	Total	AM+PM Cars	AM+PM Trucks	AM+PM Total
Total length of roadway links in study area	**Miles**						234			
Traffic Volume-all links	**Vehicles per hour**	515908	13829	529737	378652	26921	405573	894560	40750	935310
Percent Volume		97.39%	2.61%	100.00%	93.36%	6.64%	100.00%	95.64%	4.36%	100.00%
Vehicle miles traveled per hour	**VMT/HR**	49540	1456	50996	38434	2918	41352	87974	4374	92348
Percent of Vehicle miles traveled per hour		97.14%	2.86%	100.00%	92.94%	7.06%	100.00%	95.26%	4.74%	100.00%
Particulate Emissions	**Grams/ hour**	236.7	30.2	266.9	183.7	60.4	244.1	420.4	90.6	511
Percent Particulate Emissions		88.68%	11.32%	100.00%	75.26%	24.74%	100.00%	82.27%	17.73%	100.00%
Average emission rate per VMT	**Grams/VMT**	0.004778	0.020742	0.005234	0.00478	0.020699	0.005903			
Average emission rate per Vehicle	**Grams/hr/Vehicle**	0.000459	0.002184	0.000504	0.000485	0.002244	0.000602			
Particulate Emissions-Gasoline vehicles	**Grams/ hour**	212	15	227	157	37	194	369	51.8	420.8
Percent Particulate Emissions-Gasoline vehicles		93.39%	6.61%	100.00%	81.01%	18.99%	100.00%	87.69%	12.31%	100.00%
Particulate Emissions-Diesel vehicles	**Grams/ hour**	25	15	40	27	24	50	0.876901	0.123099	1
Percent Particulate Emissions-Diesel vehicles		61.75%	38.25%	100.00%	53.08%	46.92%	100.00%	87.69%	12.31%	100.00%

Table 5. **Summary of traffic volume statistics (Vehicles per hour) by hour of day**

AM HOURS	Hour beginning	Midnight	1	2	3	4	5	6	7	8	9	10	11
	Vehicles per period												
Total	850418	47491	31967	24733	23156	29227	50272	95252	120082	121611	109721	99319	97587
4 peak hrs	446666												
peak hour avg	111666.5												
Fraction of ADT	0.4180	0.0233	0.0157	0.0122	0.0114	0.0144	0.0247	0.0468	0.0590	0.0598	0.0539	0.0488	0.0480
Fraction of AM peak hour average		0.4253	0.2863	0.2215	0.2074	0.2617	0.4502	0.8530	1.0754	1.0891	0.9826	0.8894	0.8739

PM HOURS	Hour beginning	Noon	13	14	15	16	17	18	19	20	21	22	23
Total	1184177	98299	100457	108452	118916	120762	119870	114812	103786	88561	78741	71232	60289
4 peak hrs	474360												
peak hour avg	118590												
Fraction of ADT	0.5820	0.0483	0.0494	0.0533	0.0584	0.0594	0.0589	0.0564	0.0510	0.0435	0.0387	0.0350	0.0296
Fraction of PM peak hour average		0.8289	0.8471	0.9145	1.0027	1.0183	1.0108	0.9681	0.8752	0.7468	0.6640	0.6007	0.5084

Table 6. Maximum Particulate Concentrations (ug/m3) in the study area.	Average	Maximum	Year 1991	Year 1992	Year 1993	Year 1994	Year 1995
Annual Average	0.103	0.105	0.103	0.105	0.105	0.102	0.102
24-Hour PM Concentrations (ug/m3); Max Values		0.495	0.495	0.416	0.417	0.382	0.309
24-Hour PM Concentrations (ug/m3); 2nd High Values		0.397	0.363	0.341	0.397	0.306	0.290

Table 7. Selected NO_2 Emission Rates by Vehicle Classification

Vehicle Classification Number	Vehicle Class Abbreviation	N0x Emission rate g/VMT
1	LDGV	0.178
2	LDGT1	0.235
3	LDGT2	0.235
4	LDGT3	0.374
5	LDGT4	0.374
6-13	all HDGVs	2.82
14	LDDV	0.871
15	LDDT12	1.031
16	HDDV2b	6.47
17-19	HDDV3-HDDV5	11.07
20	HDDV6	14.06
21	HDDV7	14.06
22	HDDV8a	14.06
23	HDDV8b	14.06
24	MC	NA
25	HDGB	NA
26	HDDBT	NA
27	HDDBS	NA
28	LDDT34	1.03

Table 8. Statistics of Peak Hour Traffic Volumes and NO_x Emissions

		AM	AM	AM	PM	PM	PM
	Units	Cars	Trucks	Total	Cars	Trucks	Total
Total length of roadway links in study area	Miles	234	234	234	234	234	234
Traffic Volume-all links	Vehicles per hour	515908	13829	529737	378652	26921	405573
Maxmum traffic volume on any link	Vehicles per hour	593	51	608	599	114	657
Vehicle miles traveled per hour	VMT/HR	49540	1456	50996	38434	2918	41352
Spacing of vehicles	veh/mile	10.41	9.50	10.39	9.85	9.23	9.81
Spacing of vehicles	feet	507	556	508	536	572	538
NOx Emissions	Grams/ hour	8990	1728	10718	6974	3463	10437
Fraction of Total		0.84	0.16	1.00	0.67	0.33	1.00
Average emission rate per VMT	Grams/VMT	0.181	1.187	0.210	0.181	1.187	0.252
Average emission rate per Vehicle	Grams/hr/Vehicle	0.017	0.125	0.020	0.018	0.129	0.026
Average distance traveled per Vehicle	Miles per vehicle/hr	0.096	0.105	0.096	0.102	0.108	0.102
NOx Emissions-Gasoline vehicles	Grams/ hour	8774	812	9586	6807	1626	8433
NOx Emissions-Diesel vehicles	Grams/ hour	216	917	1133	167	1837	2004

Figures

Figure 1. 1991 Wind Rose for LaGuardia Airport

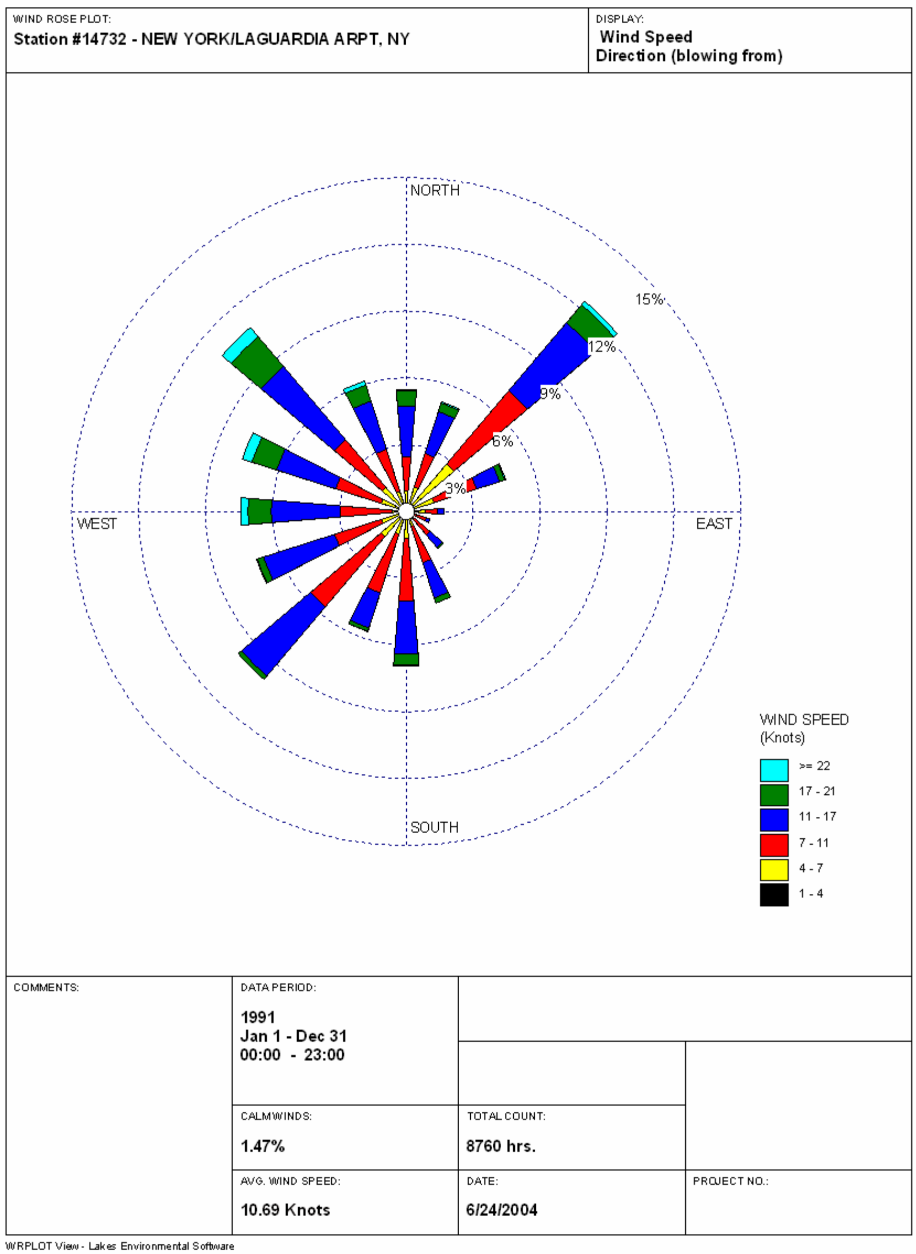


Figure 2. Wind Rose for the Five-Year Period (1991 – 1995) LaGuardia Airport

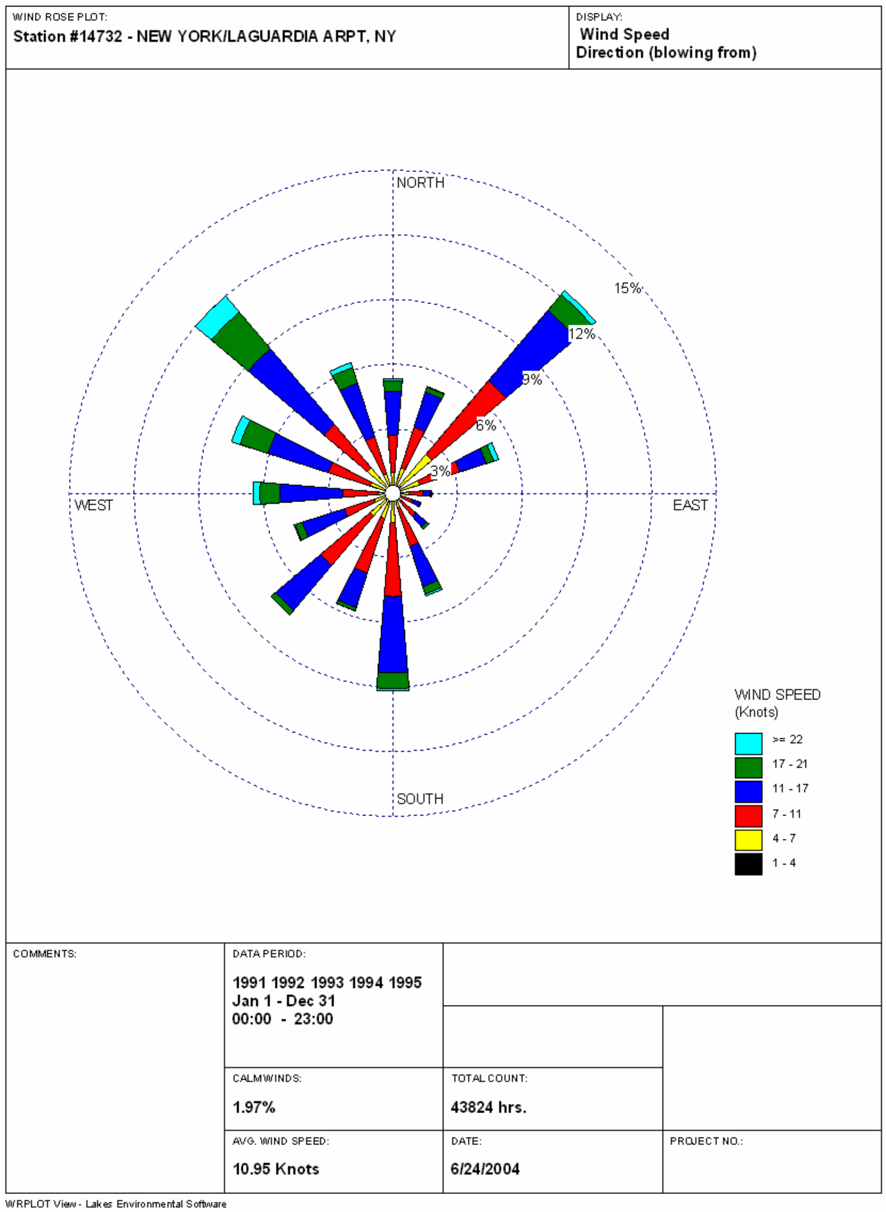


Figure 3. Roadway Links

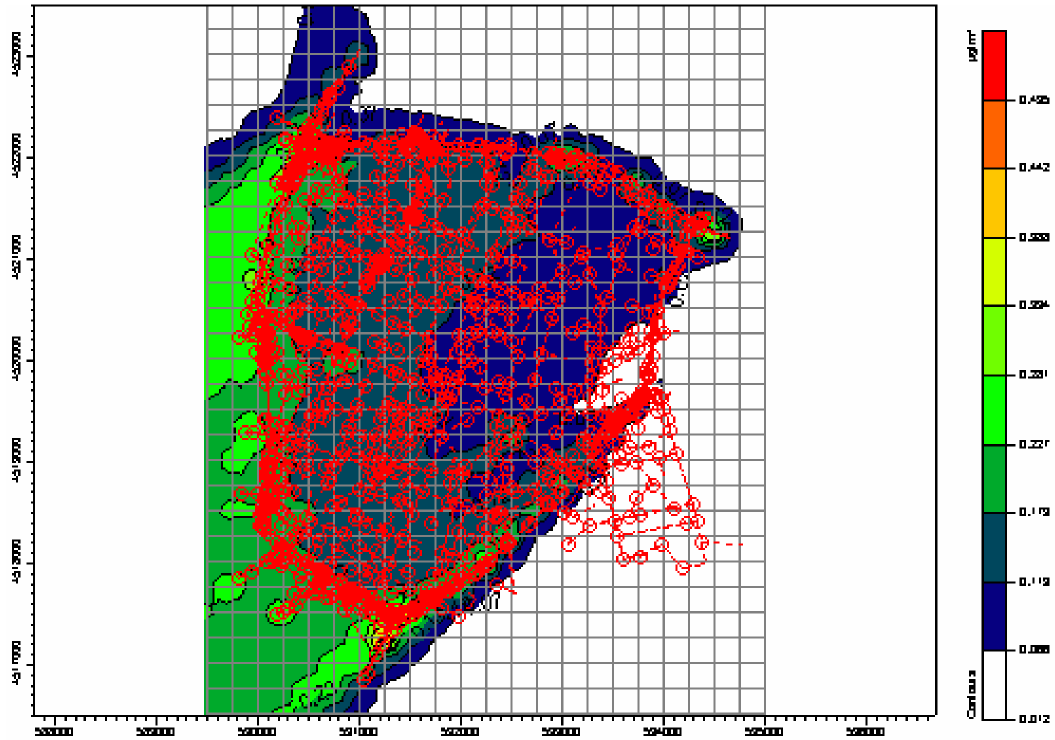


Figure 4. Roadway Links of Northwest Segment

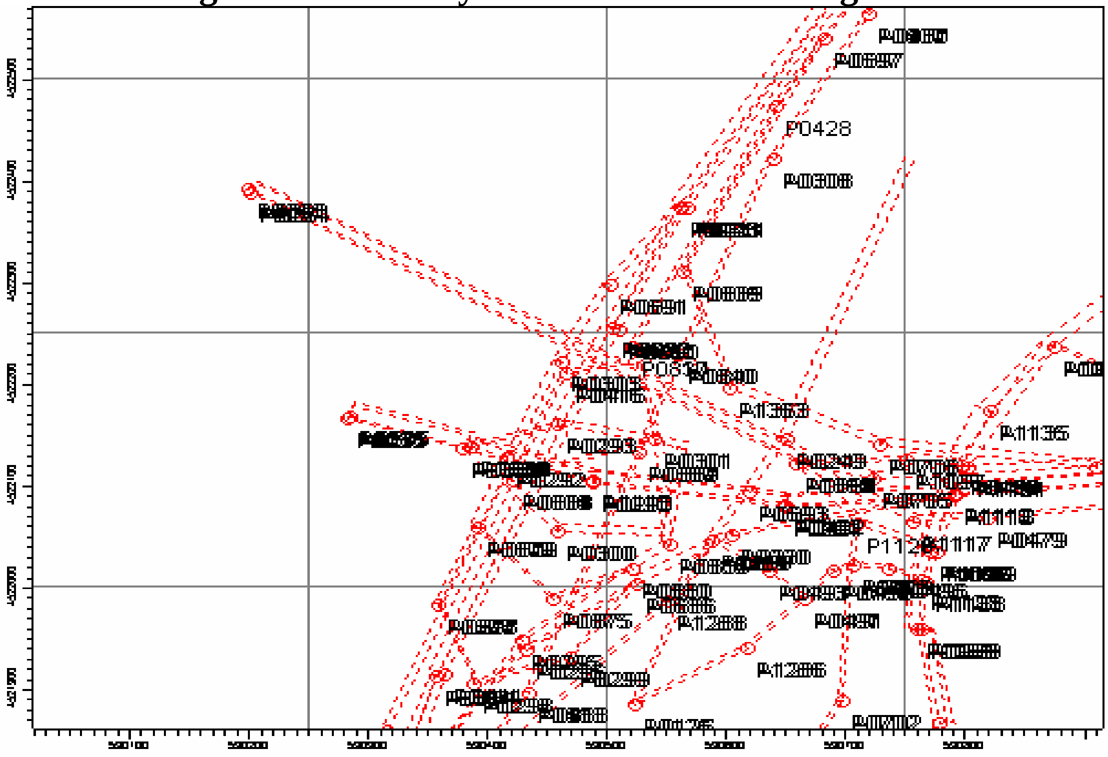


Figure 5. Annual Average Concentrations in the Study Area for the Five-Year Period 1991 - 1995

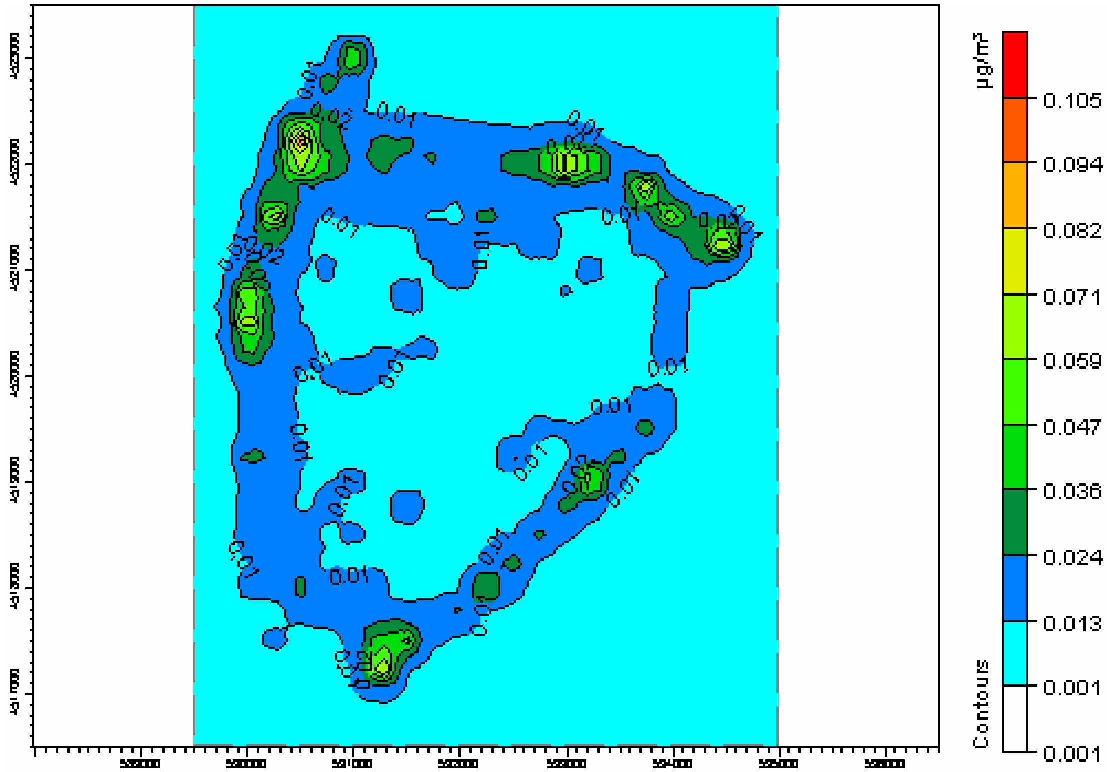


Figure 6. Maximum 24-Hour Average PM_{10} Concentrations for Five year Period (1991 – 1995)

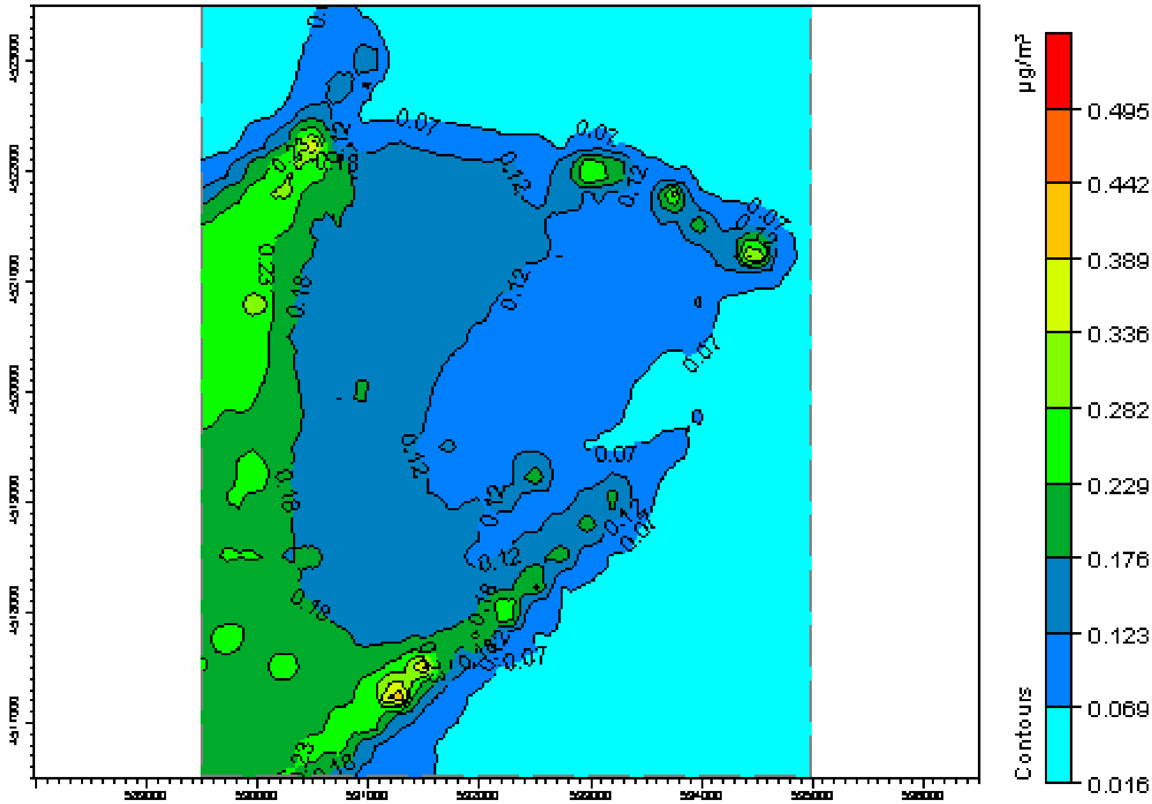
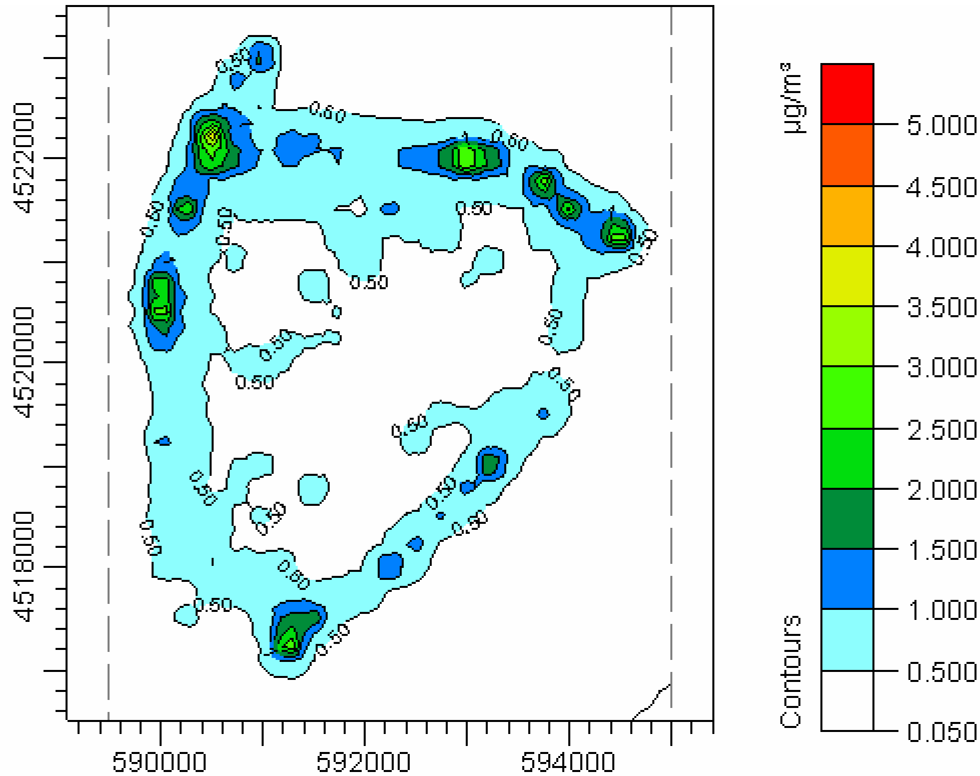


Figure 7. Nitrogen oxides. All Traffic and Links. Variable emissions. 1993 Annual average concentrations



Chapter 5

Analysis of South Bronx Garbage Flow Scenarios

José Holguín-Veras, Ellen Thorson, Athanasios Ziliaskopoulos, Kyriacos Mouskos, David Sackey, Arun Kochar and Curtis Barret

The two chapters in this section of the report describe three scenario analyses in the area of traffic and air quality modeling. These analyses were conducted to examine how sensitive the results were to removing some waste transfer stations or relocating them. According to current policy, waste transfer stations can be permitted in areas that are zoned as M3. These are heavy industrial land use zones. However, waste transfer stations may also be located in M1 and M2 areas that are for lighter industrial activities provided they take extra measures to reduce environmental impacts. M1 areas are sometimes a buffer between residential areas and heavier industrial areas. The scenario analyses in these two chapters examine the impact of removing or relocating three waste transfer stations that are currently located in M1 or M2 zoned areas to examine the impact that would have on traffic and air quality. According to the *Commercial Waste Management Study* published in March 2004 by the Department of Sanitation, the following waste transfer stations are in M1 and M2 zones:

Company	Address	Type of Station	Zone	Permitted Throughput	Community Board
Metropolitan Transfer Station	287 Halleck St. 10474	Putrescible	M-1	825	BX2
USA Waste Services of NYC, Waste Management Inc.	98 Lincoln Ave. 10455	Putrescible	M-2	3,000	BX1
Bronx County Recycling, LLC	475 Exterior St. 10451	Fill Material	M-2	6,000	BX1

Transportation Scenario Analyses

Three scenarios were analyzed. In the first scenario (Scenario 1a), the following three waste transfer stations were closed and the flows to these stations were diverted to other transfer stations in proportion to their market share – U.S.A. Waste Services/Waste Management, Bronx County Recycling, and Metropolitan Transfer Station. In the second scenario (Scenario 1b), these three waste transfer stations were closed and their flows were removed. In the third scenario (Scenario 2), the three waste stations were relocated. The locations of the transfer stations for the base case and the scenarios are shown in Figures 14 – 16. The daily traffic flows for the base case and scenarios are shown in Figures 17 - 20.

Figure 14. South Bronx waste transfer stations – base case.

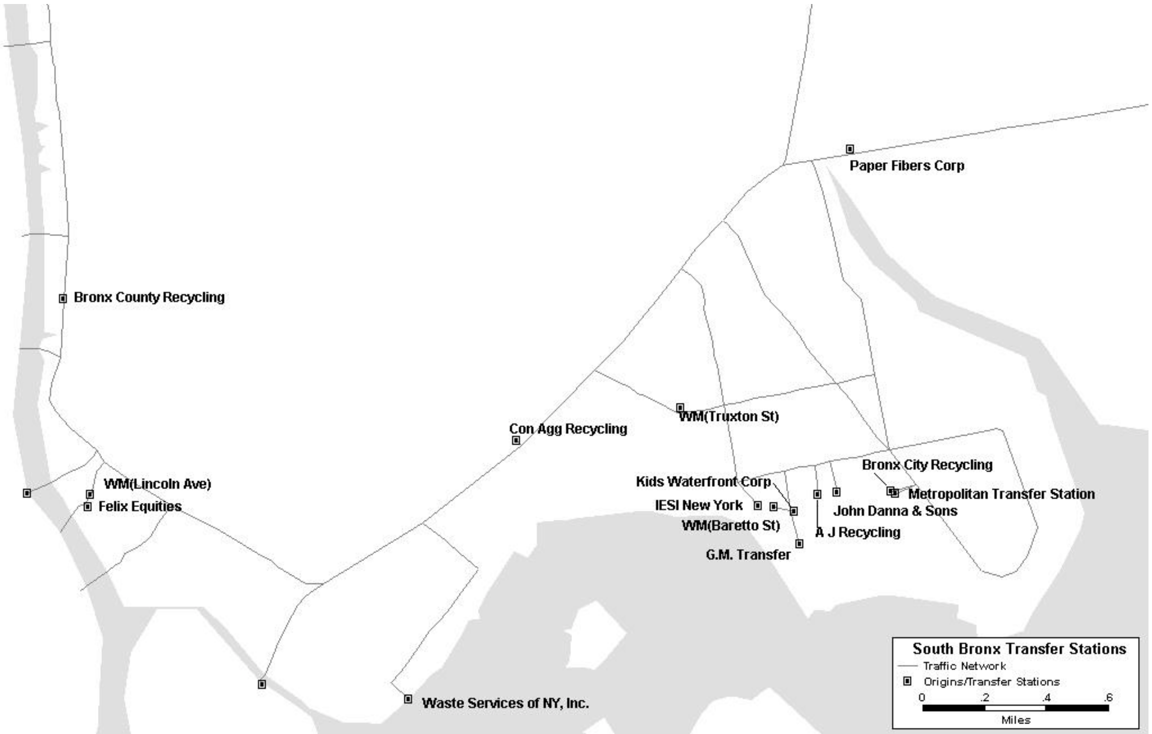


Figure 15. South Bronx waste transfer stations – scenarios 1a and 1b.

Figure 16. South Bronx waste transfer stations – scenario 2.

Figure 17. South Bronx daily garbage traffic - base case.

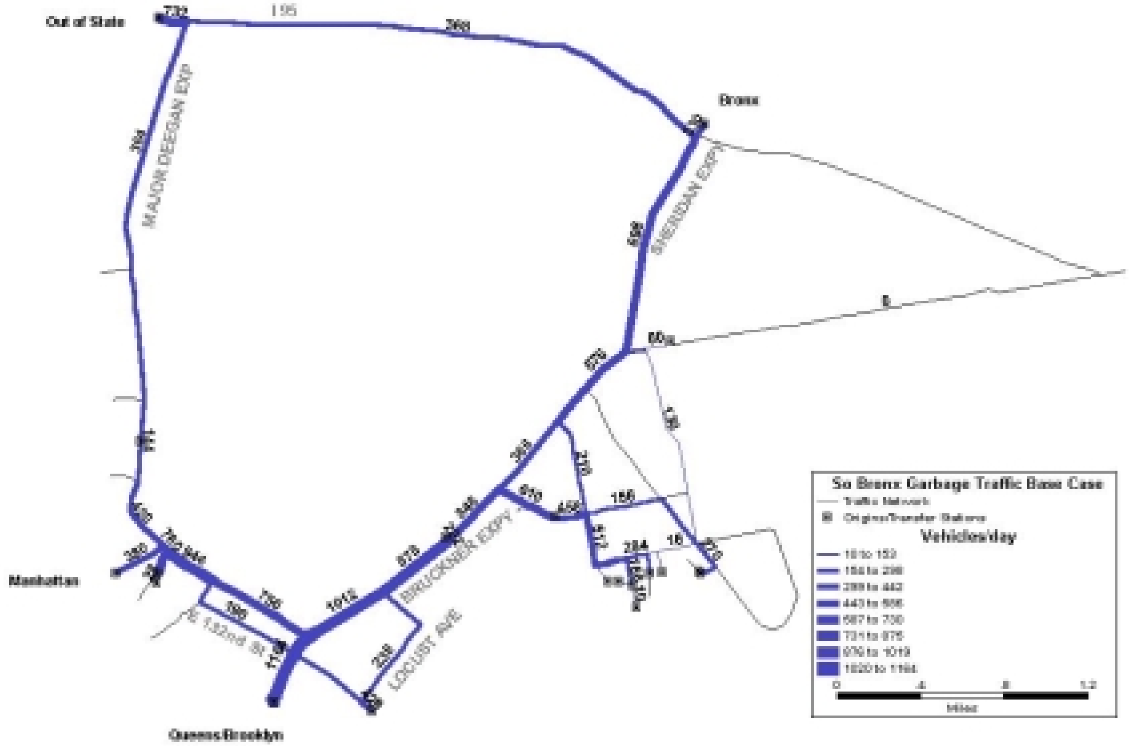


Figure 18. Scenario 1a - 3 waste transfer stations closed and garbage traffic diverted to other stations.

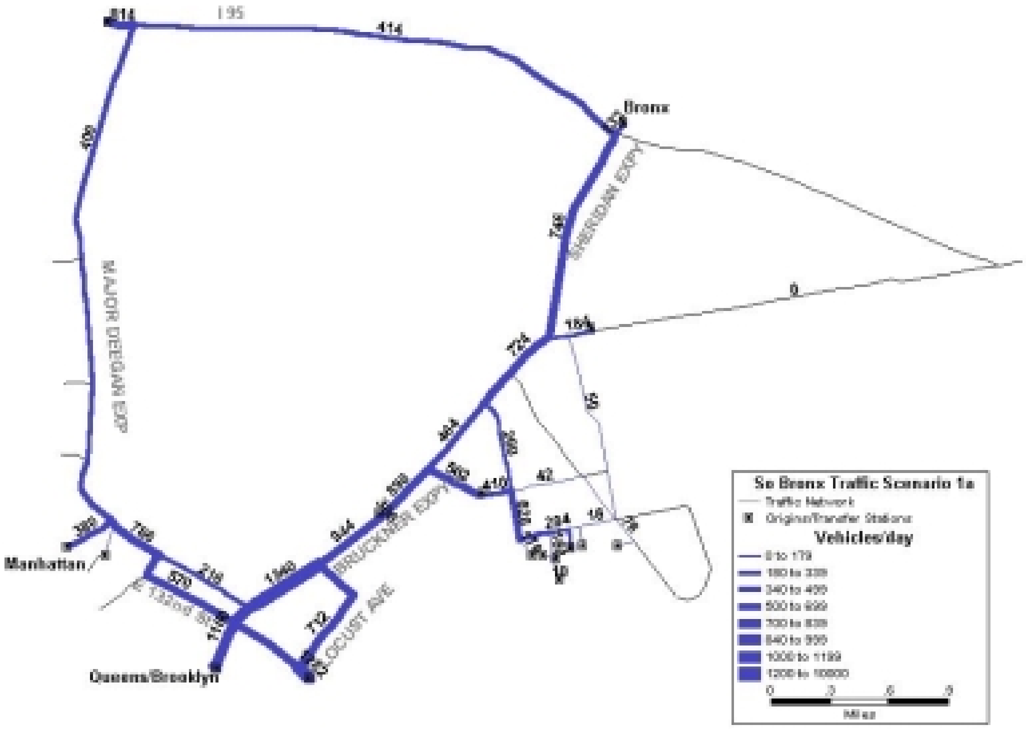


Figure19. Scenario 1b – 3 waste transfer stations closed.

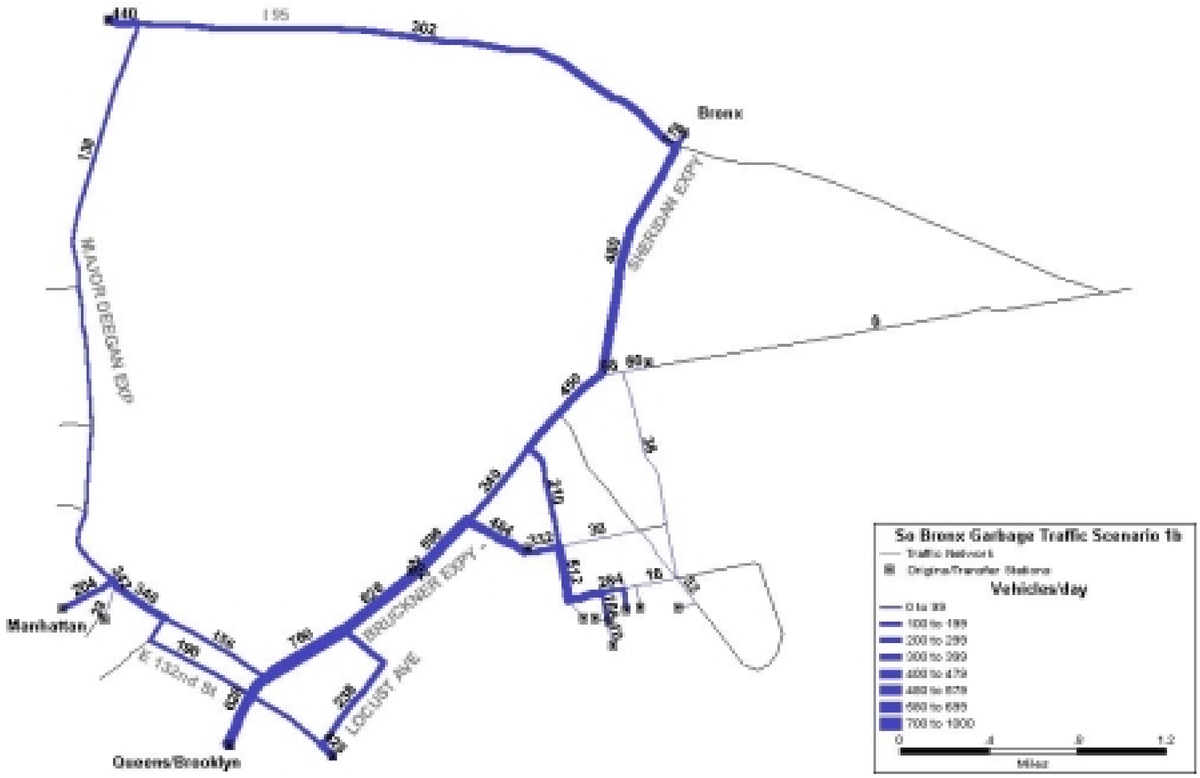
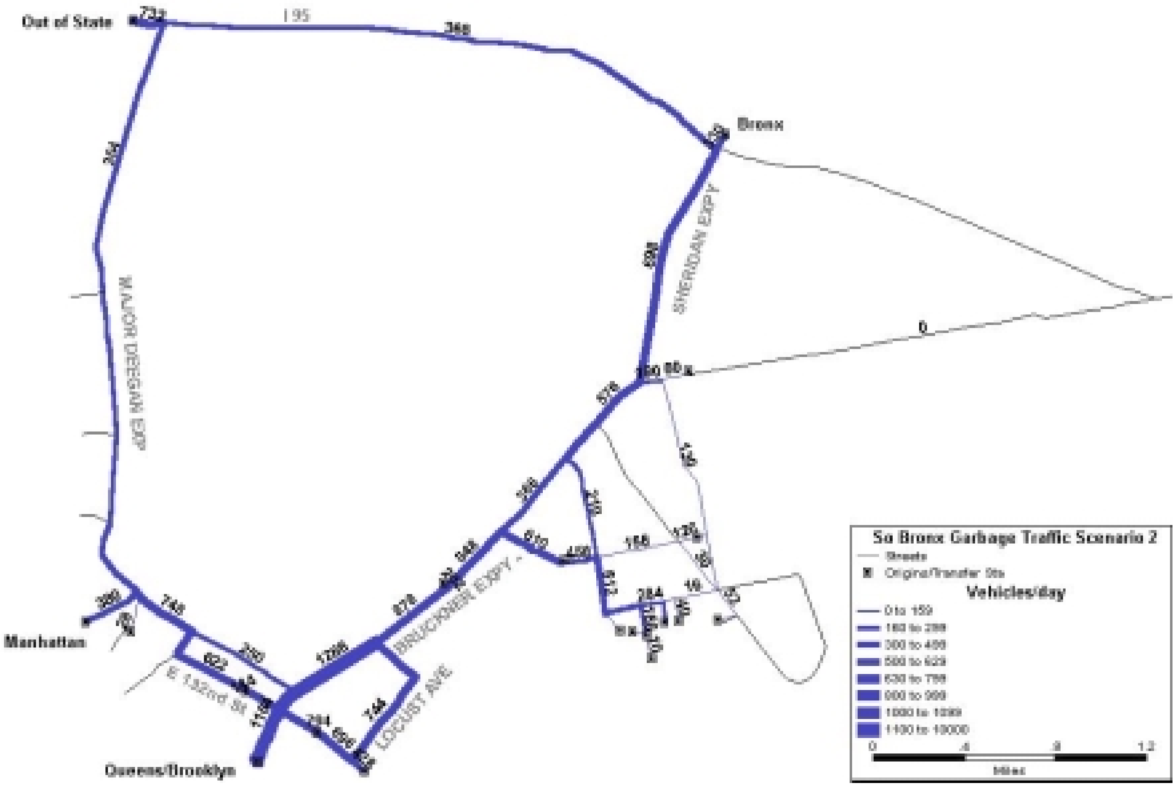


Figure 20. Scenario 2 – 3 waste transfer stations relocated.



A comparison of the traffic flows in scenario 1a (Figure 18) with those in the base case (Figure 17) reveals several changes. First, the traffic on the southern Major Deegan has decreased because of the removal of the Bronx County Recycling Center and the Waste Management facility on Lincoln Avenue. Second, the traffic on the Bruckner has increased because of the diversion of flows from these two stations. Third, the flows on links outside of the southern Major Deegan have increased because 950 tons of the garbage processed at the Waste Management facility on Lincoln Avenue was shipped from the area by rail. Closing this facility results in a diversion of 950 tons from rail to truck thereby causing a general increase in truck flows. Lastly, the removal of the Metropolitan Transfer Station in Hunt's Point results a decrease in traffic in the eastern part of that region.

A comparison of the traffic flows in scenario 1b (Figure 19) with those in the base case (Figure 17) reveals one expected change – an overall decrease in traffic throughout the study area. Finally, a comparison of the traffic flows in scenario 2 (Figure 20) with those in the base case (Figure 17) reveals that, while most link flows are the same, there are three notable changes. First, there is a decrease in traffic on the southern Major Deegan. As in the case of scenario 1a, this is the result of removing the Bronx County Recycling Center and the Waste Management facility on Lincoln Avenue from the area. The second change is a substantial increase in traffic on the southern Bruckner and on East 132nd St. This is the result of moving these two facilities into the area. Lastly, traffic in the southeastern part of Hunt’s Point is reduced as the result of moving the Metropolitan Transfer Station farther north.

Chapter 6

Ambient Air Impact of Traffic Emissions for Scenarios of Traffic Associated with Waste Transfer Stations

Bruce Egan and John Purdum

This chapter describes air quality modeling results associated with the scenarios described in the previous chapter pertaining to traffic patterns associated with the removal or relocation of three waste transfer stations in the study area. The traffic estimates provided by the results described in the previous chapter were used as inputs to an air quality model.

1. SUPPLEMENTAL ANALYSES OF WASTE TRANSFER TRUCK TRAFFIC.

XI. Particulate emissions for the alternative South Bronx garbage truck flow scenarios

The previous chapter described garbage truck traffic flow projections for a base case plus three different garbage flow scenarios associated with the potential closure and or relocation of three waste transfer stations in the South Bronx. The base case is the present day case. For Scenario 1a, three waste stations are closed and the waste flows to these stations are diverted to other transfer stations. For Scenario 1b, the same three stations are closed but the truck flows were removed. For Scenario 2, the three waste stations were relocated. There are up to 79 roadway links associated with each of these scenarios.

The methodology of the modeling for these scenarios follows that described in chapter 4. The same dispersion model (ISCST3), the same 5 years of meteorological data from LaGuardia airport and the same receptor array were used in the analyses. However, instead of assuming a distribution of cars and trucks of various sizes and fuel types, the air quality models described in this chapter use the garbage truck traffic flow rates in and out of the South Bronx provided by the traffic model estimates. To estimate the PM_{10} emissions on a daily basis associated with these different scenarios, the roadway link lengths for each link and then the vehicle miles traveled (VMT) on each link were calculated. The trucks traveling into the Bronx were assumed to have a weight of 10 tons. The trucks traveling out of the Bronx were assumed to have a weight of 23 tons. For purposes of estimating emission rates for these truck flows, we assumed that the trucks were all diesel-powered and had emission rates per VMT in proportion to their weight. Therefore the outbound trucks were assumed to have an emission rate 2.3 times that of the inbound trucks. To allow simple scaling of the emissions generated, we assumed for modeling purposes that the inbound trucks have a normalized PM_{10} emission rate of 1 gram per vehicle mile traveled (g/VMT). For reference purposes, in our prior report, we assumed that trucks in this size range emitted between 0.18 and 0.24 g/VMT corresponding to diesel-powered trucks manufactured in the years 1998 through 2003.

For the emissions scenarios considered here, the ambient air concentrations calculated for any given scenario are directly proportional to the assumed emission rate. Therefore, if new or better information becomes available on the emission rates for the garbage truck fleet, the estimates of the air quality impacts can be linearly adjusted. Each of the scenarios has different truck traffic volumes and routings. For scenario comparison purposes from a relative standpoint, one may use the normalized values tabulated or plotted directly.

Table 1 compares the overall summary of truck flow rates, the VMT, and total normalized PM_{10} emissions on a daily basis for each of the scenarios. These summary statistics are tabulated directly from the traffic model estimates. The emissions comparisons are based on the sum of all the individual vehicles and are therefore for the entire study area.

It may be seen that the total normalized emissions for Scenario 1a is the largest, having a value about 15 % greater than the base case. At the other extreme, the emissions for Scenario 1b, which eliminates three waste transfer stations, are about 65% of those for the Base case. Scenario 2 is associated with total emissions about 6% larger than the Base case.

XII. Particulate emissions and air quality modeling for alternative South Bronx garbage truck flow scenarios

Because hour-by-hour meteorological conditions are input to the dispersion model and because meteorological conditions vary with time of day two different assumptions were adopted regarding how the emissions from the trucks varied by time of day. The first assumption was that the traffic flow rates were constant, the same for all hours. This would be consistent with scheduling efforts that attempt to even out the truck flow volumes by time of day. The second assumption was that the traffic volume followed the same peak and off peak rates as were assumed in our prior report. Thus the flow rates are larger during peak hours and smaller during off peak hours, but averaging to the total daily rate. This pattern is identified as ‘variable’ in this report.

Figures 1 through 8 provide isopleths of the annual average PM_{10} concentrations for each of the cases for the latest modeling year of 1995. Compared to the base case, Scenario 1a shows a greater impact localized in the southern part of the study area. Scenario 1b shows a lesser impact in this area but also overall associated with the removal of the trucks in this scenario. Scenario 2 shows results somewhat between those of the Base case and Scenario 1a. The results are similar for all 5 years of meteorological data.

Table 2 compares the maximum annual average PM_{10} concentrations predicted for the different scenarios. The maximum values and their locations follow the observations made above of the concentration patterns.

Table 1. Truck Traffic Volume and Normalized PM10 Emissions by Scenario

Scenario	Daily Truck Volume Inbound	Daily Truck Volume Outbound	Daily Truck Volume Total	Daily Truck VMT Inbound	Daily Truck VMT Outbound	Daily Truck VMT Total	Normalized Daily Truck Emissions Inbound	Normalized Daily Truck Emissions Outbound	Normalized Daily Truck Emissions Total
	Vehicles per day	Vehicles per day	Vehicles per day	(VMT)	(VMT)	VMT	grams/day	grams/day	grams/day
Base Case	15596	7530	23126	3869	3003	6872	3869	6907	10776
Scenario 1a	15668	9440	25108	3996	3647	7643	3996	8389	12385
Scenario 1b	8888	2426	11314	2236	2064	4300	2236	4748	6984
Scenario 2	15968	8274	24242	3995	3213	7208	3995	7391	11386

Table 2. Maximum Annual Average PM10 Concentrations	
Scenario	**Maximum Concentrations (ug/m3)**
Base Case-Truck volumes constant with time of day	0.346
Scenario 1b-Truck volumesc constant with time of day	0.384
Scenario 1a-Truck volumes constant with time of day	0.263
Scenario 2-Truck volumes constant with time of day	0.363
Base Case-Traffic volumes vary with time of day.	0.237
Scenario 1a-Traffic volumes vary with time of day.	0.265
Scenario 1b-Traffic volumes vary with time of day.	0.175
Scenario 2-Traffic volumes vary with time of day.	0.244

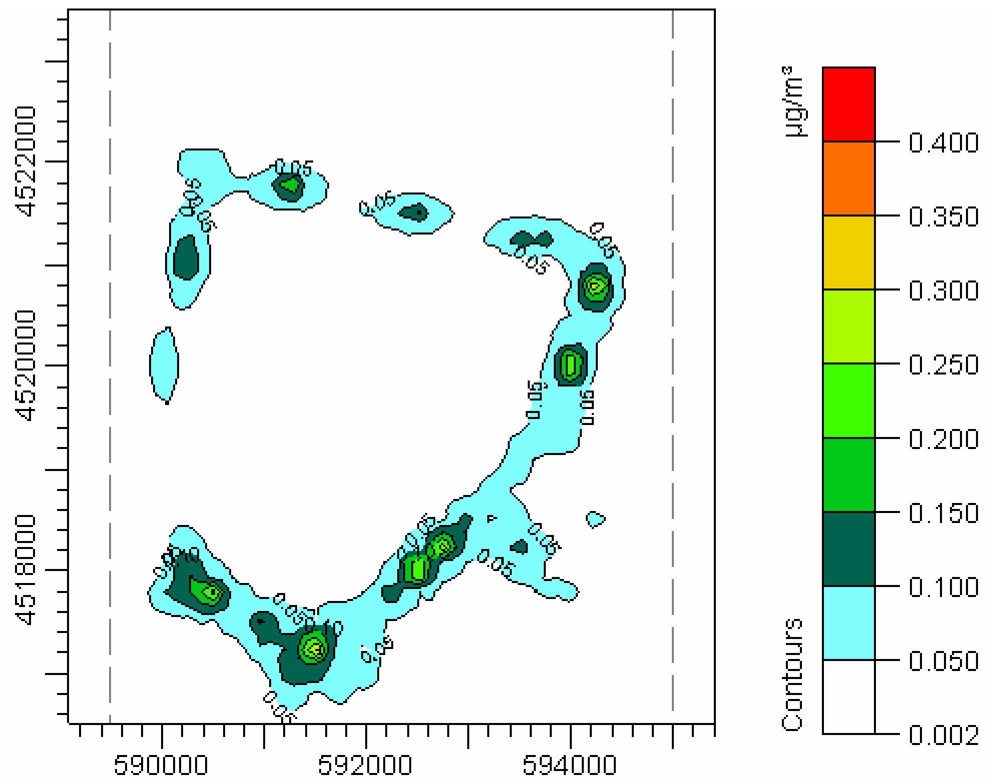


Figure 1.Base Case Scenario. 1995 Annual average PM10 concentrations.

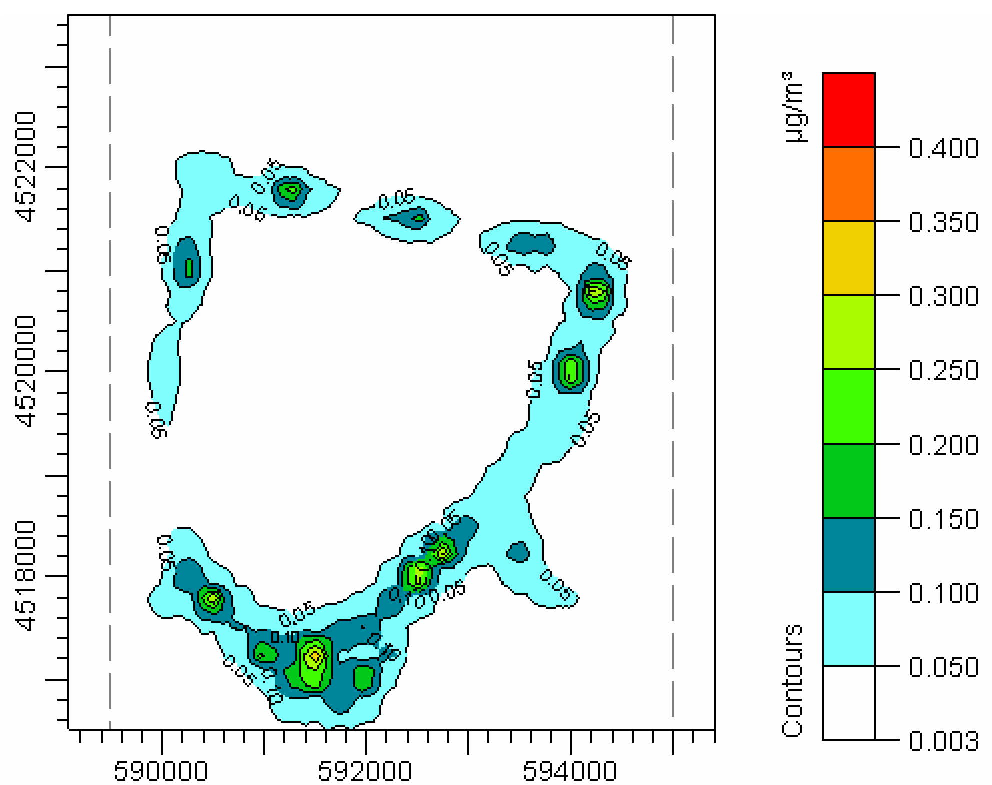


Figure 2. Scenario 1a. 1995 Annual average PM10 concentrations

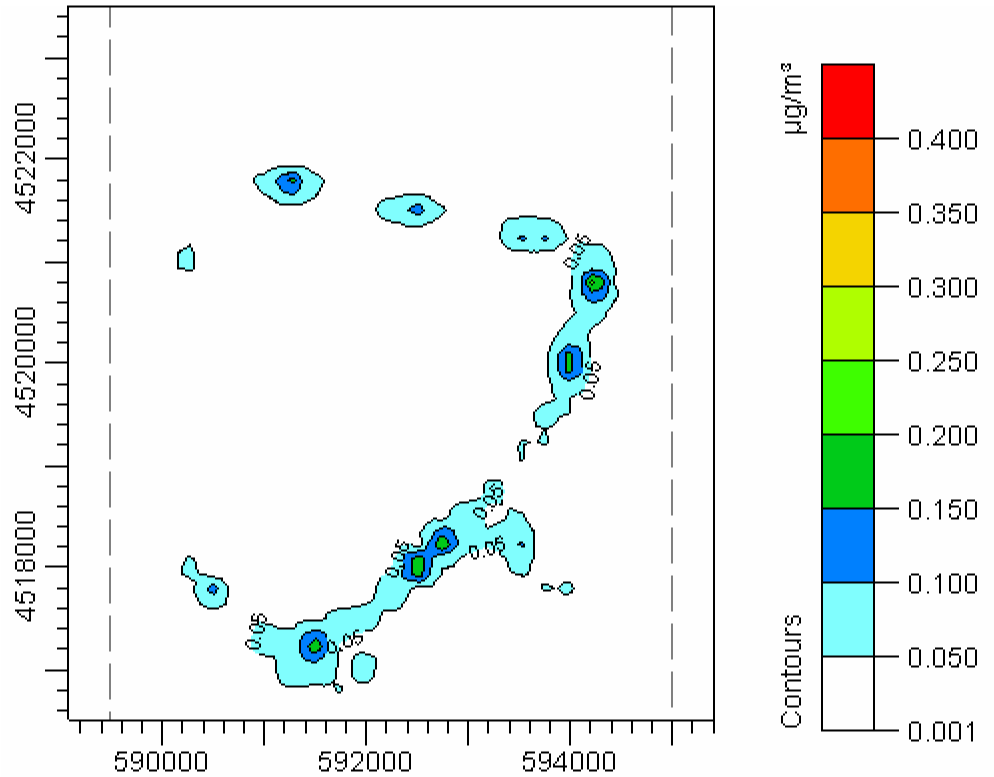


Figure 3. Scenario 1b. 1995 Annual average PM10 concentrations

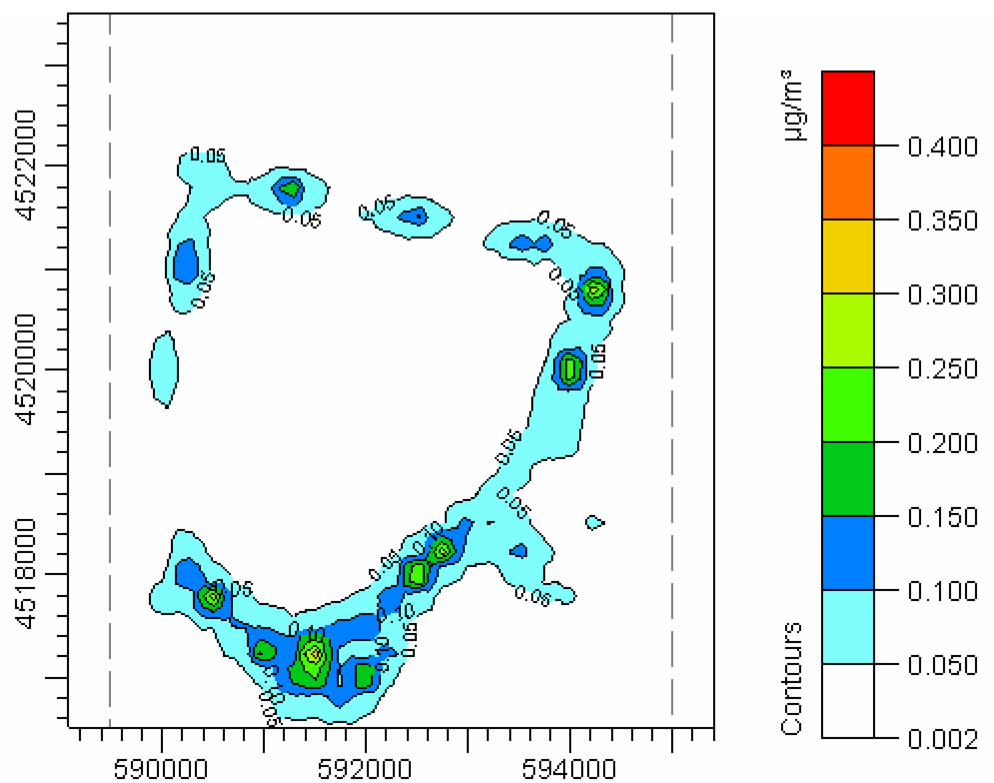


Figure 4. Scenario 2. 1995 Annual average PM10 concentrations

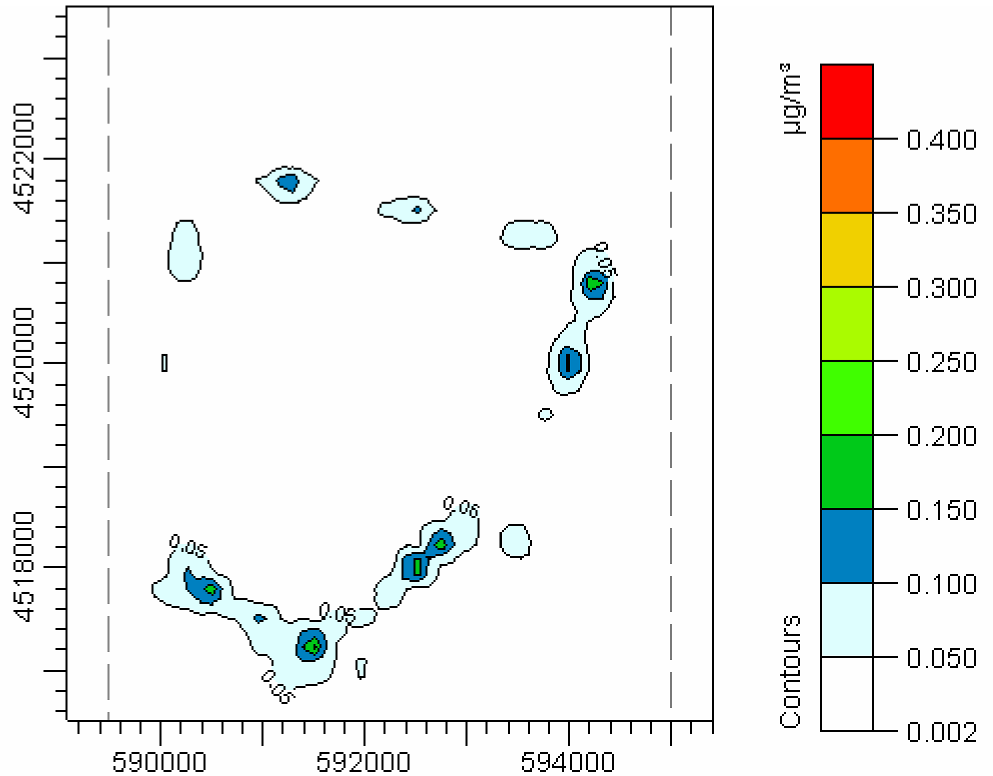


Figure 5. Base Case Scenario. Variable emissions. 1995 Annual average PM10 concentrations

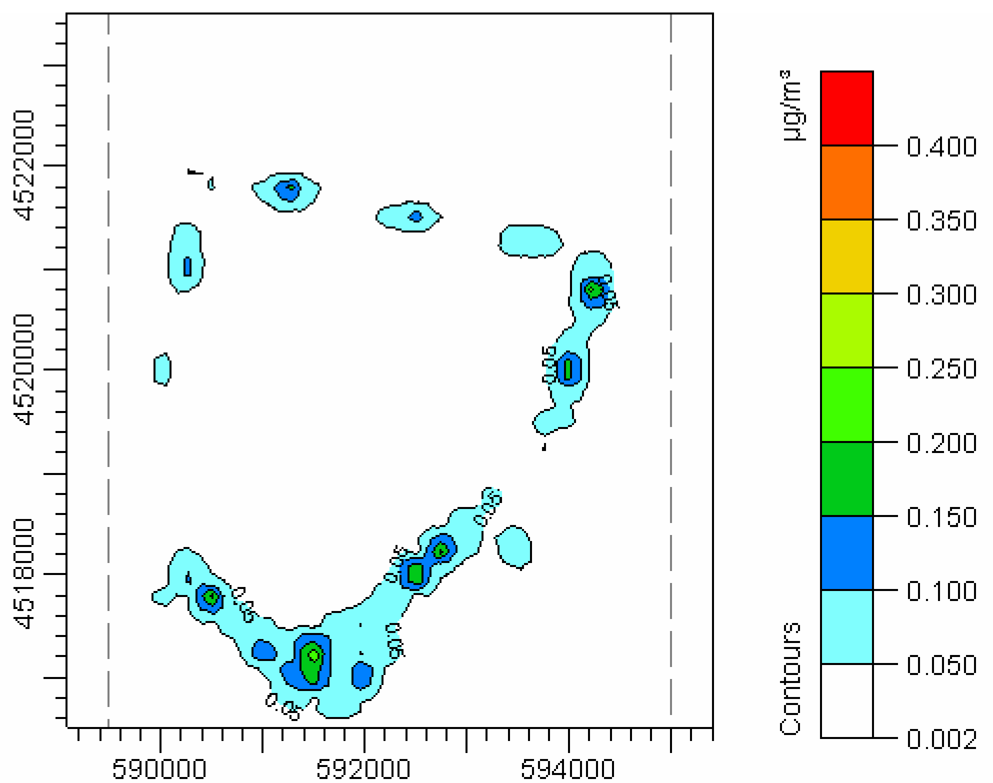


Figure 6. Scenario 1a. Variable emissions. 1995 Annual average PM10 concentrations

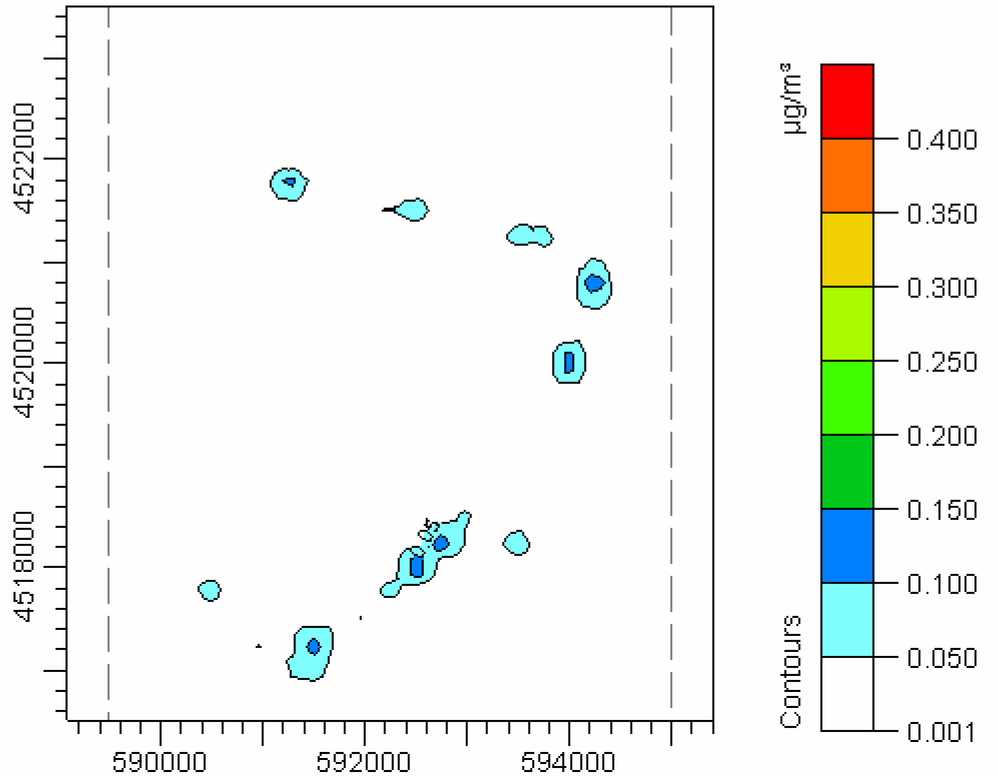


Figure 7. Scenario 1b. Variable emissions. 1995 Annual average PM10 concentrations

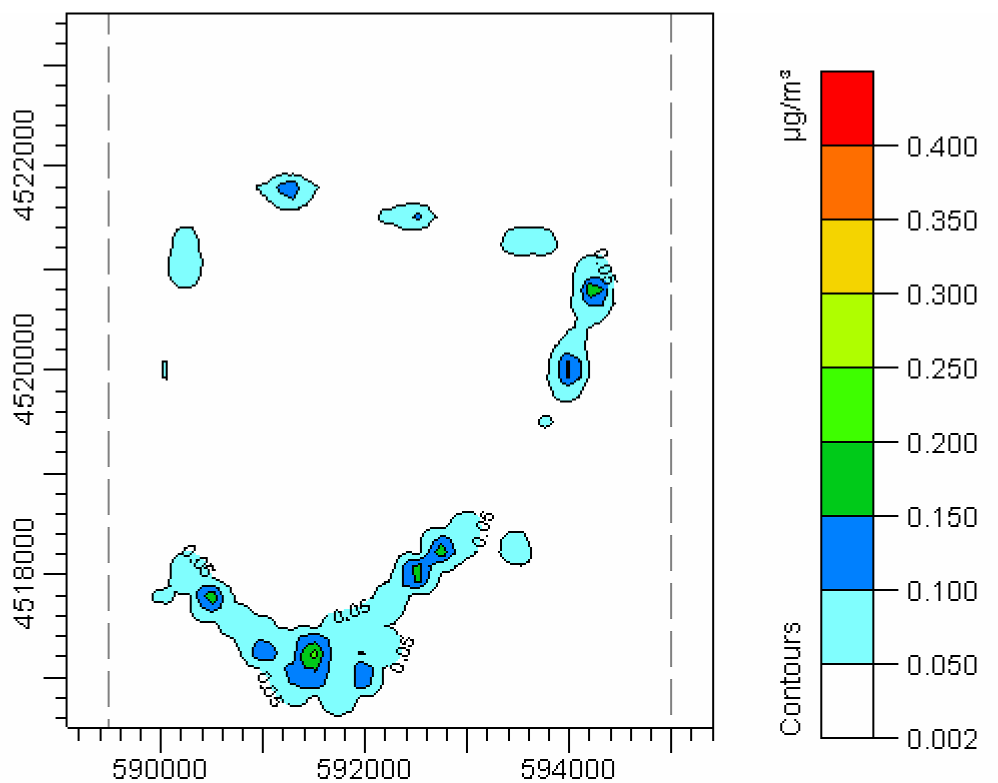


Figure 8. Scenario 2. Variable emissions. 1995 Annual average PM10 concentrations

Chapter 7
Waste Transfer and Environmental Justice: A Literature Review

by Cary Hirschstein, MUP
with assistance from Rae Zimmerman, PhD and Nicole Dooskin, MUP Candidate

Introduction

Recent studies on environmental justice and waste related activity indicate that significant disparities exist for race, ethnicity and income and the siting of adverse environmental uses and waste facilities. This section provides a literature review of environmental justice studies focused around waste management and general environmentally hazardous uses, taken from nationwide studies conducted since 1998. Issues of race, income, ethnicity and minority move-in theory are discussed, as well as the presence of illegal waste activity, and limitations and considerations for environmental justice research. A brief focus is directed towards New York City in consideration of adverse environmental uses and industrial zoning. The findings of these studies overwhelmingly suggest that the environmental impacts of waste transfer activities on minority and low-income populations need to be taken into account in policy and planning for the siting and operations of waste transfer stations.

Many researchers, policy makers and advocates claim that environmental health and justice issues need to be given a greater spotlight in public, governmental and scientific realms. The 1999 Institute of Medicine report *Toward Environmental Justice: Research, Education & Health Policy Needs* looked at environmental health issues across the United States.[5] The Institute concluded that environmental health issues in minority communities are not given enough weight in discussions throughout government, public health, medicine and science. Their reports suggest that a higher value needs to be placed on the problems of communities bearing disproportionate burdens of environmental hazards.[6]

What is Environmental Justice?

Before reviewing the literature on environmental justice and waste transfer, it is critical to define the construct of "environmental justice." According to the United States Environmental Protection Agency (U.S. EPA), environmental justice:

> "…is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development,

[5] Institute of Medicine. 1999. *Toward Environmental Justice: Research, Education, and Health Policy Needs.* National Academy Press.
[6] Ibid.

> implementation, and enforcement of environmental laws, regulations, and policies."[7]

The EPA defines fair treatment in this case to mean:

> "that no group of people, including a racial, ethnic, or a socioeconomic group, should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal, and commercial operations or the execution of federal, state, local, and tribal programs and policies."[8]

Meaningful involvement is characterized by a public process whereby:

> "(1) potentially affected community residents have an appropriate opportunity to participate in decisions about a proposed activity that will affect their environment and/or health; (2) the public's contribution can influence the regulatory agency's decision; (3) the concerns of all participants involved will be considered in the decision making process; and (4) the decision makers seek out and facilitate the involvement of those potentially affected."[9]

Thus, we can define several critical elements of true environmental justice, according to this definition. An environmental injustice occurs when any one of these items is compromised. First, the idea of justice is constructed around demographic indicators such as race, income and national origin. In doing so, many environmental justice studies focus on low-income and minority communities in comparison with general regional populations. Second, specific communities within the greater population should not bear disproportionate burdens of adverse environmental hazards from a range of private and public sources. These burdens may take the form of polluted air, soil and water, intense traffic congestion, higher health risks and financial costs associated with such uses. Last, affected communities and stakeholders should be given full opportunity to partake in and influence government decision-making processes regarding environmental issues in their community. This is a critical element that much environmental justice research in the literature often misses – the voice of the community and how it may or may not be appropriately accounted for in local, state and federal decision-making. Research tends to focus on the first two elements, disparities of adverse environmental burdens in communities of low-income and minority race and ethnicity.

Enacted in 1994 to support Title VI of the Civil Rights Act of 1964, Executive Order 12898 required that:

> "Each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and

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[7] United States Environmental Protection Agency. *Environmental Justice Web Site*. February 10, 2004. Accessed 6 May 2004: http://www.epa.gov/compliance/environmentaljustice/index.html
[8] Ibid.
[9] Ibid.

> adverse human health or environmental effects of its program, and activities on minority populations and low-income populations."[10]

Today, local, state and federal agencies are required by the executive order to address environmental justice in their decision-making processes. Whether or not this has been adequately achieved throughout all levels and sectors of government is an item of debate.

Race, ethnicity and income

Numerous researchers over the past decades have documented cases of environmental injustice across the country, finding disproportionate impacts on minority and low-income populations. This literature review begins by highlighting a few more recent studies ranging from Massachusetts, Virginia and Maryland to Mississippi and Southern California.

Daniel R. Farber and Eric J. Krieg analyzed social and geographic distributions of environmental hazards across 368 communities in the State of Massachusetts in 2002.[11] Their research suggests that working-class communities and communities of color in Massachusetts bear disproportionate burdens of environmentally hazardous facilities and sites, including waste management sites. The study examined income and race-based inequities along the spatial distributions of 17 environmentally hazardous facilities. These facilities included industrial facilities, power plants, incinerators, toxic waste sites, landfills and waste transfer stations. Farber and Krieg also created a measure of cumulative exposure and set up a rating system to track overall environmental hazards throughout cities and towns. Data was culled from the 1990 U.S. Census and from sources collected in spring and summer 2000 by the Massachusetts DEP, U.S. EPA and the Massachusetts Toxics Use Reduction Institute. The study focused on a total of 351 data points, or 351 cities and towns/minor civil divisions. 12 sub-towns in Boston and 7 sub-towns in Barnstable were also considered, for a total of 370, but these areas were calculated separately and not included in the total.

Farber and Krieg's findings suggest that working-class communities and communities of color in Massachusetts bear disproportionate burdens of environmentally hazardous facilities and sites. With respect to waste management:

> "Whereas lower-income communities make up 50.8% of all towns in the state, they are home to 58.9% of all incinerator ash landfills, 66.7% of all demolition landfills, 71.4% of all illegal sites, 74.5% of all sludge landfills, 69.5% of all tire piles, and 58.9% of all transfer stations."[12]

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[10] Colorado Department of Transportation Research Branch, *Environmental Justice in Transportation Planning, Phase II*. December 2003, p.6.

[11] Faber, Daniel R. and Krieg, Eric J., "Unequal exposure to ecological hazards: Environmental injustices in the Commonwealth of Massachusetts," *Environmental Health Perspectives* 110(suppl 2): 277-288 (2002).

[12] Faber, Daniel R. and Krieg, Eric J., p. 281.

Furthermore, when all landfill types are analyzed together, communities with higher percentages of residents of color have much greater rates of landfills per square mile. In towns where less than 5% of the population is of color, there is an average 0.13 landfill types per square mile. However, in communities where 25% or more of residents are people of color, there is an average of 0.36 landfill types per square mile, or roughly 3 times higher.[13]

Another recent study found interrelationships among race, poverty and age in residential proximity to industrial sources of air pollution. In 2001, Perlin, Wong and Sexton looked at the siting of Toxic Release Inventory (TRI) facilities in three study areas: Kanawha Valley, West Virginia, Baton Rouge-New Orleans, Louisiana, and the greater Baltimore, Maryland metropolitan area.[14] Perlin et al. examined the proximity of TRI industrial air pollution sources to residential neighborhoods, analyzing race (White or African American), poverty (households living above or below the poverty level), age (birth to 5 years or over 65 years), and proximity to TRI facilities (residences up to 3 miles from a facility). A key finding of the study was that significantly higher numbers of African American children under 5 years of age lived in low-income homes that were in close proximity to one or more TRI facilities, when compared to White children.

Preston conducted a study in 2000 assessing environmental awareness among Head Start families throughout 20 rural counties in the Mississippi Delta Region.[15] The investigator surveyed 763 female heads of households with children age 2-5 in Head Start. The study found a significant correlation between Black populations within counties and indicators of poor watershed quality, including drinking water contaminant level violations and difficulties in water quality monitoring and facility maintenance. The author also suggests that Black communities bear a heavier burden of environmental hazards, finding that black families reported higher numbers of landfills and chemical plants near their homes.

One 1998 study sought to get at the roots of how environmental justice disputes arise and develop in communities, in an effort to analyze the roles of community members and officials in decision-making processes. Jeanne Nienaber Clarke and Andrea K. Gerlak conducted a qualitative assessment of a garbage dump siting decision in Pima County, southern Arizona.[16] Their most noteworthy finding was that environmental racism was a product of the county's heterogeneous cultural and ethnic mix, specifically that the Latino community believed it reflected reality, while the White majority population did not even recognize it as an issue. In fact, the authors suggest that the nature of officials' replies to environmental hazard siting issues initially led to the claims of environmental racism.

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[13] Ibid.

[14] Perlin SA, Wong D, Sexton K. *Residential proximity to industrial sources of air pollution: Interrelationships among race, poverty, and age*. J Air Waste Manage Assoc. 2001;51:406-421. From Northridge, M.E., Stover, G.N., Rosenthal, J.E., Sherard, D. Environmental equity and health. *American Journal of Public Health*. February 2003, 93, 2, pp. 209-214.

[15] Preston, B. "Factors affecting environmental awareness among Head Start families in Mississippi." *Am J Prev Med*. 2000;19:174–179. From Northridge, M.E., Stover, G.N., Rosenthal, J.E., Sherard, D. "Environmental equity and health." *American Journal of Public Health*. February 2003, 93, 2, pp. 209-214.

[16] Nienaber Clarke, Jeanne and Gerlak, Andrea K. "Environmental Racism in Southern Arizona?" *Environmental Injustices, Political Struggles*. Durham: Duke University Press, 1998, pp. 82-100.

"Minority move-in" or environmental injustice?

A central debate in determining the roots of environmental disparity is whether adverse environmental uses are sited near minority and low-income populations, or if minorities and low-income residents tend to locate in areas in which these uses are already present, described as the theory of "minority move-in" by Morello-Frosch, Pastor, Porras and Sadd.[17] In *Environmental Justice and Regional Inequality in Southern California: Implications for Future Research*, research suggests that environmental justice disparities in Southern California are likely due to the siting of hazards rather than the theory of "minority move-in." Conducted in 2000, Morello-Frosch et. al. utilized air emissions inventories and air exposure modeling data to study the causes of disproportionate environmental burdens for communities of color in Southern California, specifically the siting of treatment, storage, and disposal facilities.

Firstly, Census tracts with treatment, storage and disposal facilities from the U.S. Environmental Protection Agency's Toxic Release Inventory (TRI) were compared along demographic lines to tracts without such facilities.[18] Results revealed that communities of color bear the greatest burden of treatment, storage and disposal facilities and TRI facilities in Southern California. A longitudinal analysis indicated that environmental disparities across communities were due to siting of TRI facilities, rather than market-based "minority move-in" mechanisms. The study also looked at health effects of toxic outdoor air impacts from mobile and stationary sources, combining estimated long-term annual average outdoor concentrations of 148 hazardous air pollutants, as listed in the 1990 Clean Air Act Amendments, with demographic and land use data from the 1990 U.S. Census and Southern California Association of Governments reports. Findings of this portion of the study suggested that race may predict cancer risk distributions in populations throughout the region, controlling for socioeconomic and demographic factors.

Illegal waste activities

Community residents in the South Bronx often complain of illegal waste activities, such as the presence of waste transfer facilities that operate without a permit.[19] However, it has been difficult for many to get a hand on the extent of such waste operations. In *Garbage Wars: The Struggle for Environmental Justice in Chicago*, David Naguib Pellow presents a historical review of waste management and environmental justice in Chicago, IL.[20] He cites an interesting study conducted by the Chicago Department of Streets and Sanitation (DOSS), whereby the agency showed that populations in the top ten city neighborhoods suffering from illegal dumping are at least 60% Black or Latino. Furthermore, they suggest that wards where residents of color represent a majority account for 79% of the total garbage illegally dumped in Chicago. This

[17] Morello-Frosch, R., Pastor Jr., M., Porras, C., and Sadd, J. "Environmental Justice and Regional Inequality in Southern California: Implications for Future Research." *Environ Health Perspect* 110(suppl 2):149-154 (2002).
[18] Ibid.
[19] Conversation with Paul Lipson, The Point Community Development Center, Bronx, NY, Summer 2003.
[20] Pellow, David Naguib. *Garbage Wars: The Struggle for Environmental Justice in Chicago*. Cambridge, MA: The MIT Press, 2002.

disparity indicates that these Chicago communities bear the burden of not only permitted adverse environmental uses, but also illegal, non-permitted waste activities. The example of the DOSS report also illustrates the crucial need to account for illegal waste activities when considering adverse environmental impacts on minority populations in environmental justice studies.

Waste and Environmental Justice in New York City

Only a few recent environmental justice studies have focused on waste-related activities and hazardous environmental uses in the New York City region. The lack of such current research in the New York metropolitan area highlights a need for future studies to examine environmental disparities throughout the city's various subpopulations.

Fricker and Hengartner analyzed the presence of environmentally undesirable sites across 2,216 Census tracts and 354 undesirable facilities in the five boroughs of New York City.[21] Using 1990 Census data, they gauged racial and ethnic demographics near sites such as landfills, sewage treatment plants, incinerators, bus garages and federally listed TRI sites and transfer, storage and disposal facilities. The researchers utilized generalized linear and additive modeling techniques, and found that race and ethnicity are significantly linked with the existence of environmentally undesirable sites in New York City. Specifically, the percentage of Hispanics within a tract was associated significantly with the presence of such sites. In the Bronx and Queens, Black populations are closer to environmentally adverse sites, though less so in Manhattan.

A discussion of environmental justice and the siting of environmentally hazardous uses in New York City is not complete without a look at zoning. Such facilities tend to be located in areas zoned for industrial uses (identified as M zones, for manufacturing), and many argue that these properties are more often home to low-income minority populations. Once again, the debate of "minority move-in"[22] becomes an issue. Do low-income and minority residents in New York City locate themselves in housing near or in areas zoned for manufacturing uses, which are more likely to become sites of hazardous facilities because of the zoning, or are these sites placed in minority and low-income neighborhoods because they do not have the voice and political clout to prevent the environmental injustice? Though this question is very difficult to answer, Juliana Maantay's review of the expansion and decrease of the city's industrially zoned land provides some insight into the demographic and spatial trends of zoning changes in New York City.

In 2001's *Zoning, Equity, and Public Health*, Maantay examined the location and spatial increase and decrease of New York City's industrial zones between the years of 1961 and 1998.[23] She compared rezoned areas across economic and demographic characteristics, looking at how the areas changed and relevant public policies influencing such rezonings. One of the focuses of the research was to understand whether or not land use policy in New York City is inherently

[21] Fricker, R. Jr. and Hengartner, N. "Environmental equity and the distribution of toxic release inventory and other environmentally undesirable sites in metropolitan New York City," *Environmental and Ecological Statistics* 8, 33-52, 2001.
[22] Morello-Frosch, R., Pastor Jr., M., Porras, C., and Sadd, J.
[23] Maantay, Juliana. Zoning, Equity, and Public Health. *American Journal of Public Health*, 2001; 91: 1033-1041.

discriminatory, shifting burdens of harsher land uses to poor and minority communities. Maantay utilized Census data, zoning records, interviews and literature to compare city Census tracts with their boroughs. She included waste transfer stations in her focus.

The findings of this study suggest that about 22% of New York City residents live in Census tracts that contain M (manufacturing) zones.[24] Firstly, between 1961 and 1998, there was a distinct trend in the reduction of M zoned land. Out of 409 M zoning changes, there were 3 rezonings from manufacturing to non-manufacturing for every 2 rezonings to manufacturing. 20% (82) of the total zone changes were considered large or (comprising 4-10 square blocks) or very large (comprising more than 10 square blocks). 60 of these 82 rezonings led to decreases in industrial zoned land. The greatest number of large increases was borne by the Bronx, which also has the smallest number of major decreases. Conversely, Manhattan experienced the fewest major increases and the most major decreases. Maantay also found that increases in M zoning was usually associated with communities comprised of more minority residents, lower incomes and lower rates of home ownership when compared across borough averages. In contrast, most rezonings away from M zones occurred in areas with less minority residents, higher incomes and greater rates of home ownership. Her research also indicates than as time passes, the areas adversely impacted by the rezonings diverge even farther from the city, borough and M-zone statistical means for income, percent minority population and homeownership rates. Thus, Maantay's work brings zoning into the environmental justice discussion as an important intermediary, suggesting a significant correlation between industrial zoning changes, race and income in New York City.

Limitations and considerations of environmental justice research

While environmental justice research has been crucial to the environmental justice movement, some researchers question the quality of past research efforts. Bowen and Wells reviewed over 200 environmental justice articles written nationwide between 1980 and 1998, in an effort to determine the quality of research in the field, major methodological hurdles, recommendations for future research needs, and key lessons for policy makers.[25] Bowen and Wells identified only 40 studies they considered to be adequate empirical research with satisfactory research design, or only 1 in 5. They site cases of weak and inaccurate studies, including Robert Bullard's 1983 study of Houston and Paul Mohai and Bunyan Bryant's 1992 environmental justice work. Key findings of their review include a 1992 EPA study reporting that there is a lack of data on the health impacts of adverse environmental pollutants by demographic measures. They support this claim. Furthermore, Bowen and Wells assert that many studies utilize Toxic Release Inventory (TRI) data, but may thus be flawed as TRI data seriously suffers from sampling and measurement issues. Similarly, the authors claim environmental justice research is marred by research design issues. The authors discuss

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[24] Ibid.

[25] Bowen, William M. and Wells, Michael V., "The politics and reality of environmental justice: A history and considerations for public administrators and policy makers." *Public Administration Review*, November/December 2002, Vol. 62, No. 6, pp. 688-698.

methodological obstacles to improved environmental justice research and call for research on the health impacts of environmental hazards.

A few recently published handbooks help to guide decision-making processes for siting and operating waste transfer stations. The Waste Transfer Station Working Group of the National Environmental Justice Advisory Council delivered a national examination of waste transfer siting and operations in 2000, entitled *A Regulatory Strategy for Siting and Operating Waste Transfer Stations.* [26] The report provides recommendations of measures to alleviate transfer station burdens on communities. The group's recommendations spanned Resource Conservation and Recovery Act solid waste management planning, facility siting, best management practices, community participation, marine waste transfer stations, air quality and clean air act, waste reduction, and regulatory review and enforcement. Similarly, the United States EPA has released a handbook entitled *Waste Transfer Stations: A Manual for Decision-Making*, which was developed from the work of the National Environmental Justice Advisory Council Waste Transfer Station Working Group.[27] This document provides guidance on planning and siting a transfer station, station design and operations, facility oversight and various applicable resources. The EPA also hosts an environmental justice web site to provide resources to government agencies and the public.[28] Lastly, the agency is currently developing a *Toolkit for Assessing Potential Allegations of Environmental Injustice*, and released a draft for public commentary in September 2003.[29]

Despite a large body of environmental justice research, several needs exist in the field. First, a greater focus on waste transfer issues is required, especially focusing at local levels where critical problems exist. Not only is research required, but also a need exists for a general increase in public discourse and attention at local, state and federal policy-making and regulatory bodies. Specifically, environmental impacts of waste transfer activities on minority and low-income populations need to be taken into account in policy and planning for the siting and operations of waste transfer stations. Second, as Bowen and Wells argue, there is a need for research that connects the presence of adverse environmental hazards with health consequences in communities suffering environmental disparity burdens.[30] Third, as previously stated, the literature needs to turn an eye to various decision-making processes impacting environmental justice issues, examining the role of affected stakeholders and officials, and the policies and programs governing these decisions. A fourth important element in the waste and environmental justice field is a need to understand the roots of environmental injustice, and the multitude of factors that interact to cause disparities. Juliana Maantay's work with industrial zoning changes in New York City is a step in the right direction, examining the role that land use plays in the siting of environmental hazards in dense urban areas.[31] The work of Morello-Frosch, Pastor,

[26] National Environmental Justice Advisory Council. (2000) A Regulatory Strategy for Siting and Operating Waste Transfer Stations. United States Environmental Protection Agency, March 2000.
[27] United States Environmental Protection Agency, *Waste Transfer Stations: A Manual for Decision-Making.* July 2002. Accessed 6 May 2004: http://www.epa.gov/epaoswer/non-hw/muncpl/pubs/r02002.pdf
[28] Available at http://www.epa.gov/compliance/environmentaljustice/index.html
[29] United States Environmental Protection Agency, *Toolkit for Assessing Potential Allegations of Environmental Injustice, Draft.* September 8, 2003. Accessed 6 May 2004: http://www.epa.gov/compliance/resources/publications/ej/ej_toolkit.pdf
[30] Bowen, William M. and Wells, Michael V.
[31] Maantay, Juliana.

Porras and Sadd in examining the theory of "minority move-in" is also a worthy effort in this vain.[32] Lastly, a need exists to determine whether the ideal of environmental justice is adequately promoted and enforced by government agencies across the nation. Knowledge of environmental disparities exists, and it is crucial to ensure that steps are being taken to correct these injustices to protect communities bearing heavy environmental burdens.

[32] Morello-Frosch, R., Pastor Jr., M., Porras, C., and Sadd, J.

Chapter 8
Environmental Equity Issues Associated with the Location of Waste Transfer Stations in the South Bronx

Zvia Segal Naphtali

Executive Summary

This chapter of the report summarizes the results of a study exploring environmental equity issues associated with the location of Waste Transfer Stations in the South Bronx in New York City. The two main objectives of the study are: (1) to develop and test the use of GIS techniques and models that will facilitate and streamline the analysis of demographic and socio-economic data about the people living in close proximity to these Waste Transfer Stations; and (2) to determine whether a disproportionate number of people from specific racial or ethnic or socioeconomic groups live in proximity to these sites.

The analysis of the racial, ethnic, and socioeconomic characteristics of the population around the existing Waste Transfer Stations in the Bronx was conducted primarily for those residing within one mile of the Waste Transfer Stations. A set of four distances ranging from ¼ mile, ½, ¾ and 1 mile buffers of the Waste Transfer Sites were evaluated for the relative stability of these characteristics in the immediate vicinity of the sites.

Information on racial and ethnic characteristics was obtained from the 2000 Census data at the Census Block level (which is the smallest geographic unit for which these data from the census are available). Information on socioeconomic characteristics -- income, poverty and housing values – was obtained from the 2000 Census data aggregated at the Census Block Group level (which is the smallest geographic unit for which these data from the census are available).

Waste Transfer Stations in the South Bronx

The data for the location of the Waste Transfer Stations was obtained from the New York City Department of Sanitation. **Waste Transfer Stations** are facilities where haulers take trash, recyclables, and construction waste. Material is then moved and delivered to its corresponding facility for processing and disposal. Transfer stations are defined as fixed facilities used for the primary purpose of transferring solid waste from one solid waste transportation vehicle to another. Waste transfer stations are divided into three categories according to the type of waste they handle:

- **Putrescible Material:** Refers to food wastes and organic matter that rots and decomposes.
- **Non-Putrescible Material** are other materials such as paper and cardboard.
- **Fill materials** are construction wastes.

According to the NYC Solid Waste Management Plan, New Yorkers discard over 13,000 tons of residential trash every day. In addition, it is estimated that the city generates over 20,000 tons of commercial waste per day. In order to discard this waste New York City has about 63 private waste transfer stations. These transfer stations are generally located in neighborhoods that are zoned for manufacturing uses. Because several areas in the South Bronx are designated for such uses, it has a disproportionate share of these facilities. Approximately 15 waste transfer stations, or about 24% of the city's total number of these stations, are estimated to be located there. These stations handle over 31% of New York City's solid waste. Meanwhile, the South Bronx has about 6.5% of the City's population.

As described in chapter 2 of the Phase I report of this project, it is estimated that more than 3,000 trucks drive through the Hunts Point peninsula of the South Bronx every day as a result of waste transfer and other commercial activities. Due to such high levels of diesel truck traffic, residents have been complaining for years about air and noise pollution. Many residents believe that the diesel fumes associated with traffic generated by these activities are associated with the asthma rates observed in the South Bronx. These rates are among the highest in the United States and have been steadily increasing since 1980.

Highlights of the Findings

ON CENSUS BLOCKS AND BLOCK GROUPS

The general findings with respect to socio-economic, racial and ethnic characteristics – including race, ethnicity, household income, poverty and housing value -- of the populations that live within a mile or less of the Waste Transfer Stations (WTS) locations are summarized briefly below. A more detailed discussion is provided in the conclusions section.

- Populations living in close proximity (within 1 mile) to the south Bronx Waste Transfer Sites tend to be more Black and Hispanic than in the Bronx as a whole.
- Their socioeconomic characteristics – median household income, poverty status, value of owner-occupied housing units – are generally lower within one mile distance from the Waste Transfer Stations than in the Study Area, the Bronx as a whole, and the other boroughs.

Importance of the study

An equity study based on the location of Waste Transfer Stations in the South Bronx is significant since this area has a higher proportion of Blacks and Hispanics relative to other boroughs in New York City.

I. INTRODUCTION

Objectives

Environmental equity has been an issue on the national agenda for several decades. By now a number of effective environmental justice assessment techniques have been developed. This study makes a contribution to these efforts by developing a GIS model that streamlines such an assessment.

- The main objective of this research component of the project is to use Geographic Information Systems (GIS) to study the association between the spatial location of waste transfer stations and variables related to demographics such as race and ethnicity and socio-economic conditions such as poverty, median household income, and housing values.

- The overall research question is whether local communities around Waste Transfer Stations bear disproportionate burdens caused by the siting of these facilities. Specifically, the study compares the percentages of Black and Hispanic residents within given radii of waste transfer stations with those of Bronx Borough and New York City. It also looks at household income, poverty and owner-occupied housing values within given radii of the waste transfer stations.

Finally, the objective of this study and this report is to describe a method for performing an environmental justice assessment using modeling techniques that are available in ArcGIS, one of the leading software packages. It is intended to make the method more available, to simplify the process of selecting appropriate techniques, and to guide the reader in carrying out the assessment.

Synopsis of the Methodology

GIS is used to analyze the demographic characteristics around waste transfer stations in the South Bronx section of New York City. The purpose of the analysis is to characterize the demographic composition of minority populations in proximity to South Bronx waste transfer stations, and examine the extent to which these local communities may bear disproportionate burdens caused by the siting of these transfer stations. Block- and block group data from Census 2000 are used in the analysis.

Buffers of different radii were drawn around each waste transfer station: 1/4 mile, 1/2 mile, 3/4 and 1 mile. <u>In each case, statistics are calculated for the entire buffer area including smaller buffers within them (the ½ mile buffer includes the ¼ mile)</u>. The total population and the number of Blacks and Hispanics in the buffered areas were calculated. The data are then aggregated across all transfer stations along the 1/4 mile, 1/2 mile, and 3/4 and 1 mile groupings, and compared to average percentages of Black and Hispanic residents in reference areas such as the South Bronx, Bronx County and New York City to determine if localized disparities exist.

Additional socio-economic variables by Census Block Groups were examined. These variables include poverty, median household income and housing values.

Buffers of different radii were drawn around each waste transfer station: 1/4 mile, 1/2 mile, 3/4 and 1 mile. The number of people in poverty was totaled across Census Block Groups and the percentage in poverty was calculated for each buffer distance.

To compute median household income, a more complex method was required. The census data provides information on the number of households in each interval of household income. The number of households in each interval in each of the Census Block Groups in a buffer was added up for each buffer distance. In this way the total number of households in each of the intervals of household income was calculated, for each buffer distance. These were used to estimate the median values for household income for each buffer distance.

II. Using GIS based Techniques to Estimate the Demographic Characteristics of Populations Near the Waste Transfer Stations

GIS-based Techniques to Estimate Demographic Characteristics[33]

There are three common GIS-based methods for estimating study area population characteristics. They are known as (1) areal interpolation, (2) polygon intersection, and (3) polygon containment. Each involves a different approach for identifying the census reporting units that overlay a study area. The chart below shows the effects of these three methods.

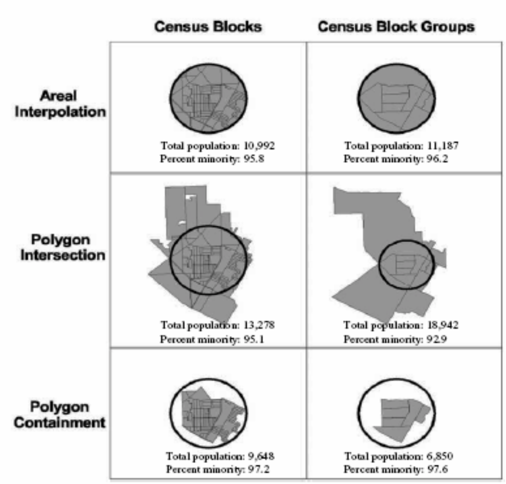


Figure 2-2. Census reporting units and study area geography

33 This discussion is based on a recent section in a report on "Effective Methods for Environmental Justice Assessment" (NCHRP Report 532), published by Transportation Research Board, the National Cooperative Highway Research Program, 2004, page 31

The value of inspecting and discussing this chart is that it provides a basis for evaluating the advantages and disadvantages of different ways of buffering the Waste Transfer Stations.

METHOD 1: AREAL INTERPOLATION

The first method is called "Areal Interpolation" and is considered the most accurate of the three methods. The most common way of doing Areal Interpolation is the area-weighted interpolation. The use of the method is based on an assumption that populations within the census units (blocks or block groups) are uniformly distributed which is clearly not the case in the area that is the focus of this report[34].

Even a cursory examination of the census data for the blocks and block groups that make up the buffers which were created shows that it is not possible to assume a uniform distribution of population. This assumption does not hold for this area of the South Bronx. A number of blocks or block groups near the Waste Transfer Stations were zoned for commercial or industrial use or have parks and have population only at the edges of the blocks or block groups. There were almost no blocks or block groups that contained only parks with no populations.

The second Areal Interpolation approach takes into consideration the non-uniform distribution of the population. This type of area-weighted interpolation could have been used, if there were a practical method to carry it out. For example, areas zoned for commercial or industrial use which are unpopulated can possibly be subtracted from the calculations of areas. The parks could not be subtracted because when a block is split, it is also difficult to know how the population should be distributed.

Finally, these area-weighted methods of Areal interpolation are difficult to apply with the software available and would also require a finer grain and detailed census block by block analysis.

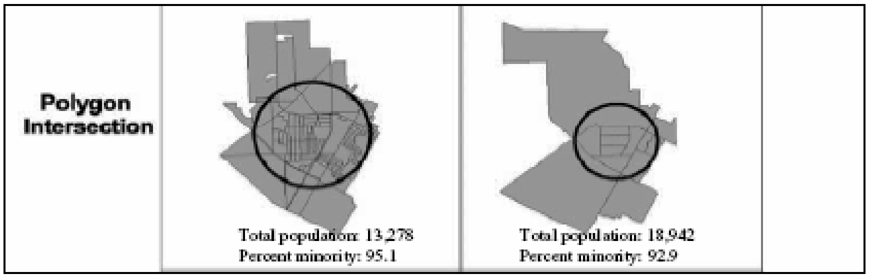
ArcGIS software can be used to perform the other types of analysis discussed below, i.e. Polygon Intersection and Polygon Containment. In particular, the model building facility in ArcGIS 9, which was used, can readily be set up to do the Polygon Intersection type of analysis.

METHOD 2: POLYGON INTERSECTION

Polygon Intersection tends to over-predict population. This method includes in the totals each census block or block group which is within the selected buffer distance, or which is intersected by the buffer as shown in the picture below. This is the method that was used. The picture below shows what happens when the edges of the buffer intersect Census Blocks or Census Block Groups which are relatively large compared to those in the interior of the buffer. The picture seems to imply a large error created by selecting a substantial area which is really further away than implied by the buffer distance. The reality is that some of the Census Blocks or Census Block Groups are larger because they are sparsely populated or unpopulated.

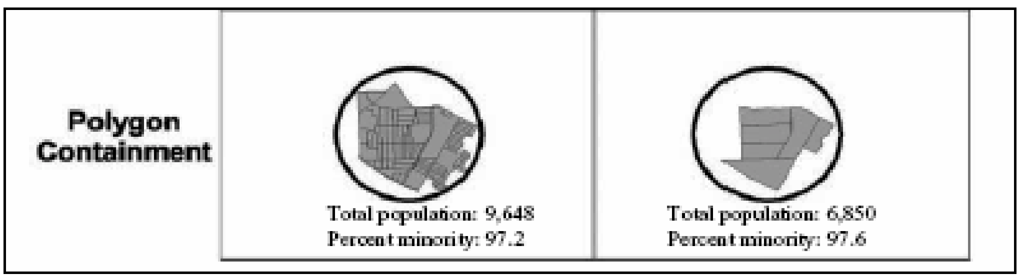
[34] In the next section the non-uniform distribution of the population in the areas close to the Waste Transfer Stations is discussed – see section on "unpopulated" census blocks and block groups.

Census Block Census Block Group



This method is readily available with the model building function in ArcGIS 9.

METHOD 3: POLYGON CONTAINMENT



The Polygon Containment method tends to under-predict population. This method includes in the totals ONLY those census units that are entirely within the selected buffer distance. It excludes the census units that are not intersected by the buffer. A variation on this is a method provided by ArcGIS in which the centroid of each polygon is used to determine if it is included within the buffer, instead of requiring the entire polygon to be within the buffer. However, this method of selection is not available with the model building function in ArcGIS 9.

MODEL BUILDING

The Advantages of Using an ArcGIS model
to Facilitate the Demographic Analysis Using Buffers

In order to perform the analyses for this study, several steps were required, repeatedly and in the same sequence for various sets of data.

The basic tasks were:

(a) To create buffers with a specified distance (¼ mile, ½ mile, ¾ mile and 1 mile) around a set of selected points, for example, the Waste Transfer Stations that handle putrescible material.

(b) To select the regions (Census Blocks or Census Block Groups) that are inside the buffers or are intersected by the buffers.

(c) To aggregate data in the selected regions (e.g. total population, population in specific ethnic or racial categories, number of households in specific income categories, etc.)

(d) To produce a table with the aggregated data for the buffer radius specified. For this task a spreadsheet was used.

With the model, the basic tasks (described in a-c above) can be easily repeated for different specified distances from the selected points (the selected Waste Transfer Stations) to create the data needed to analyze the effects of distance from the selected points. The data for various distances from the selected points was exported to a spreadsheet, where the effects of various distances from the selected points were analyzed (e.g. Waste Transfer Stations that handle putrescible material).

The advantage of working with a model over doing each step separately is the increase in efficiency because input data can be altered and the model can be executed again for another set of data. For example, the ArcGIS model that was constructed increased the efficiency in executing the larger task. At the beginning stage of work, a set of different distances was used (1/8 mile, ¼ mile, 3/8 mile, ½ mile, 5/8 mile, ¾ mile, 7/8 mile and 1 mile). When the data indicated that another set of distances was needed (see discussion of "unpopulated Census Blocks" below), it was possible to easily repeat the analysis with a different set of buffers (¼ mile, ½ mile, ¾ mile and 1 mile).

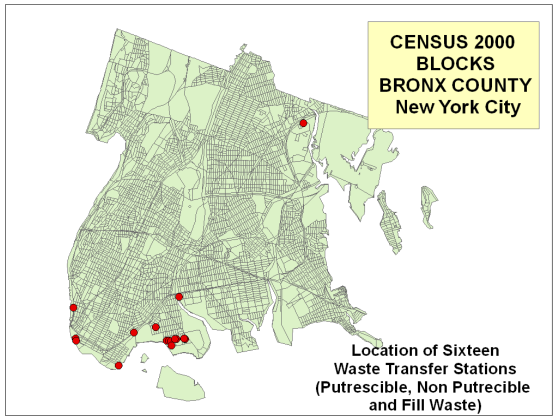
Furthermore, the analysis for different distances (¼ mile, ½ mile, ¾ mile and 1 mile) can be repeated for different types of underlying Census Block data, or Census Block Group Data, and for different selections of points (e.g. All Waste Transfer Stations, Waste Transfer Stations that handle construction waste or schools or water treatment plants, etc.)

THE BUFFERS

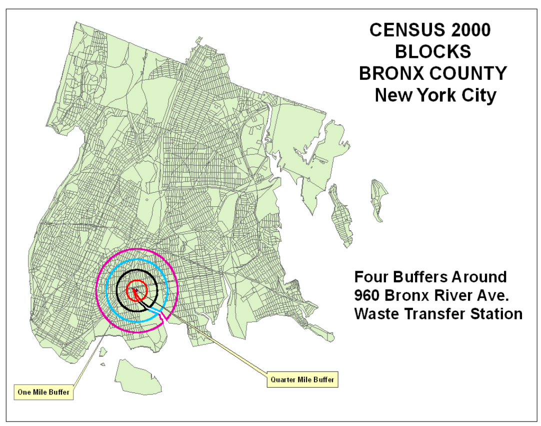
A critical variable determining the impact of facilities like Waste Transfer Stations on the community is the distance between the facility and the people affected.

This study uses four buffers of fixed radius around the Waste Transfer Stations, and data by Census Blocks or Census Block Groups to examine the demographic and socio-economic characteristics of the people who live in the study area. A set of four distances -- ¼ mile, ½, ¾ and 1 mile buffers -- of the Waste Transfer Sites were evaluated for the relative stability of these characteristics in the immediate vicinity of the sites. Also compared were the demographic and socio-economic characteristics of the people who live in the study area with those of the borough and the city as a whole.

Location of Waste Transfer Stations in
Bronx County and Census Blocks



Sample Map of Radii Around a Waste
Transfer Station: ¼, ½, ¾, and 1 Mile Radii

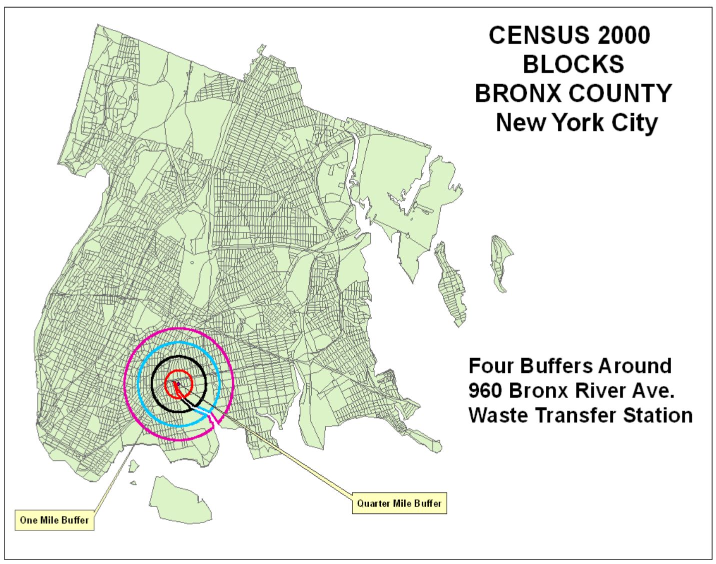


The size and number of buffers that were finally settled on were the result of a close study of the characteristics of the areas in close proximity to the Waste Transfer Stations.

At the first stage of this study the Census blocks and block groups in the immediate vicinity of the Waste Transfer Stations were closely inspected. Although other possibilities were considered, a decision was made to use four buffers (¼ mile, ½ mile, ¾ mile and one mile). This decision was arrived at after testing a number of possible distances such as buffers in 1/8 mile increments around the Waste Transfer Stations. There are a large number of "unpopulated" census blocks and block groups in the areas close to the shoreline and adjacent to most of the Waste Transfer Stations. These areas are largely unpopulated because they are zoned for commercial and industrial use. Therefore, using a 1/8 mile buffer did not make sense and ¼ mile increments were tried instead. The results appeared to be more productive. The final study was conducted using distances of ¼ mile, ½ mile, ¾ mile and one mile producing results that can be interpreted.

Clear differences were found between the characteristics of the populations in close proximity to the Waste Transfer Stations and those at greater distances. It also became evident that at a distance greater than one mile the data tended to level out, and become more like the Bronx as a whole. Also, when buffering all the Waste Transfer Stations, or all the putrescible Waste Transfer Stations, buffers greater than one mile radius took in an area which included a substantial part of the entire Bronx.

Sample Map of Radii Around a Waste Transfer Station: ¼, ½, ¾, and 1 Mile Radii



ON USING SMALL-AREA CENSUS DATA: CENSUS BLOCKS AND BLOCK GROUPS

The smallest units of data provided in 2000 Census reports that are below the level of tracts or counties are Census blocks and block groups. These small-area census data offer the most detailed demographic information useful for our analysis and are best to use in situations where the scale of effects to be analyzed requires a high degree of demographic resolution, such as when effects are limited to relatively small, localized areas[35].

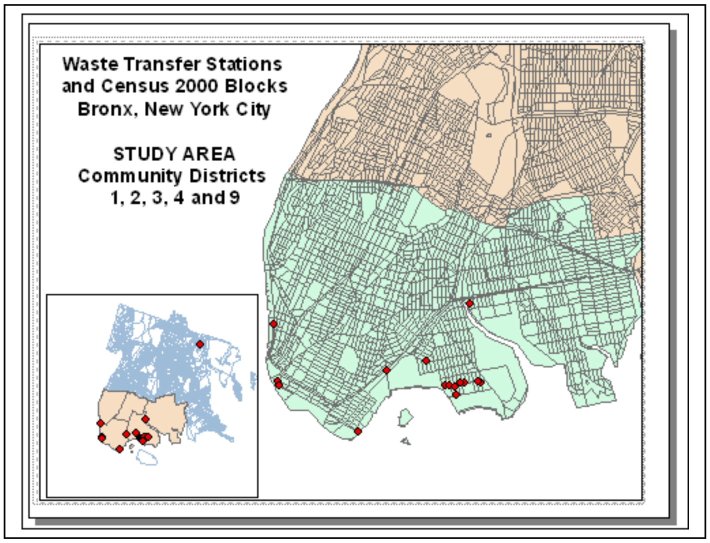
[35] This discussion is based on a section in a report on "Effective Methods for Environmental Justice Assessment" (NCHRP Report 532), published by Transportation Research Board, the National Cooperative Highway Research Program, 2004, page 31

Small-area census data can also be used if results of studies using large-area census data are questioned, making it necessary to obtain the "best available" or most accurate census data. Finally, a combination of Census block groups and blocks is needed because, while blocks offer the highest level of resolution, not all potentially necessary data are reported at the block level (for example, poverty, income and housing value).

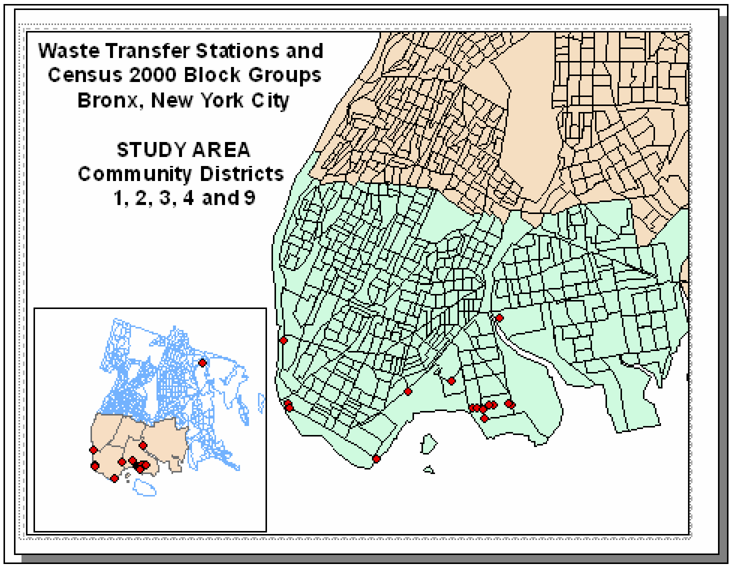
OVERLAYING DEMOGRAPHIC DATA WITH BUFFERS

Census Blocks and Block Groups are bounded on all sides by visible features such as streets, shoreline, etc. The maps below show the Census 2000 blocks and block groups, the study area boundaries and the location of the Waste Transfer Stations.

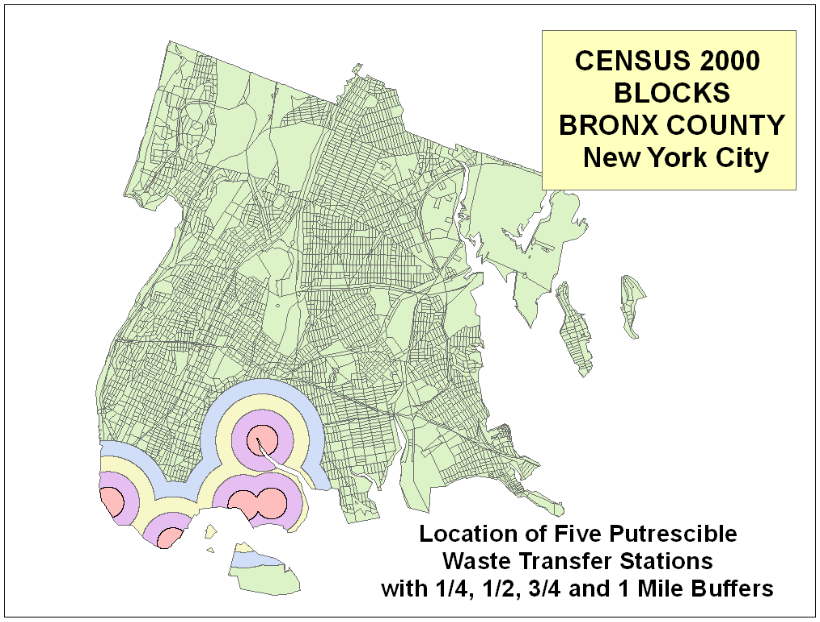
CENSUS BLOCKS

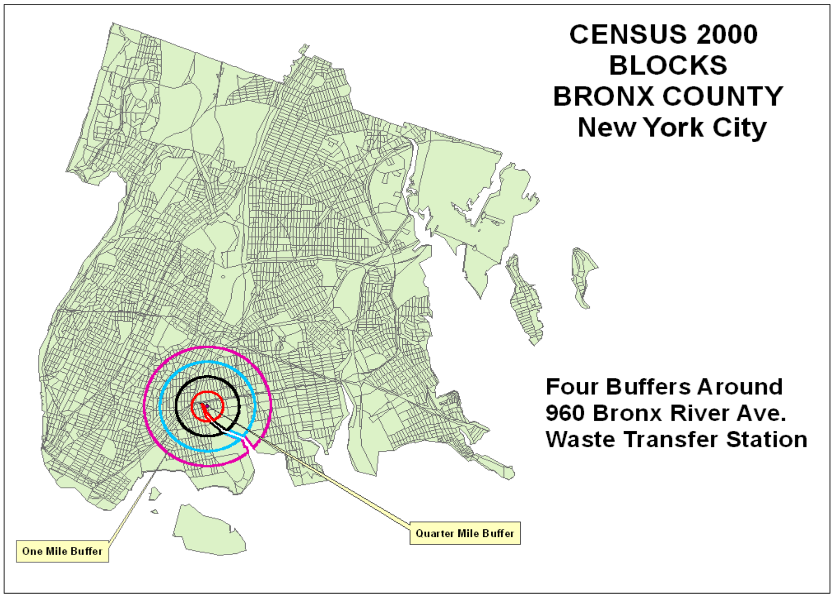


CENSUS BLOCK GROUPS



Since buffers do not coincide exactly with the boundaries of the Census Blocks and Block Groups, a method was needed to estimate the population characteristics of the buffer area.





AN EXAMINATION OF THE CENSUS 2000 DATA

ON UNPOPULATED CENSUS BLOCKS AND CENSUS BLOCK GROUPS

Maps and data for the **CENSUS BLOCKS** of the Bronx were downloaded from the New York State Data Center web site. The Census SF-1 (Summary File 1) file has a limited number of variables of interest. These include Total Population, Race and Hispanic origin.

The Census SF-3 file provided the data on income, poverty, and owner-occupied housing values. This data is not available for **CENSUS BLOCKS**, the smallest geography available.

CENSUS BLOCK GROUPS

The variables for the Census Blocks were part of the ArcGIS map file and therefore no further work was needed to retrieve variables from a larger file. On the other hand, the data for income, poverty, and housing values were obtained from the New York State Data Center and were available as an SPSS file (with a data dictionary attached). The variables household income, poverty, and owner-occupied housing values had to be extracted from the SF-3 files and prepared for analysis.

Below is a report on the percent Unpopulated Census Blocks (Part 1) and the percent Unpopulated Census Block Groups (Part 2)[36].

Finally, the effects of unpopulated Census Blocks and Block Groups on the analysis are also discussed as is the effect of sparsely populated areas on the size of buffers that can be used in the analysis.

PART 1:
UNPOPULATED CENSUS BLOCKS

In the Bronx as a whole -- There are 4,885 Census Blocks of which 1,189 blocks (24.3%) are unpopulated (i.e., have a population of zero).

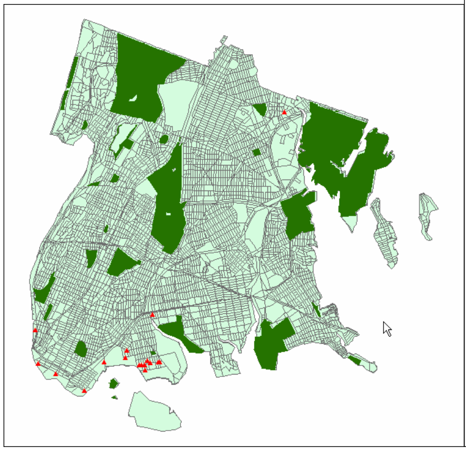
For the **Study Area** (Community Districts 1, 2, 3, 4 and 9) the percent unpopulated is higher – 34.8% (604 out of the 1734 Census Blocks are unpopulated).

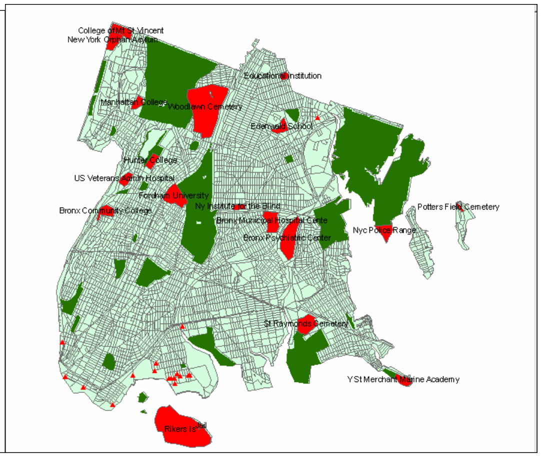
The analysis began with a visual investigation of the unpopulated Census Blocks to determine whether they are just unpopulated Blocks or whether they include (or are entirely) parks, cemeteries, schools, jails, etc.

[36] See below on the various issues that surfaced in the process of working with the Census SF-3 data for Block Groups data.

The Waste Transfer Stations were placed on the map and also the Bronx parks to investigate this question: Are any of the unpopulated areas parks?

The map (on the left below) shows, most parks are in the northern part of the Bronx. How about Cemeteries, educational institutions, jails, etc.? Again, most of them are not in the study area (with the exception of Riker's Island).





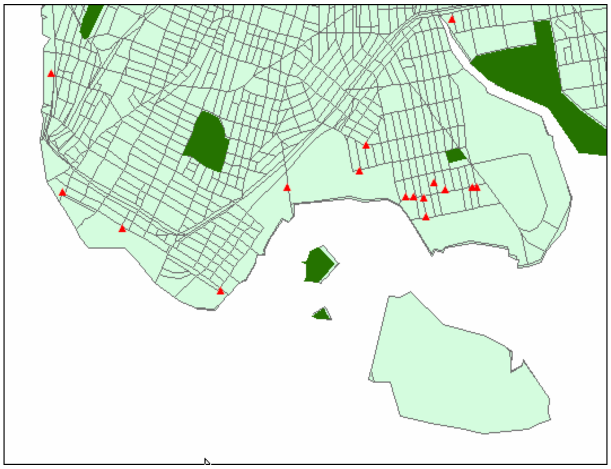
Parks in the Bronx (Green areas) Cemeteries, hospitals, educational institutions, jails (Red areas)

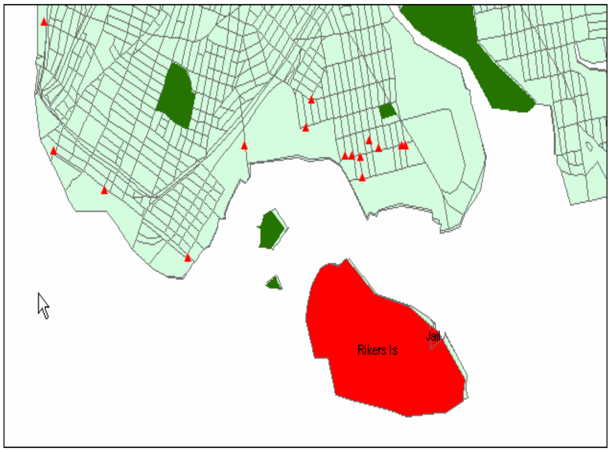
NOTE: The geographic locations of each of the small Parks in the Study Area were also examined. First, their location has to be adjusted because some of them were slightly displaced. It was discovered that each of these parks was occupying a populated Census Block and they therefore cannot be simply excluded as "unpopulated".

As is clear from the map on the right above, other places such as cemeteries, etc., are of no concern regarding the question of whether they are populated, since they are not in the study area.

The Case of Riker's Island

The case of Riker's Island is worth mentioning. It is a populated Census Block but since it has a special population it was decided that it should not be included in the analysis. The total population is 12,780 of which 3443 are Hispanics (of all races), 7897 are Blacks, 1584 are White, etc.

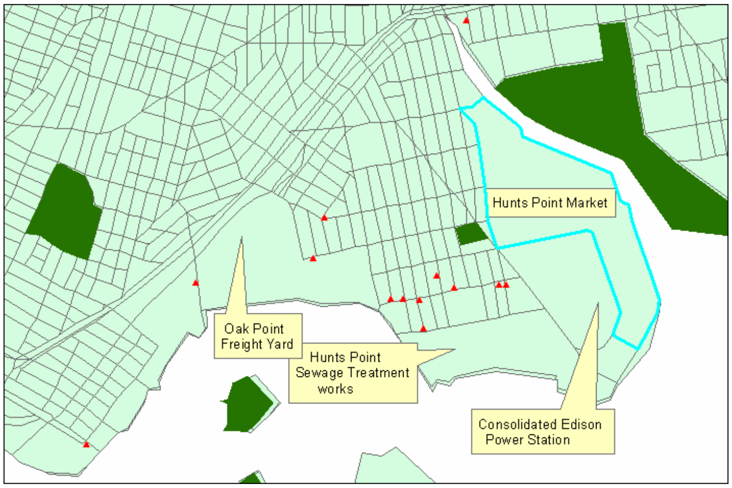




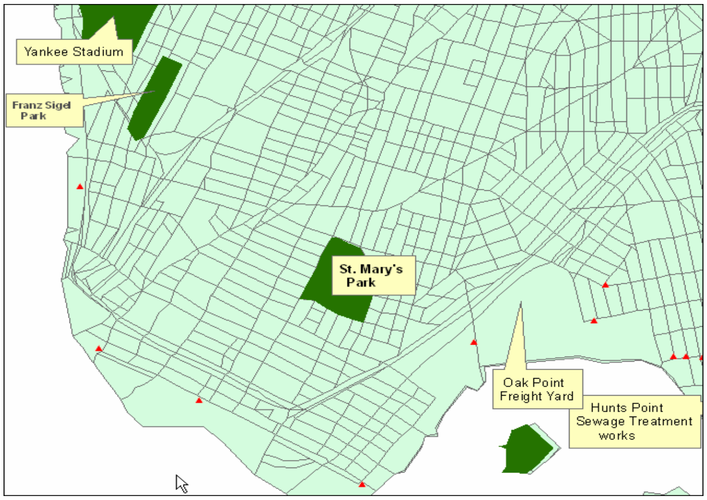
Riker's Island population is in
a jail
Riker's Island is a single Census Block

UNPOPULATED CENSUS BLOCKS: FURTHER ANALYSIS

Using the Hagstrom Map as a guide, the large Census Blocks were investigated in the area surrounding the cluster of the Waste Transfer Stations on the southern part of the Bronx. They are shown in the map below. These include the Hunts Point Market, the Consolidated Edison Power Station, the Hunts Point Sewage Plant, the Oak Point Freight Yard, and other railroad yards around the edge of the Bronx. **All are unpopulated!**



Moving along the shoreline to the west and inspecting the population composition of the Census blocks surrounding the remaining Waste Transfer Stations, the same situation exists. Railyards and freight terminals run along the shoreline and blocks near them are unpopulated.

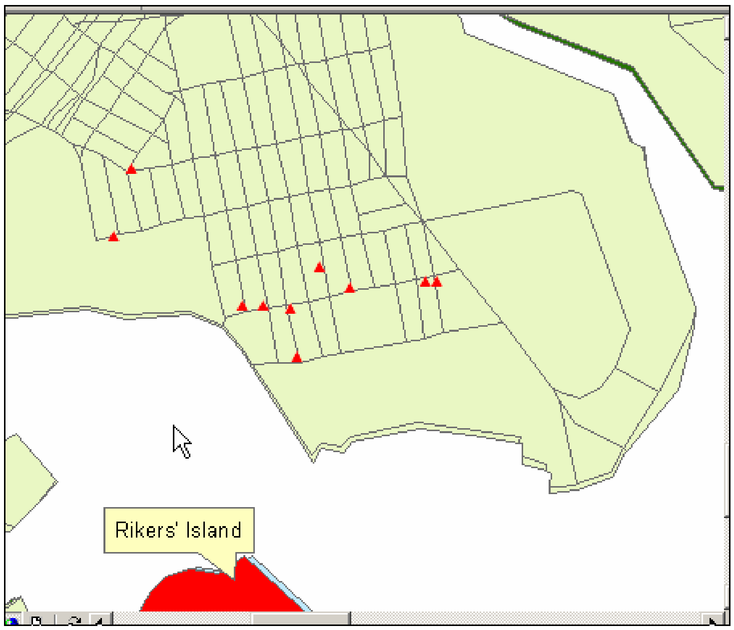


Conclusion:

Inspecting the Census Blocks surrounding the Waste Transfer Stations visually revealed that there will be a substantial number of unpopulated Census Blocks in the buffers surrounding them.

A Discussion of the Potential Effect of Unpopulated Blocks on the Sizes of Buffers That Can Be Used In the Analysis

The map below shows the cluster of Waste Transfer Stations (WTS) in the southeast Bronx and the Census Blocks. While the WTS are close to each other, it appears that there is no census block with more than one WTS. However, the small Census blocks containing the WTS, as well as those that are north of them, are largely unpopulated. The larger Census Blocks were discussed above and these are all unpopulated. Therefore, buffers of 1/8 mile may include few, if any, people. Larger buffers were, therefore, used in the analysis of the demographics and socio-economic characteristics.



UNPOPULATED CENSUS BLOCKS IN THE STUDY AREA
Community Districts 1, 2, 3, 4 and 9

The latest Community Districts maps for New York City were downloaded from the website of the New York City Department of City Planning (NYCDCP) and the Borough of the Bronx was clipped out. A separate map was created for Community Districts 1, 2, 3, 4 and 9, which comprise the study area. Next, the percent unpopulated Census Blocks in the Study area was calculated.

The percent unpopulated in the Study Area (Community Districts 1, 2, 3, 4 and 9) is much higher -- 34.8% (604 out of the 1734 Census Blocks are unpopulated) -- than in the Bronx as a whole [There are 4885 Census Blocks of which 1189 blocks (24.3%) are unpopulated (i.e., have a population of zero)].

PART 2: UNPOPULATED CENSUS BLOCK GROUPS

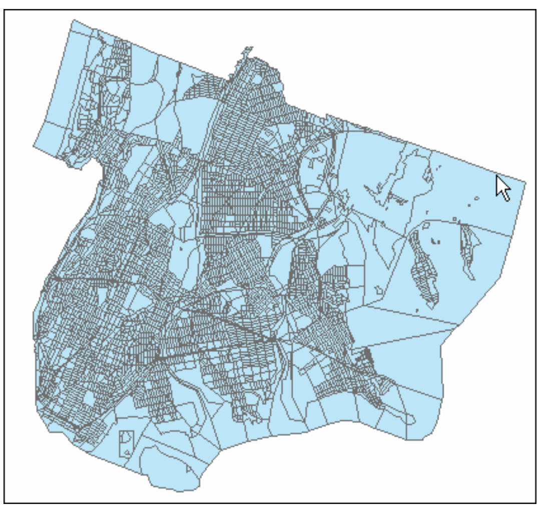
Preparing the data

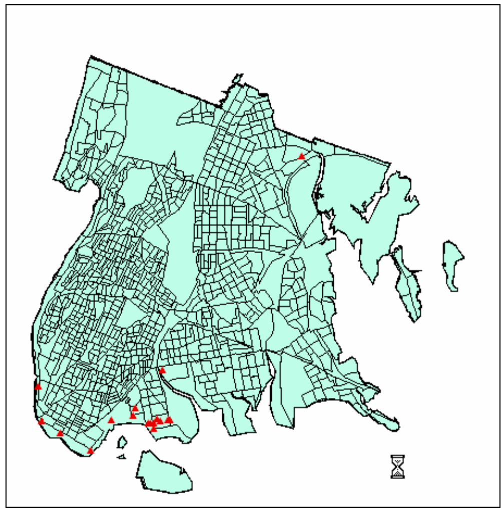
The variables of interest are household income, poverty, and owner-occupied housing values. These variables were extracted from the SF-3 files (made available to us by the NYS Data Center in SPSS format) and prepared for analysis (see further discussion below). The desired variables were next extracted from the SPSS file and saved as separate files. The smaller SPSS data files were next converted into dBase (the format acceptable in ArcGIS). These data files were brought into ArcGIS and linked to the map of the Census Block Groups (which was downloaded from the New York State Data Center web site).

Two files with data on: (1) Race, Poverty, and Income; and (2) Owner-occupied Housing values were created.

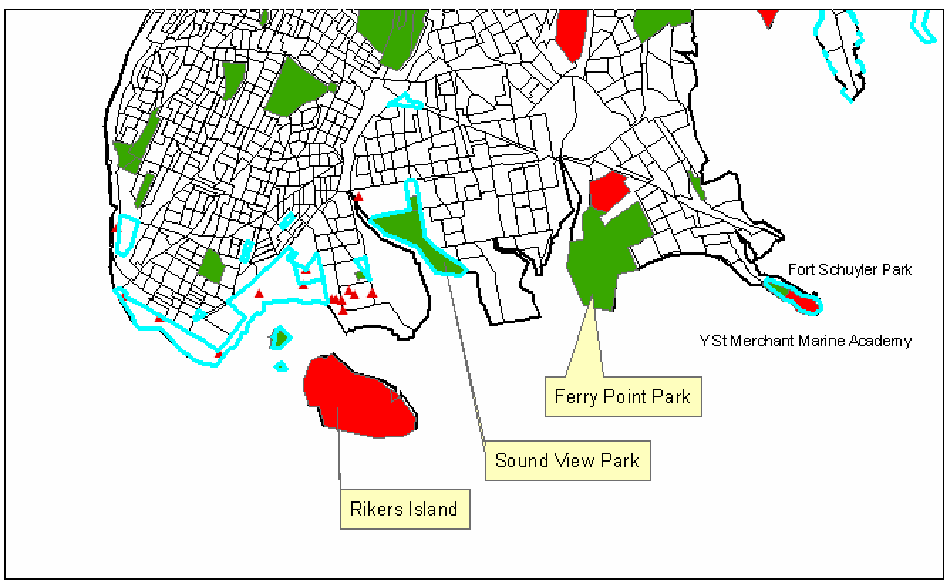
Preparing the Map -- Clipping out the water areas

Like the case of the Census Blocks, the clipped map -- "CLIPPED Bronx Block Groups" -- was carefully examined. It has 957 records. The unclipped and clipped maps were compared to determine whether any Census Block Groups were lost in the process of clipping. The unclipped map ("Bronx Block Groups") has the same number of records. No Block Groups were lost in the clipping of the water areas!

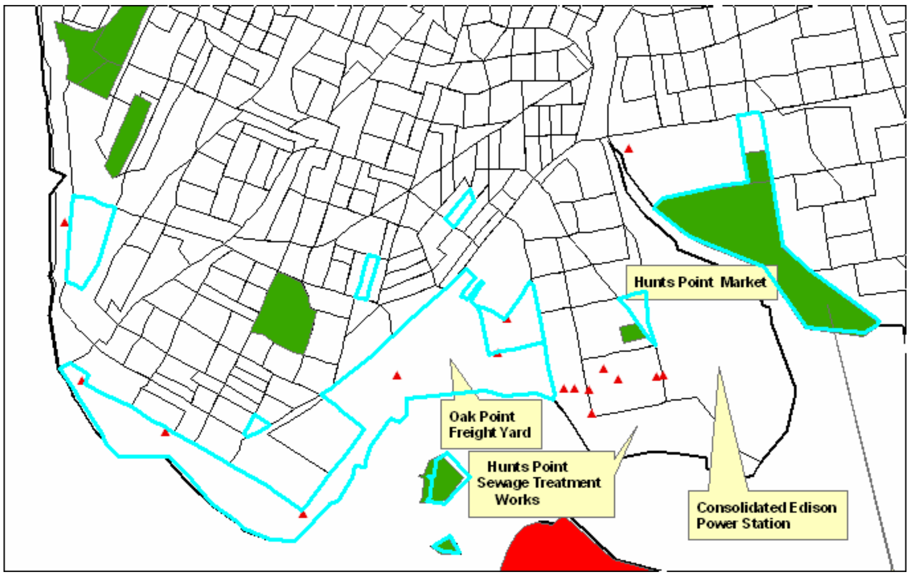




UNPOPULATED CENSUS BLOCK GROUPS
IN THE BRONX



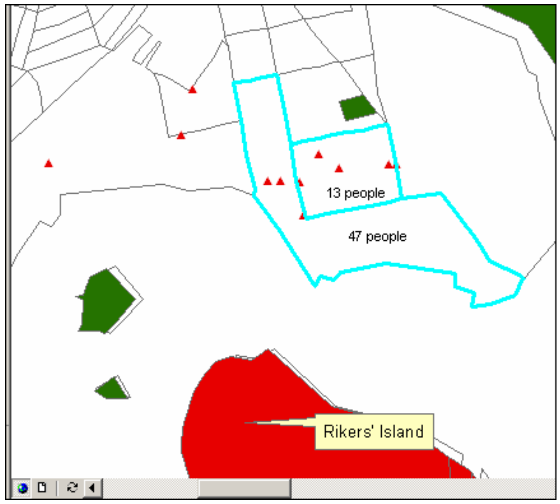
There are only 24 unpopulated Census Block Groups in the Bronx. There is a total of 957 Block Groups and 933 are populated. **The percent unpopulated is 1.8%.**



Like in the case of the Census Blocks, using the Hagstrom Map as a guide to what various places are, the large Census Block Groups surrounding the cluster of the Waste Transfer Stations on the southern part (including the Hunts Point Market, the Consolidated Edison Power Station, the Hunts Point Sewage Plant, the Oak Point Freight Yard, and other railroad yards around the edge of the Bronx) were visually investigated.

Some areas that were unpopulated when the Census Blocks were inspected now have people in the Block Groups. For example, there are 184 people listed in the Hunts Point Market Census Block Group. There are 47 people listed in the Census Block Group for the Hunts Point Sewage Treatment Works. Rail yards and freight terminals run along the shoreline. **There are no people listed for the Oak Point Freight yards.** Unlike the case of the Census blocks, the rail yards are now a single Census Block Group. Also, two of the Census Block Groups where most of the Waste Transfer Stations are located have very low populations –

There are 13 people in Block group 360050097002
There are 47 people in Block group 360050097003



CONCLUSION: Using small buffers around these Waste Transfer Stations will select this Census Block Group repeatedly. There is a limit to how much information one can generate about 13 people (or 47) from the Census, and clearly there will be difficulty in interpreting the data.

UNPOPULATED CENSUS BLOCK GROUPS IN THE STUDY AREA
Community Districts 1, 2, 3, 4 and 9

There are only 17 unpopulated Census Block Groups in the study area. There are 398 total Block Groups and 381 are populated. The percent unpopulated is 4.3%. Inspecting the Census Block Groups surrounding the Waste Transfer Stations visually revealed that some of the unpopulated Census Blocks Groups will surely fall in buffers surrounding the Waste Transfer Stations.

III. Results and Interpretations

A. Waste Transfer Stations and Demographic Analysis Using Buffers and data by Census 2000 Blocks

A. 1. Census Blocks Percent Black and Hispanic

The GIS MODEL was used to conduct demographic analysis using four buffers of 1/4, 1/2, 3/4 and 1 mile. The points buffered were Waste Transfer Stations in the Bronx.

The buffers are used to select Census Blocks and perform a demographic analysis. The percentage Blacks and Hispanics in the selected areas were calculated from total Bronx population counts. The data were then aggregated across selected transfer stations, as well as all of them, using distances of 1/4 mile, ½, 3/4 and 1 mile for buffers. The data were then compared to average percentages of Black and Hispanic residents in reference areas such as the South Bronx (Study Area), Bronx County and New York City to determine if localized disparities existed. A number of additional variables were examined next. These are available only at the Census Block Group level -- household income, poverty, and owner-occupied housing values.

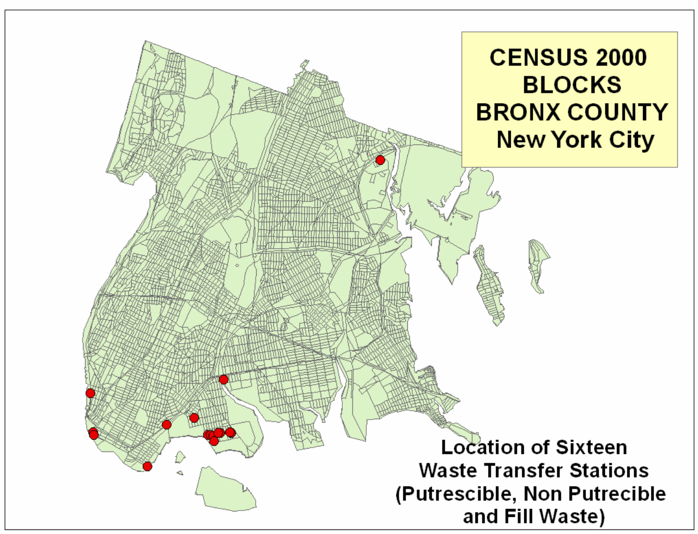
The section below begins with a demonstration and a discussion of the results of buffering ALL Waste Transfer Stations, all the Putrescible WTS and buffering each of two stations in order to inspect the characteristics of the population in the vicinity of individual WTS more closely.

Waste Transfer Stations and Demographic Analysis Using Buffers

The results obtained using the new Demographic Analysis Program are reported below for 1/4, 1/2, 3/4 and 1 mile buffers around All the Waste Transfer Stations and buffering, all the Putrescible Waste Transfer Stations and the Waste Transfer Station at 960 Bronx River Avenue and the 98 Lincoln Avenue WTS.

To avoid including the population of Rikers Island in the buffers, the maps were altered and Rikers Island was removed.

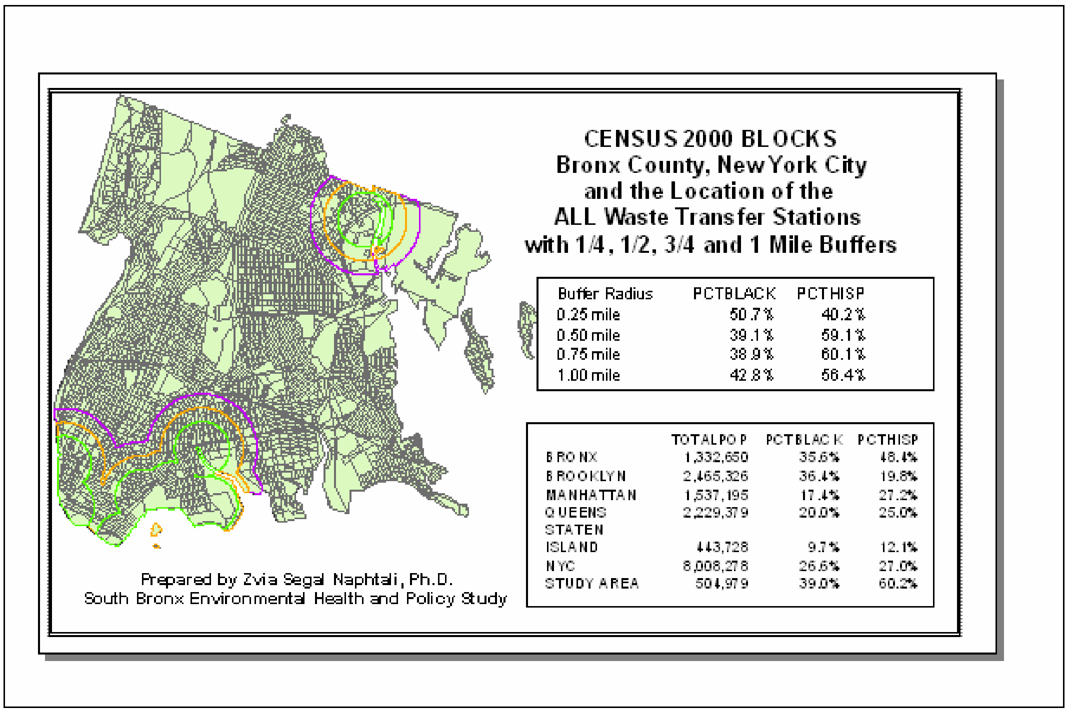
Demographic Characteristics Near
<u>All</u> Waste Transfer Stations



When the Waste Transfer Stations are closely clustered, one cannot simply add the demographics of the 16 Waste Transfer Stations taken one at a time. The buffers overlap each other. Calculating the number of people in several buffers separately means that some census blocks will be counted more than once. Therefore, the best way to proceed is to first combine the buffers in the program and avoid the overlaps.

Demographic Characteristics Near All Waste Transfer Stations

The exclusion of Rikers Island was necessary since some of the buffers would have included the population of Rikers Island.



Buffer Radius	PCTBLACK	PCTHISP
0.25 mile	50.7%	40.2%
0.50 mile	39.1%	59.1%
0.75 mile	38.9%	60.1%
1.00 mile	42.8%	56.4%

	TOTALPOP	PCTBLACK	PCTHISP
BRONX	1,332,650	35.6%	48.4%
BROOKLYN	2,465,326	36.4%	19.8%
MANHATTAN	1,537,195	17.4%	27.2%
QUEENS	2,229,379	20.0%	25.0%
STATEN ISLAND	443,728	9.7%	12.1%
NYC	8,008,278	26.6%	27.0%
STUDY AREA	504,979	39.0%	60.2%

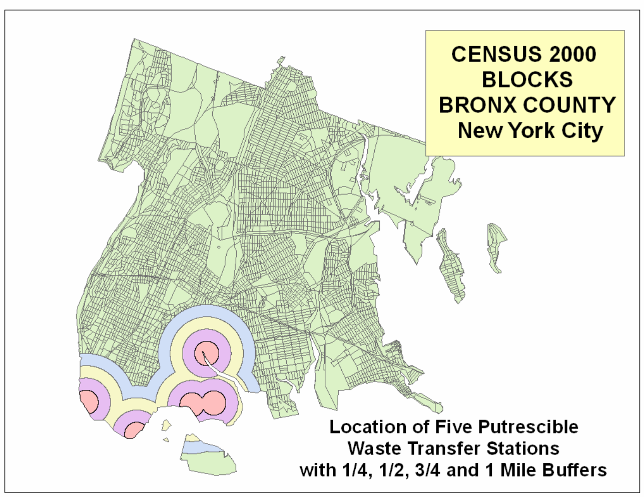
Percent Hispanic

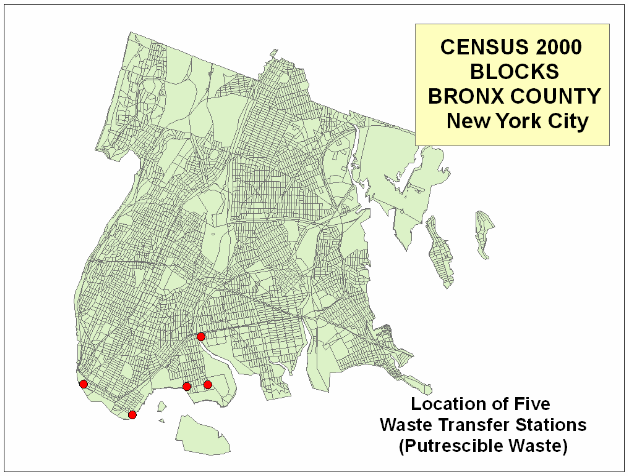
When all the WTS are buffered together, the percent Hispanic (40.2%) is lower within the 0.25 miles buffer than for the Bronx as a whole (48.4%) or the Study Area (at 60.2%). At larger distances from the WTS, the percent Hispanic approaches the level for the Study Area.

Percent Black

When all the WTS are buffered together, the percent Black is higher (50.7%) in the 0.25 miles buffer and declines at further distances from the Waste Transfer Stations. As the area taken in by the buffer increases, the percent Black begins to resemble that of the rest of the Bronx and the Study Area.

Demographic Characteristics of Areas
Near Putrescible Waste Transfer Stations

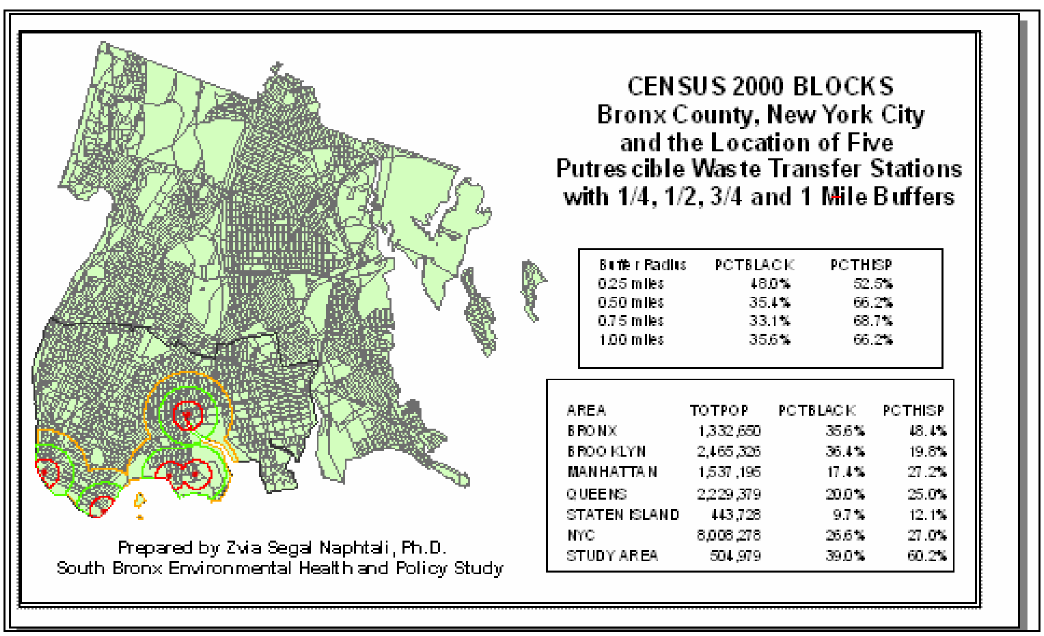




The Waste Transfer stations that handle Putrescible Waste are not as clustered together as ALL the Waste Transfer Stations. However, the buffers still overlap each other. Calculating the number of people in several buffers separately means that some census blocks will be counted more than once.

<u>Therefore, the best way to proceed is to first combine the buffers in our program and avoid the overlaps.</u>

Since the buffers in this case would include Rikers Island, as shown above, a map which excludes Rikers Island was created before analyzing the demographics in the buffers.



Buffer Radius	PCTBLACK	PCTHISP
0.25 miles	48.0%	52.5%
0.50 miles	35.4%	66.2%
0.75 miles	33.1%	68.7%
1.00 miles	35.6%	66.2%

AREA	TOTPOP	PCTBLACK	PCTHISP
BRONX	1,332,650	35.6%	48.4%
BROOKLYN	2,465,326	36.4%	19.8%
MANHATTAN	1,537,195	17.4%	27.2%
QUEENS	2,229,379	20.0%	25.0%
STATEN ISLAND	443,728	9.7%	12.1%
NYC	8,008,278	26.6%	27.0%
STUDY AREA	504,979	39.0%	60.2%

THE RESULTS:

Demographic Characteristics of Areas Near Putrescible Waste Transfer Stations

Buffer Radius	PCTBLACK	PCTHISP
0.25 miles	48.0%	52.5%
0.50 miles	35.4%	66.2%
0.75 miles	33.1%	68.7%
1.00 miles	35.6%	66.2%

AREA	TOTPOP	PCTBLACK	PCTHISP
BRONX	1,332,650	35.6%	48.4%
BROOKLYN	2,465,326	36.4%	19.8%
MANHATTAN	1,537,195	17.4%	27.2%
QUEENS	2,229,379	20.0%	25.0%
STATEN ISLAND	443,728	9.7%	12.1%
NYC	8,008,278	26.6%	27.0%
STUDY AREA	504,979	39.0%	60.2%

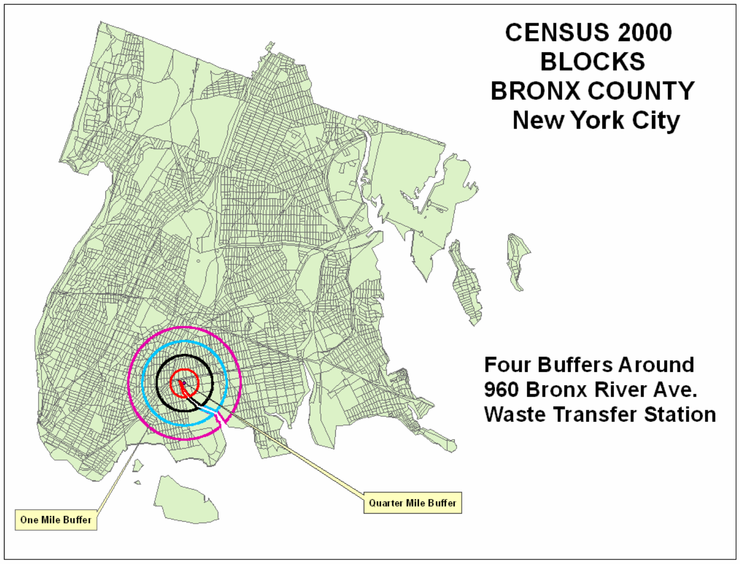
Percent Hispanic

When all the WTS handling Putrescible waste are buffered together, the percent Hispanic (52.5%) is higher within the 0.25 miles buffer than for the Bronx as a whole (48.4%) but lower than the Study Area (at 60.2%). At larger distances from the WTS, the percent Hispanic approaches the level for the Study Area.

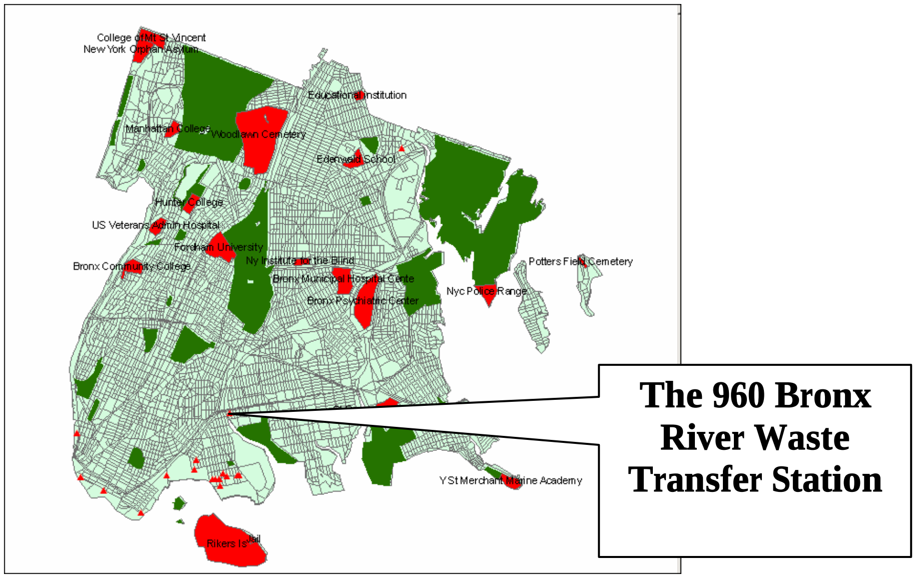
Percent Black

When all the Putrescible WTS are buffered together, the percent Black is higher 48.0% in the 0.25 miles buffer and declines at further distances from the Waste Transfer Stations. As the area taken in by the buffer increases, the percent Black begins to resemble that of the rest of the Bronx and the Study Area.

Two Waste Transfer Stations that handle Putrescible waste were also buffered (one at a time) and analyzed. As the map below shows, Rikers Island population was not included in any of the buffers around the **960 Bronx River Avenue Waste Transfer Station.**

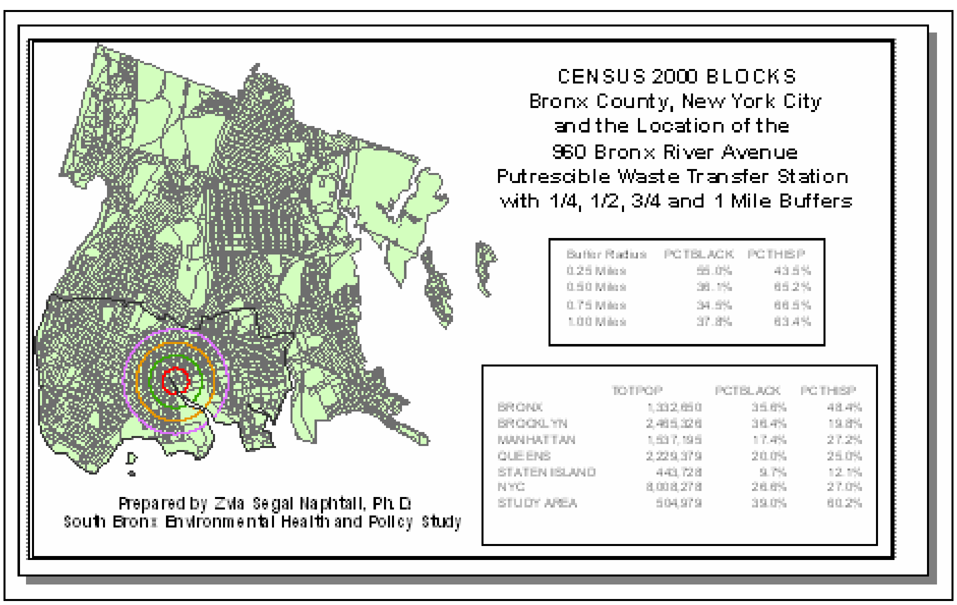


**Four Buffers around the
960 Bronx River Avenue Waste Transfer Station**



The map above shows cemeteries, hospitals, parks, educational institutions & Jails

960 Bronx River Avenue Waste Transfer Station
Percent Blacks and Hispanics in Four Buffers around the
960 Bronx River Avenue WTS



RESULTS: 960 Bronx River Avenue Waste Transfer Station

Buffer Radius	PCTBLACK	PCTHISP
0.25 Miles	55.0%	43.5%
0.50 Miles	36.1%	65.2%
0.75 Miles	34.5%	66.5%
1.00 Miles	37.8%	63.4%

Compared to other areas

PERCENT HISPANIC:

	TOTPOP	PCTBLACK	PCTHISP
BRONX	1,332,650	35.6%	48.4%
BROOKLYN	2,465,326	36.4%	19.8%
MANHATTAN	1,537,195	17.4%	27.2%
QUEENS	2,229,379	20.0%	25.0%
STATEN ISLAND	443,728	9.7%	12.1%
NYC	8,008,278	26.6%	27.0%
STUDY AREA	504,979	39.0%	60.2%

This Waste Transfer Station is closer to the central part of the Bronx and the percent Hispanic in the 0.25 mile buffer is similar to the percent Hispanics in the Bronx as a whole. It is substantially lower than in the Study Area (Community Districts 1, 2, 3, 4 and 9). The percent Hispanics in the three other buffers (65.2%, 66.5%, and 63.4%) is similar to that in the Study Area.

PERCENT BLACK

The pattern for Blacks (all blacks, including Hispanic Blacks) is the reverse. The further one moves from the WTS, the lower the percent black, reflecting the fact that areas closer to the water in general is populated by more Hispanics than Blacks.

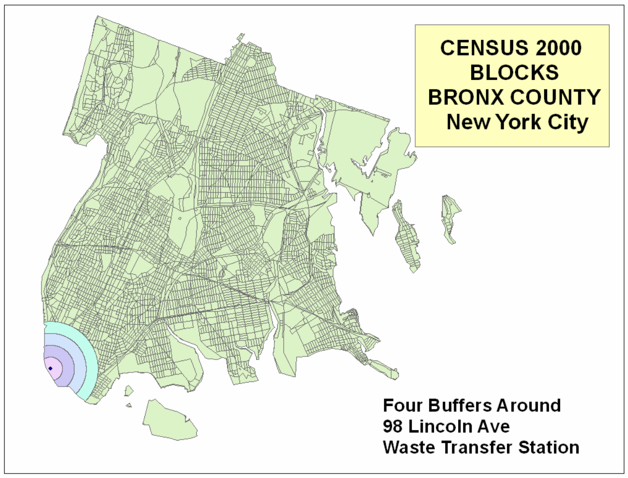
Buffer Radius	PCTBLACK
0.25 Miles	55.0%
0.50 Miles	36.1%
0.75 Miles	34.5%
1.00 Miles	37.8%

	TOTPOP	PCTBLACK	PCTHISP
BRONX	1,332,650	35.6%	48.4%
BROOKLYN	2,465,326	36.4%	19.8%
MANHATTAN	1,537,195	17.4%	27.2%
QUEENS	2,229,379	20.0%	25.0%
STATEN ISLAND	443,728	9.7%	12.1%
NYC	8,008,278	26.6%	27.0%
STUDY AREA	504,979	39.0%	60.2%

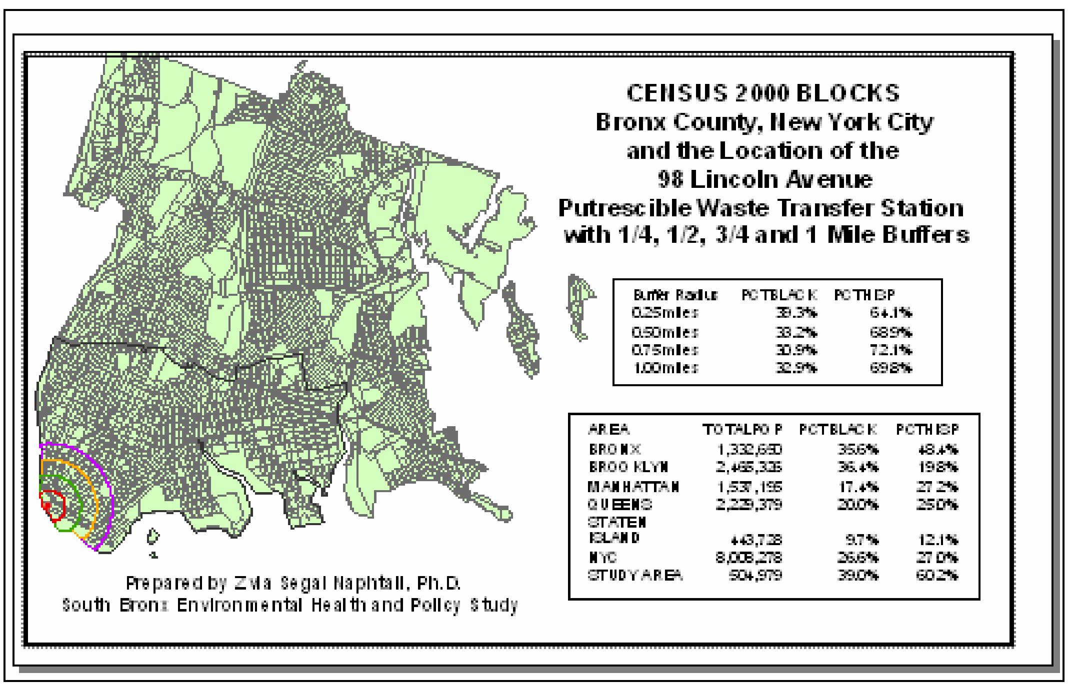
The 0.25 Miles radius around the 960 Bronx River Avenue WTS has a higher percentage Blacks than the Study Area or the Bronx as a whole (55.0% versus 35.6% for the Bronx as a whole and 39.0% for the Study Area).

Demographic Characteristics Near the 98 Lincoln Avenue Waste Transfer Station

The second Waste Transfer Station also handles Putrescible Waste and was chosen to represent the WTS closer to the water. Again the location of the Transfer Station is far enough from Rikers Island so that the population in the buffer does not include anyone in Rikers Island.



Again the percent Black and Hispanic in various size buffers were compared.



Buffer Radius	PCTBLACK	PCTHISP
0.25miles	39.3%	64.1%
0.50miles	33.2%	68.9%
0.75miles	30.9%	72.1%
1.00miles	32.9%	69.8%

AREA	TOTALPOP	PCTBLACK	PCTHISP
BRONX	1,332,650	35.6%	48.4%
BROOKLYN	2,465,326	36.4%	19.8%
MANHATTAN	1,537,195	17.4%	27.2%
QUEENS	2,229,379	20.0%	25.0%
STATEN ISLAND	443,728	9.7%	12.1%
NYC	8,008,278	26.6%	27.0%
STUDY AREA	504,979	39.0%	60.2%

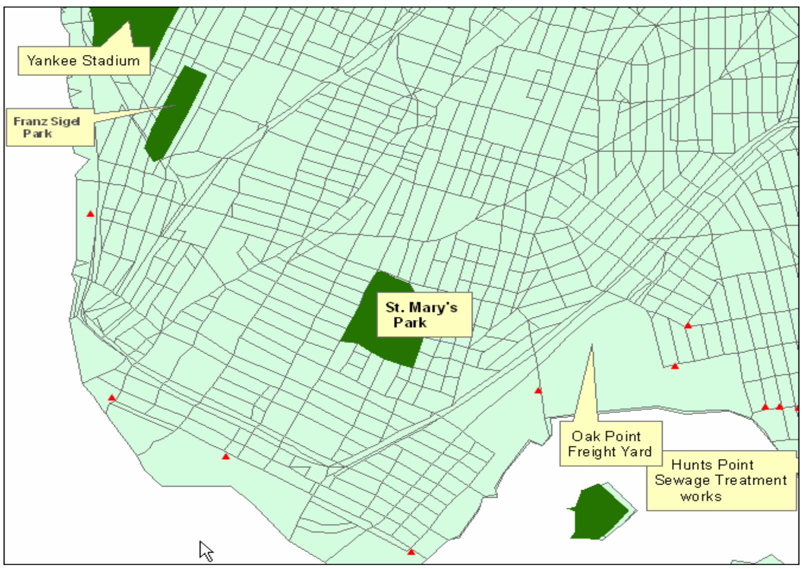
THE RESULTS:

Demographic Characteristics Near the 98 Lincoln Avenue Waste Transfer Station

Buffer Radius	PCTBLACK	PCTHISP
0.25 miles	39.3%	64.1%
0.50 miles	33.2%	68.9%
0.75 miles	30.9%	72.1%
1.00 miles	32.9%	69.8%

AREA	TOTALPOP	PCTBLACK	PCTHISP
BRONX	1,332,650	35.6%	48.4%
BROOKLYN	2,465,326	36.4%	19.8%
MANHATTAN	1,537,195	17.4%	27.2%
QUEENS	2,229,379	20.0%	25.0%
STATEN ISLAND	443,728	9.7%	12.1%
NYC	8,008,278	26.6%	27.0%
STUDY AREA	504,979	39.0%	60.2%

One point to keep in mind in examining the data for these buffers is that the WTS is near the water, and much of the buffer area does not cover populated land areas. Also, the Census Blocks close to the WTS are sparsely populated or unpopulated.



The data show that the population in the 0.25 mile radius is only 4,718 people. However, the percent black is higher than the Bronx as a whole and also higher than the Study Area. The same thing is true of the percent Hispanic. As the buffer radius increases, more populated Census Blocks are encountered, and the percent black drops, while the Hispanic percentage increases to a level higher that the Study Area, and the Bronx as a whole.

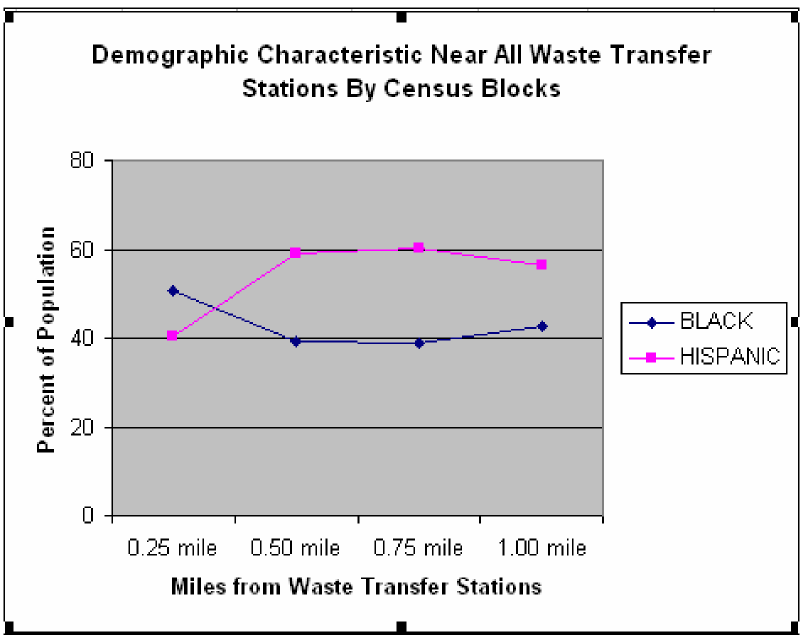
It appears that moving along the shoreline to the west and inspecting the population composition of the Census blocks surrounding the remaining Waste Transfer Stations, the same situation exists. Rail Yards and freight terminals run along the shoreline and blocks near them are unpopulated. The 98 Lincoln Avenue Waste Transfer Station is clearly surrounded by water and railroad yards. It's not surprising that there are not many people right around the waste transfer stations since they are usually located in M3 zoned areas, which are industrial areas. These areas are sometimes surrounded by M1 and M2 zoned areas that are supposed to be buffers between M3 areas and residential areas. However, the shape of these areas is never uniform so in drawing buffers around them you may have to go a long way to find a residential area in one direction but not too far in another direction.

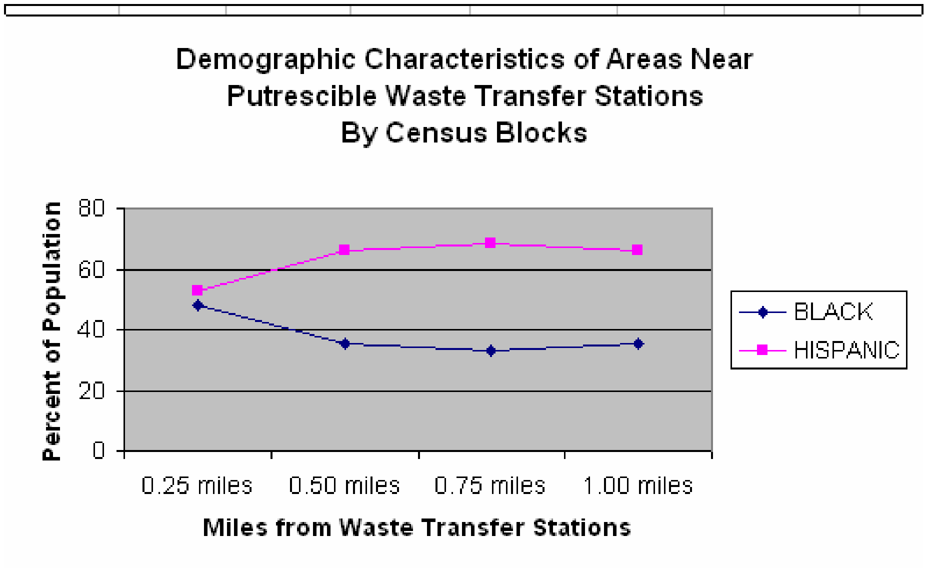
A NOTE ABOUT STATISTICS

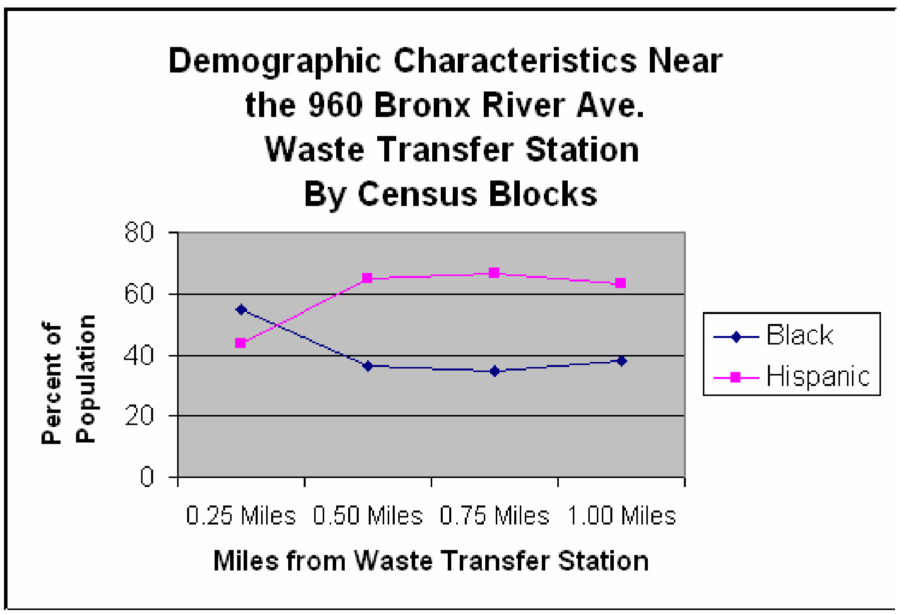
Data is available on Total Population and the number of Blacks and Hispanics (of all races) in each 2000 Census Block. These were summed for each buffer, the Bronx and other boroughs, NYC and the Study area. The sums were used to calculate the percentages for these regions.

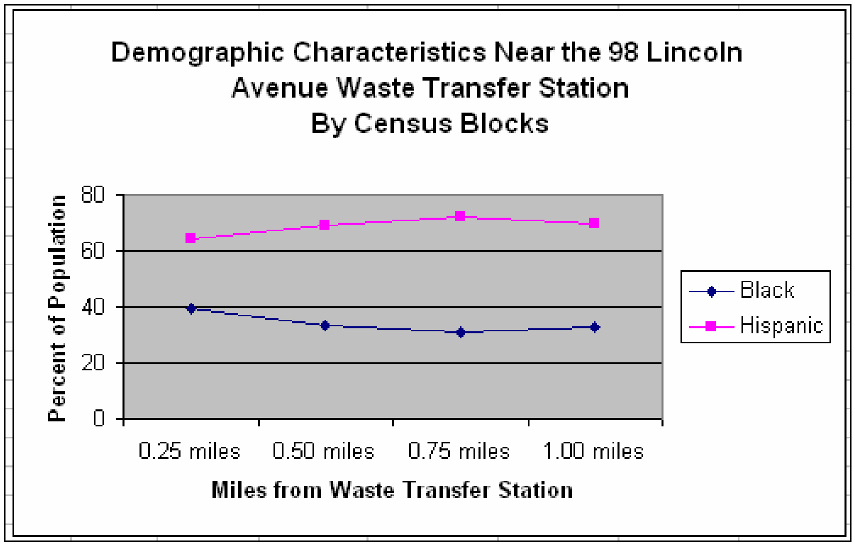
Conclusions

The four graphs below show a consistent pattern of the percent Black being higher closer to the WTS and declining as the buffer radius becomes larger.




Demographic Characteristics of Areas Near
Putrescible Waste Transfer Stations
By Census Blocks
Percent of Population
80
60
40
20
0
0.25 miles
0.50 miles
0.75 miles
1.00 miles
Miles from Waste Transfer Stations
BLACK
HISPANIC


Demographic Characteristics Near
the 960 Bronx River Ave.
Waste Transfer Station
By Census Blocks
Percent of Population
80
60
40
20
0
0.25 Miles
0.50 Miles
0.75 Miles
1.00 Miles
Miles from Waste Transfer Station
Black
Hispanic


Demographic Characteristics Near the 98 Lincoln Avenue Waste Transfer Station By Census Blocks
Percent of Population
0
20
40
60
80
0.25 miles
0.50 miles
0.75 miles
1.00 miles
Miles from Waste Transfer Station
Black
Hispanic

B. Waste Transfer Stations and
Socioeconomic Analysis Using Buffers
Working with Census Block Groups data

WORKING WITH SF-3 CENSUS BLOCK GROUPS DATA: INCOME, POVERTY, AND VALUE OF OWNER-OCCUPIED HOUSING

On Preparing Variables for Analysis using Buffers Around Waste Transfer Stations

CENSUS SF-3 HOUSEHOLD INCOME DATA

WHY COUNT DATA HAS TO BE USED

THE ISSUE: There are a number of Household Income variables available in the SF-3 file. When these variables were inspected it became clear that the best one to use is the count data for Income intervals (as shown below). The variable Median Household Income cannot be used for this project because medians for census block groups cannot be combined or aggregated in order to calculate values for the buffers or other regions of interest. Instead, the median for the buffer, or region of interest, can be computed from the count data after the counts are aggregated for the buffer or another region of interest (Study Area, the Bronx, etc). The median is also the better statistic to use with the data at hand because the distribution of income is usually skewed.

HOUSEHOLD INCOME IN 1999 [17]
Universe: Households
Total:
Less than $10,000
$10,000 to $14,999
$15,000 to $19,999
$20,000 to $24,999
$25,000 to $29,999
$30,000 to $34,999
$35,000 to $39,999
$40,000 to $44,999
$45,000 to $49,999
$50,000 to $59,999
$60,000 to $74,999
$75,000 to $99,999
$100,000 to $124,999
$125,000 to $149,999
$150,000 to $199,999
$200,000 or more

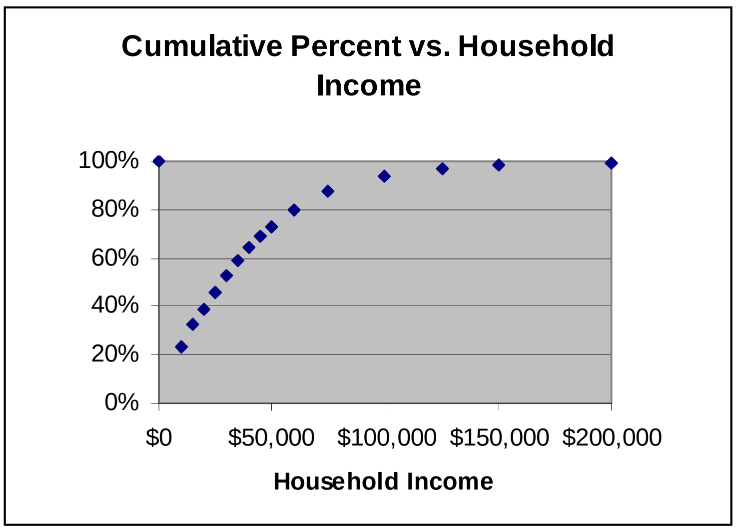
Using the count data shown above, the number of households with incomes from $10,000 to $14,999 was added up in each of the Block Groups in a buffer around a Waste Transfer Station to get the total number of households with incomes in this range. The same was done for each of the income ranges (shown on the previous page) with the result of creating a table for each of the buffers with the counts in each income range.

(2) REDUCING THE NUMBER OF CATEGORIES

The number of categories must be reduced because if data for 16 ranges of household income are combined the data will be unwieldy. The task has to be simplified.

(3) THE PROBLEM: HOW TO DECIDE ON CUT OFF POINTS FOR THESE CATEGORIES

The first step is to decide how to group the data into a smaller number of categories. To choose the breakpoints for the categories, a plot of cumulative percent vs. household income was created for the total of 957 Census Block Groups in the Bronx.



Data by Census Block Group

As the chart above shows, the median household income is about $30,000; the lowest decile cannot be determined; the lowest quartile is about $10,000; the upper quartile is about $50,000; and the upper decile is about $75,000.

The number of intervals can be reduced by combining categories into:

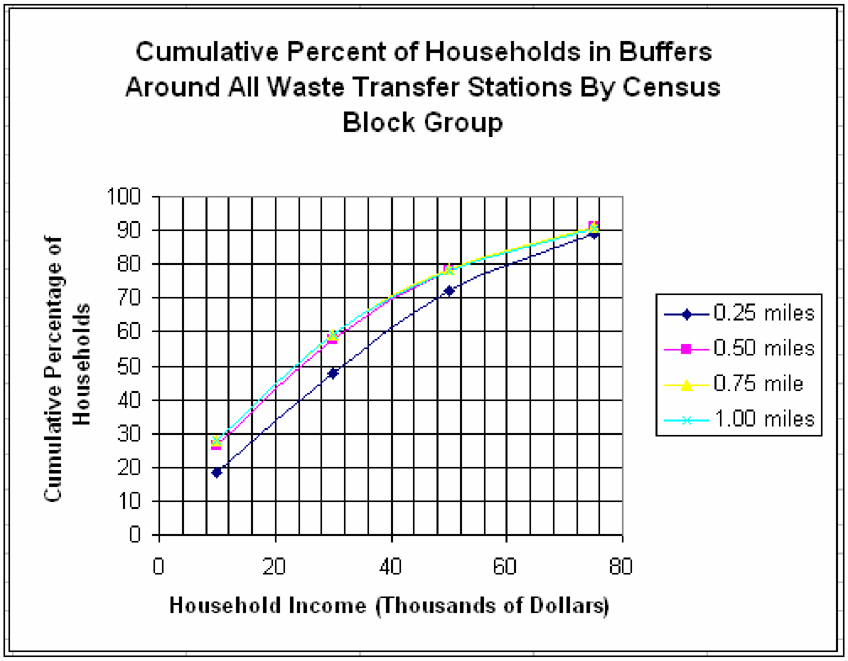
(1) Below $10,000, (2) $10,000 to $30,000, (3) $30,000 to $50,000,
(4) $50,000 to $75,000, and (5) Above $75,000

With the reduced number of categories (5 instead of 16), the data is less unwieldy.

Analysis of Household Income Using Four Buffers

Buffers around All Waste Transfer Stations

Cumulative Distribution of Household Income



Below is short discussion of how the median household income was determined for each of the buffers (shown in the chart above).

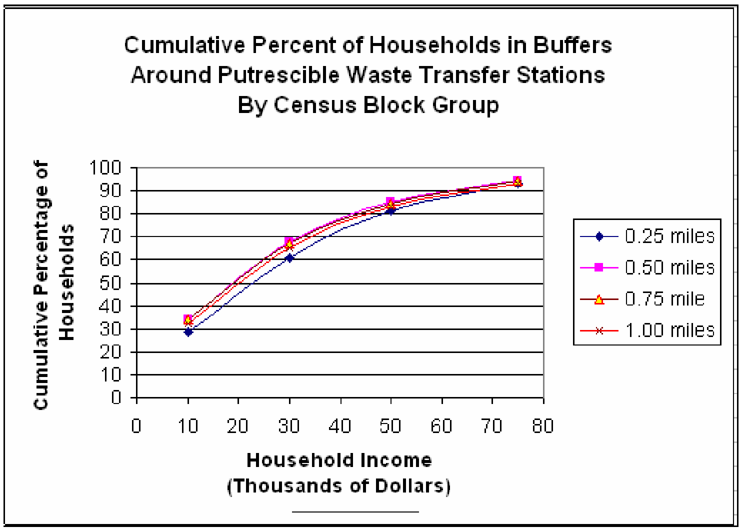
As the chart shows, the 50% line (the median) crosses the curve for the 0.25 mile buffer at $32,000; the median household income in the 0.50 miles buffer is about $24,000; median household income in the 0.75 miles buffer is about $24,000; median household income in the 1.00 miles buffer is about $24,000.

RADIUS	MEDIAN HHINCOME($)
0.25 miles	32,000
0.50 miles	24,000
0.75 miles	24,000
1.00 miles	24,000

AREA	MEDIAN HHINCOME($)
BRONX	29,000
BROOKLYN	31,000
MANHATTAN	50,000
QUEENS	42,000
STATEN ISLAND	56,000
NYC	39,000
STUDY AREA	22,000

These results are puzzling. It appears that the Household Incomes in the 0.25 mile buffer are higher than the Bronx as a whole and all the buffers have a higher median household income than the study area.

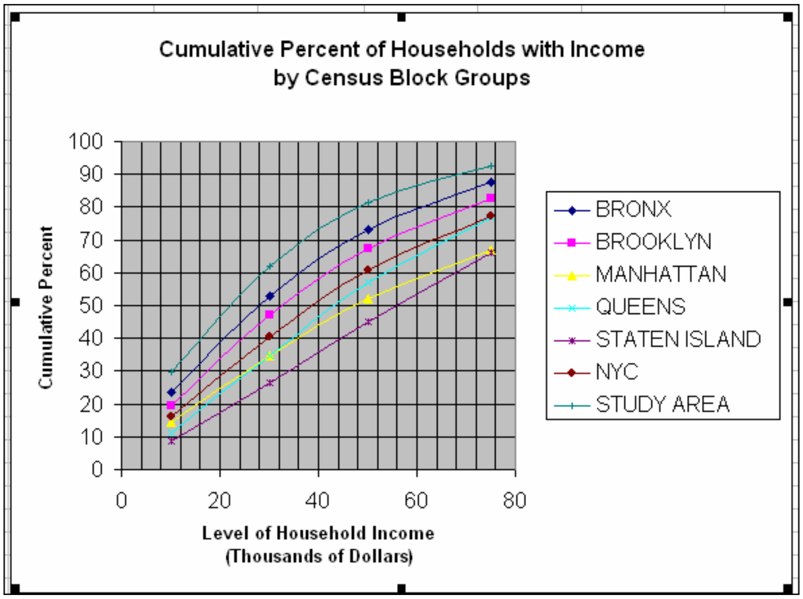
Buffers around Putrescible Waste Transfer Stations



Below is short discussion of how the median household income was determined for each of the buffers.

The chart above shows that the median household income in the 0.25 miles buffer is about $22,000; the median household income in the 0.50 miles buffer is about $19,500; median household income in the 0.75 miles buffer is about $19,500; median household income in the 1.00 miles buffer is about $20,000.

RADIUS	MEDIAN HHINCOME($)
0.25 miles	22,000
0.50 miles	19,500
0.75 miles	19,500
1.00 miles	20,000

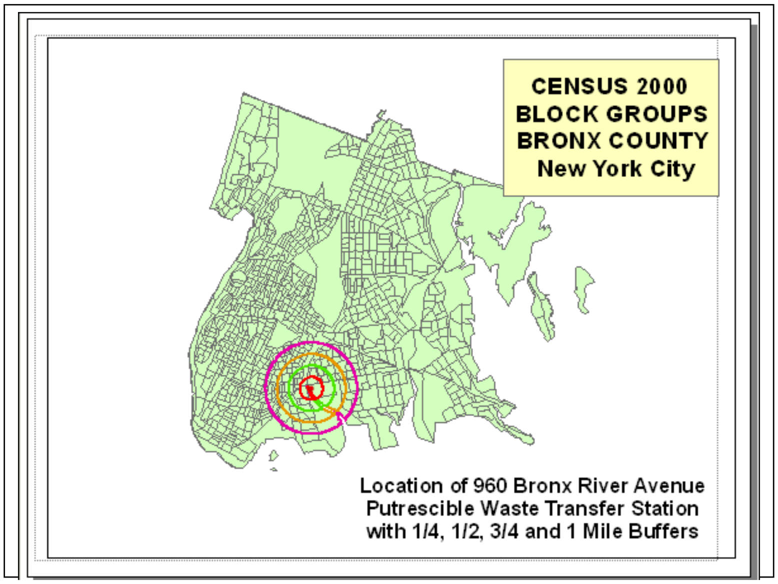


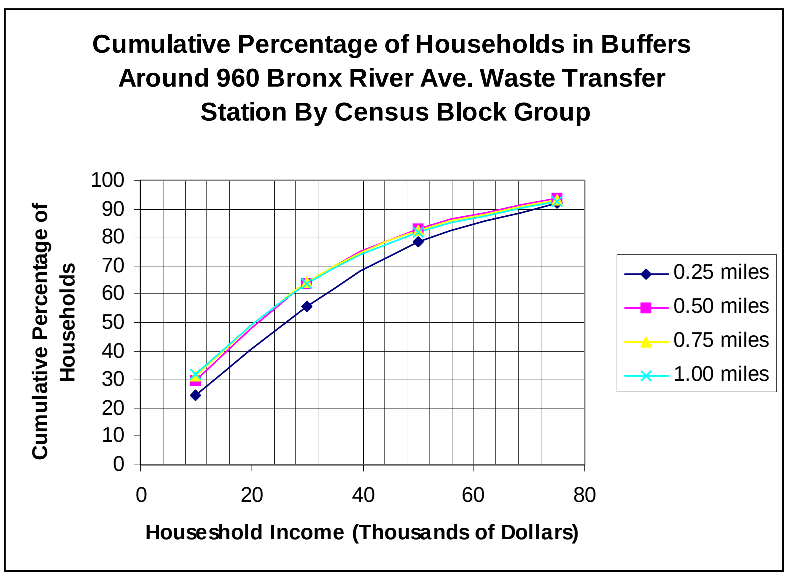
RADIUS	MEDIAN HHINCOME($)
0.25 miles	22,000
0.50 miles	19,500
0.75 miles	19,500
1.00 miles	20,000

AREA	MEDIAN HHINCOME($)
BRONX	29,000
BROOKLYN	31,000
MANHATTAN	50,000
QUEENS	42,000
STATEN ISLAND	56,000
NYC	39,000
STUDY AREA	22,000

Comparing the median Household income for the buffers around the Putrescible Waste Transfer Stations shows that the median household incomes in all four buffers are lower that in the Bronx as a whole, and lower than in all the boroughs. For the 0.25 mile buffer, it is at the same level as the study area, and it is lower than the study area for the other buffers.

Buffers around 960 Bronx River Avenue
Waste Transfer Stations



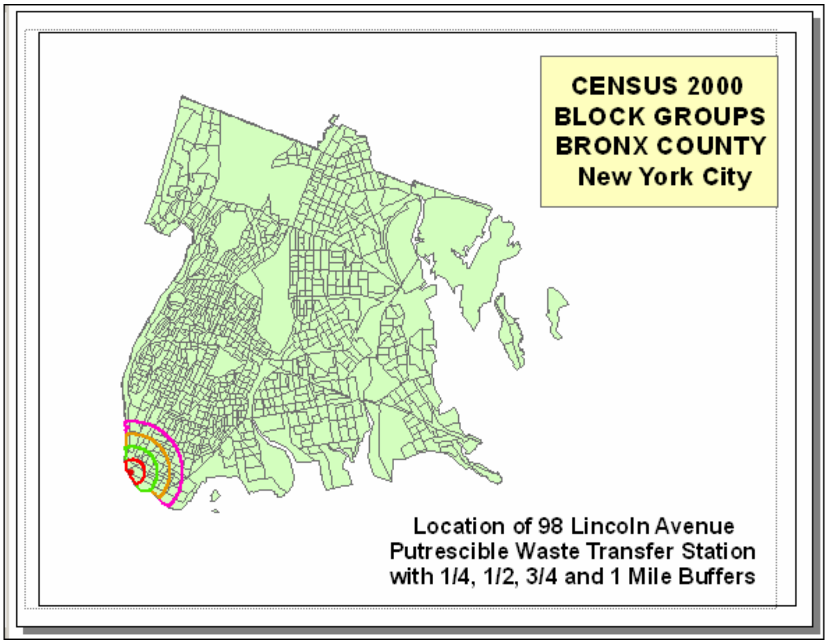


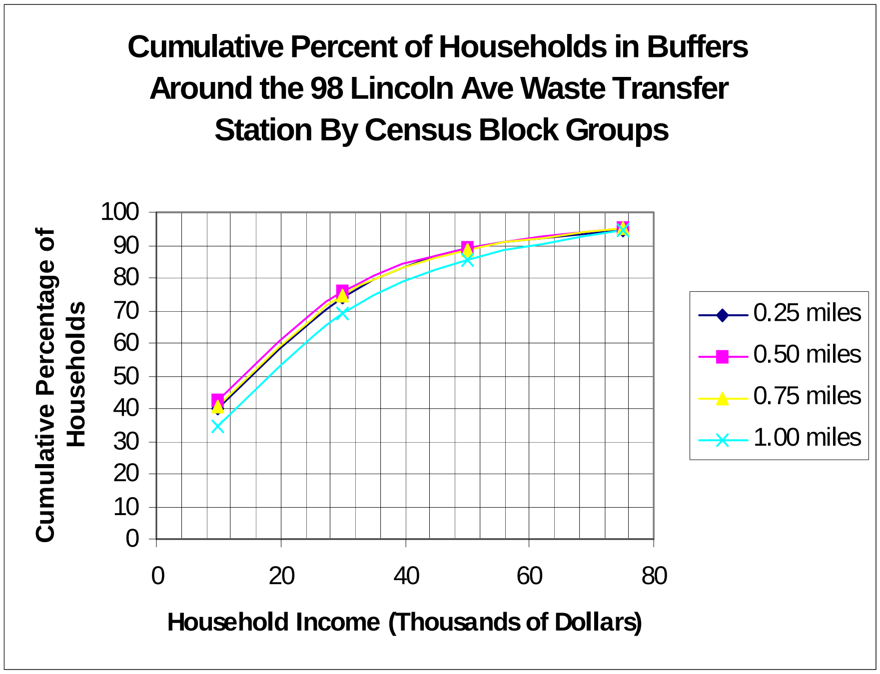
When the same procedure was applied to buffers around the 960 Bronx River Avenue Putrescible Waste Transfer Stations, it was found that the median Household Income within a quarter-mile of the Waste Transfer Station was slightly higher than at other distances and higher than for the study area. The other buffers have income below that of the study area, and below the median Bronx level and all other comparison data.

AREA	MEDIAN HHINCOME($)
BRONX	29,000
BROOKLYN	31,000
MANHATTAN	50,000
QUEENS	42,000
STATEN ISLAND	56,000
NYC	39,000
STUDY AREA	22,000

BUFFER RADIUS	MEDIAN HHINCOME ($)
0.25 miles	26,000
0.50 miles	21,500
0.75 miles	20,500
1.00 miles	20,500

Buffers around 98 Lincoln Avenue Putrescible Waste Transfer Station





BUFFER RADIUS	MEDIANHINC($)
0.25 miles	16,000
0.50 miles	14,500
0.75 miles	14,700
1.00 miles	18,500

When the same procedure was applied to buffers around the 98 Lincoln Avenue Putrescible Waste Transfer Stations it was found that the median Household Income within a quarter-mile of the Waste Transfer Station was slightly higher than at the 0.50 and 0.75 mile distances but lower than at the 1.0 mile distance.

Overall Median Household incomes in the buffers around the 98 Lincoln Avenue WTS are lower at all distances than the Bronx as a whole and the study area.

Note that data on Household Incomes is not collected in the Rikers Island Block Group.

CENSUS SF-3
DATA ON POVERTY

POVERTY STATUS OF HOUSEHOLDS IN 1999

The data on poverty status of households were derived from answers to the income questions. The income items were asked on a sample basis. Since poverty is defined at the family level and not the household level, the poverty status of the household is determined by the poverty status of the householder. Households are classified as poor when the total 1999 income of the householder's family is below the appropriate poverty threshold. (For non-family householders, their own income is compared with the appropriate threshold.) The income of people living in the household who are unrelated to the householder is not considered when determining the poverty status of a household, nor does their presence affect the family size in determining the appropriate threshold. The poverty thresholds vary depending upon three criteria: size of family, number of children, and, for 1- and 2-person families, age of the householder. (For more information, see ''Poverty Status in 1999'' and ''Income in 1999'' under Population Characteristics.)[37].

Poverty status was determined for everyone except those in institutions, military group quarters, or college dormitories, and unrelated individuals under 15 years old. Therefore, the number of those for whom poverty is determined is lower than the total population count. **Therefore, data on poverty is not calculated for the Rikers Island Block Group.**

Family income then determines who is poor. If a family's total income is less than the threshold for the family's size and composition, the family and everyone in it are considered poor. If a person is not living with anyone related by birth, marriage, or adoption, the person's own income is compared with his or her poverty threshold as an "unrelated individual." For example, the 1999 poverty threshold for a 3-person family with one member under age 18 was $13,410. If the total family income for 1999 was greater than this threshold, then the family and all members of the family were considered to be above the poverty level. The total number of people below the poverty level is the sum of the number of people in poor families and the number of unrelated individuals with incomes below the poverty threshold. Census 2000 asked people about their income in the previous calendar year. Poverty estimates in this report compare family income in 1999 with the corresponding 1999 poverty thresholds. See Table at
http://www.census.gov/prod/2003pubs/c2kbr-19.pdf

In 1999, New York State with a population of 18,449,899, the number of people below poverty level was 2,692,202, that is, 14.6%.

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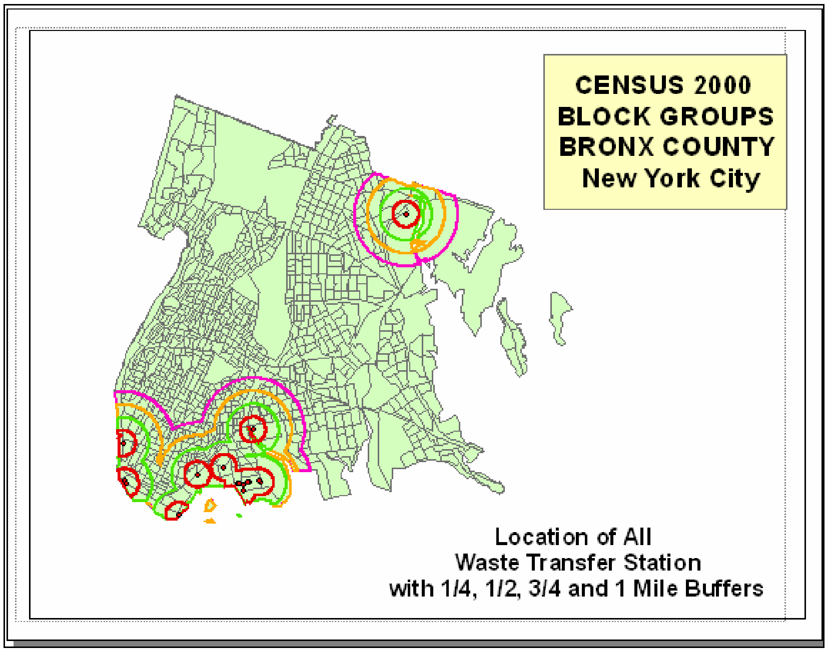
[37] **See document on the NYC Department of City Planning site**
http://www.census.gov/population/cen2000/phc-2-a-B.pdf

For a full discussion of measuring poverty see the document on the Census Bureau site at
http://www.census.gov/prod/2003pubs/c2kbr-19.pdf

Four buffers around All the WTS



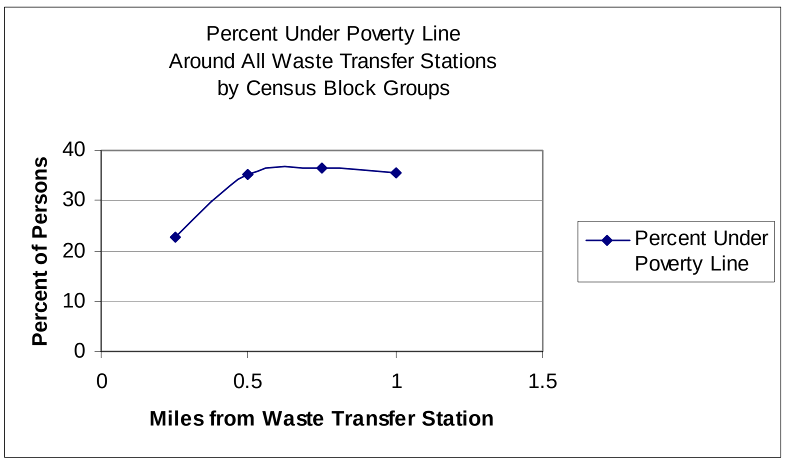
The data provided in the Census Block Group, (SF-3) files for each Block Group are the following:

- the number of persons for whom poverty was evaluated
- the number of persons below 50% of the poverty level
- the number of persons between 50% and 74% of the poverty level
- the number of persons between 75% and 99% of the poverty level
- the number of persons between 100% and 124% of the poverty level
- the number of persons between 125% and 149% of the poverty level
- the number of persons between 150% and 174% of the poverty level
- the number of persons between 175% and 184% of the poverty level
- the number of persons between 185% and 199% of the poverty level
- the number of persons above 200% of the poverty level

It is sometimes necessary to use data for differing levels of poverty, but at this time the percentage below the poverty line was calculated by adding up the first three categories and dividing by the total number of persons evaluated for poverty.

	Cumulative Percent below each level							
RADIUS	LT50%	LT75%	LT100%	LT125%	LT150%	LT175%	LT185%	LT200%
0.25 miles	12.57	16.93	22.66	27.40	32.20	37.13	38.95	41.26
0.50 miles	19.19	26.80	35.18	41.08	46.64	51.77	53.73	56.10
0.75 miles	20.76	28.56	36.48	42.71	48.20	53.22	55.21	57.96
1.00 miles	20.35	27.71	35.59	42.01	47.58	52.81	54.73	57.53

The goal is to focus on the percentage of the population that is below the poverty line -- that is, the column labeled LT100%.



Buffer RADIUS	LT100%
0.25 miles	22.66
0.50 miles	35.18
0.75 miles	36.48
1.00 miles	35.59

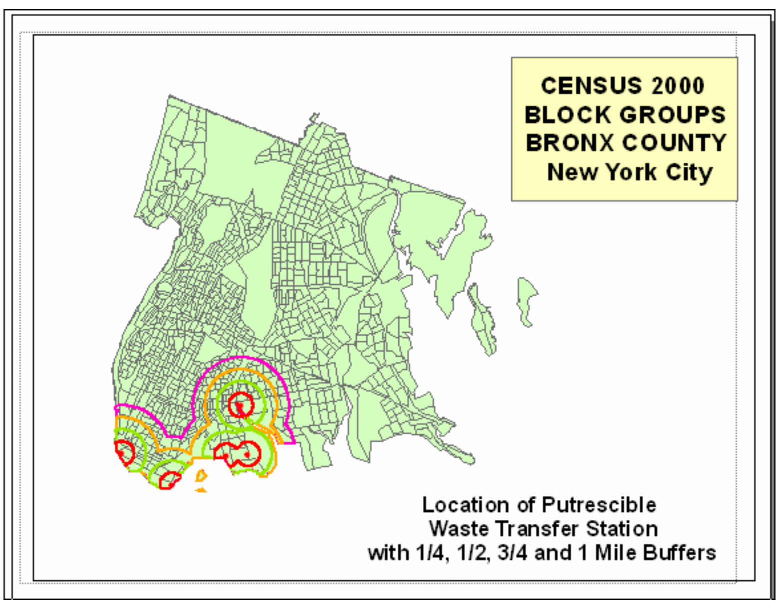
In the buffers around ALL the WTS the percent of households below poverty is 23% for the ¼ mile buffer and rises to 35-36% at greater distances.

	Percent Below the Poverty Line
Bronx	30.68
Brooklyn	25.07
Manhattan	20.00
Queens	14.57
Staten Island	10.05
New York City	21.25
Study Area	38.38

There appears to be a lower level of poverty in the ¼ mile buffer near the Waste Transfer Stations and a higher level of poverty as one moves away from the Waste Transfer Stations. Except for the ¼ mile buffer, the level of poverty is higher than for the Bronx as a whole, and close to the level of the study area.

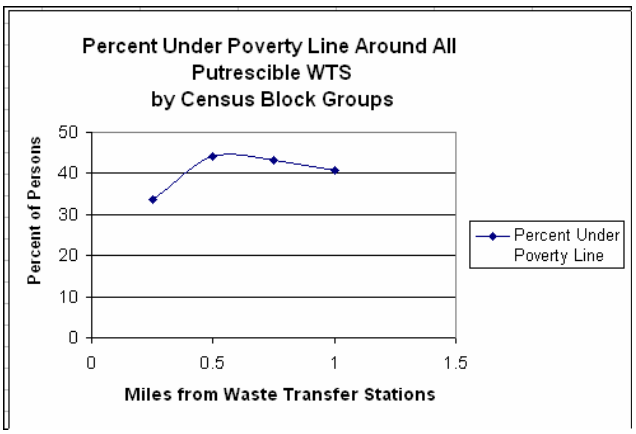
In each case, statistics are calculated for the entire buffer area including smaller buffers within them (the ½ mile buffer includes the ¼ mile).

Four buffers around the Putrescible WTS



Note: The inclusion of Rikers Island in the buffers would not have affected the calculation since Poverty status was determined for everyone except those in institutions, military group quarters, etc.

Cumulative Percent below Poverty Level								
RADIUS	LT50%	LT75%	LT100%	LT125%	LT150%	LT175%	LT185%	LT200%
0.25 miles	20.5	25.8	33.6	40.0	46.0	50.9	53.5	55.8
0.50 miles	25.1	33.8	44.2	50.7	57.2	62.5	65.0	67.5
0.75 miles	25.2	34.0	43.4	50.1	56.2	61.5	63.8	66.3
1.00 miles	23.1	31.4	40.6	47.5	53.5	59.0	61.2	64.1



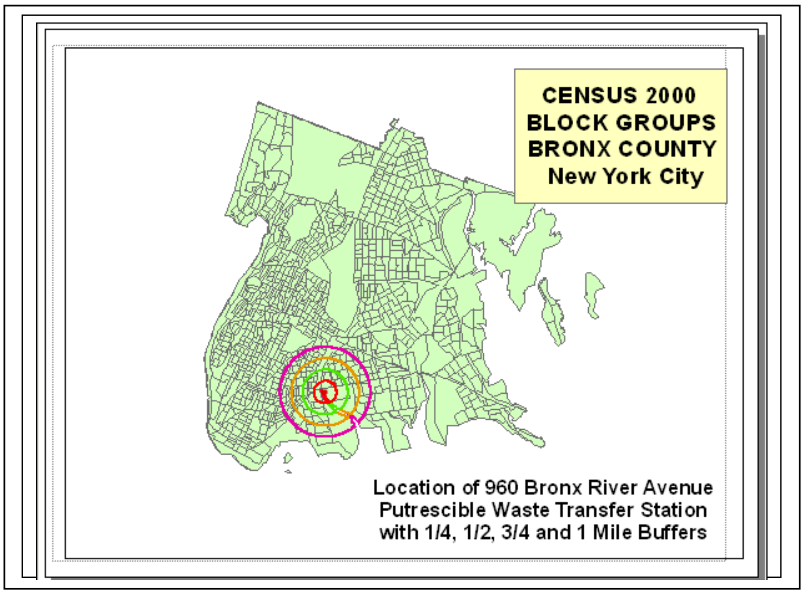
Around the Putrescible WTS the percent of persons below the poverty line ranges from 34% at ¼ mile to 44% at ½ mile and 43% at ¾ mile and drops to 41% at one mile.

Comparing the percent in poverty at various distances around the Putrescible Waste Transfer Stations, it appears that the poverty level is higher than the Bronx as a whole and higher than the study area except for the ¼ mile buffer.

Buffer RADIUS	LT100%
0.25 miles	33.6
0.50 miles	44.2
0.75 miles	43.4
1.00 miles	40.6

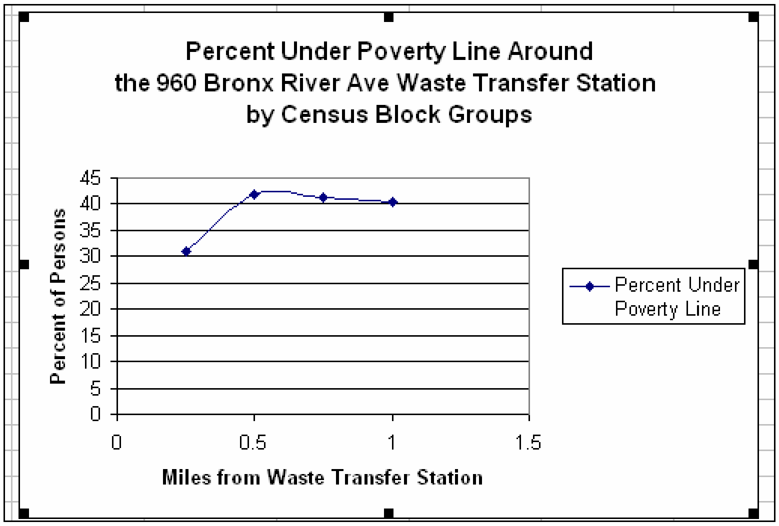
	Percent Below the Poverty Line
Bronx	30.68
Brooklyn	25.07
Manhattan	20.00
Queens	14.57
Staten Island	10.05
New York City	21.25
Study Area	38.38

Four Buffers around the
960 Bronx River Avenue Waste Transfer Station



Cumulative Percent below Poverty Level								
RADIUS	LT50%	LT75%	LT100%	LT125%	LT150%	LT175%	LT185%	LT200%
0.25 miles	19.2	24.2	31.1	36.2	41.2	46.3	49.0	51.0
0.50 miles	23.3	31.3	41.7	48.2	53.6	59.1	61.8	64.0
0.75 miles	24.4	32.1	41.1	47.5	53.1	58.4	60.8	63.1
1.00 miles	23.2	31.1	40.3	47.0	52.3	57.8	59.9	62.6

Around the WTS at 960 Bronx River Avenue, the percent of households below the poverty line ranges from 31% at ¼ mile to 42% at ½ mile and 41% at ¾ miles and drops to 40% at one mile.

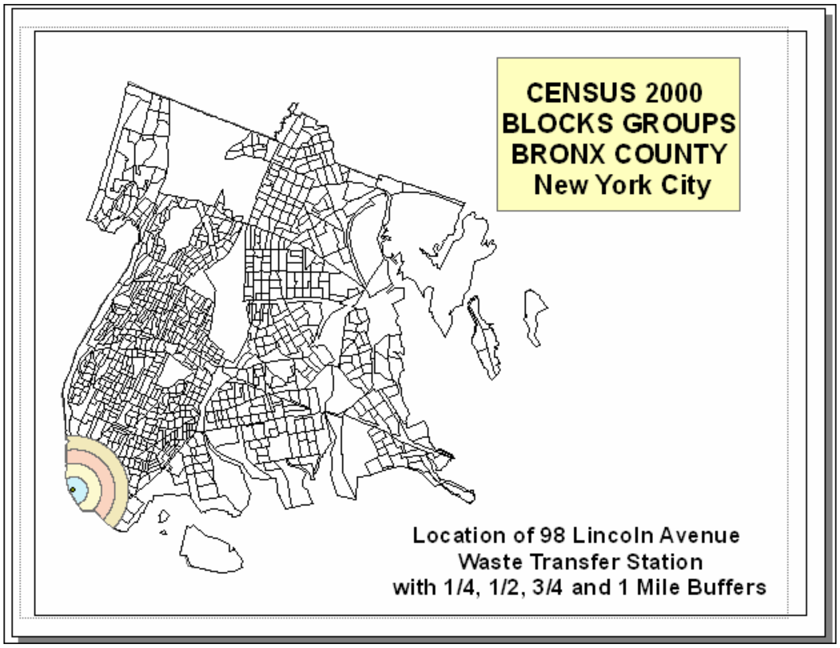


Buffer Radius	LT100%
0.25 miles	31.1
0.50 miles	41.7
0.75 miles	41.1
1.00 miles	40.3

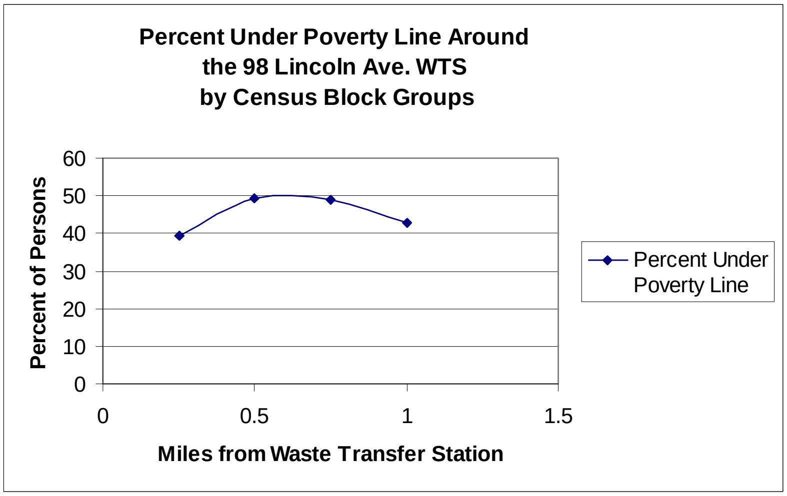
	Percent Below the Poverty Line
Bronx	30.68
Brooklyn	25.07
Manhattan	20.00
Queens	14.57
Staten Island	10.05
New York City	21.25
Study Area	38.38

Comparing the percent in poverty at various distances around the 960 Bronx River Avenue Waste Transfer Station, it appears that the poverty level at the ¼ mile distance is almost the same as the Bronx as a whole and lower than the study area. However, the poverty level at greater distances is higher than the Bronx and the study area.

Four Buffers around the
98 Lincoln Avenue Waste Transfer Station



Cumulative Percent below Poverty Level								
RADIUS	LT50%	LT75%	LT100%	LT125%	LT150%	LT175%	LT185%	LT200%
0.25 miles	23.6	29.6	39.3	49.6	57.7	61.2	63.9	67.0
0.50 miles	28.0	39.0	49.2	56.0	64.6	69.2	71.8	74.9
0.75 miles	27.4	38.6	48.7	55.9	62.9	67.6	69.9	73.0
1.00 miles	23.9	33.7	42.9	50.3	57.1	62.4	64.6	67.9



Around the at 98 Lincoln Avenue WTS, the percent of households below the poverty line ranges from 39% at ¼ mile to 49% at ½ mile and ¾ miles and drops to 43% at one mile.

	Percent Below the Poverty Line
Bronx	30.68
Brooklyn	25.07
Manhattan	20.00
Queens	14.57
Staten Island	10.05
New York City	21.25
Study Area	38.38

RADIUS	LT100%
0.25 miles	39.3
0.50 miles	49.2
0.75 miles	48.7
1.00 miles	42.9

Comparing the percent in poverty at various distances around the 98 Lincoln Avenue Putrescible Waste Transfer Station, it appears that the poverty level at all the distance radii is higher than the Bronx as a whole and the study area.

WORKING WITH CENSUS BLOCK GROUPS DATA:
CENSUS SF-3
MEAN VALUES OF OWNER-OCCUPIED HOUSING

Value is the respondent's estimate of how much the property (house and lot, mobile home and lot, or condominium unit) would sell for if it were for sale.

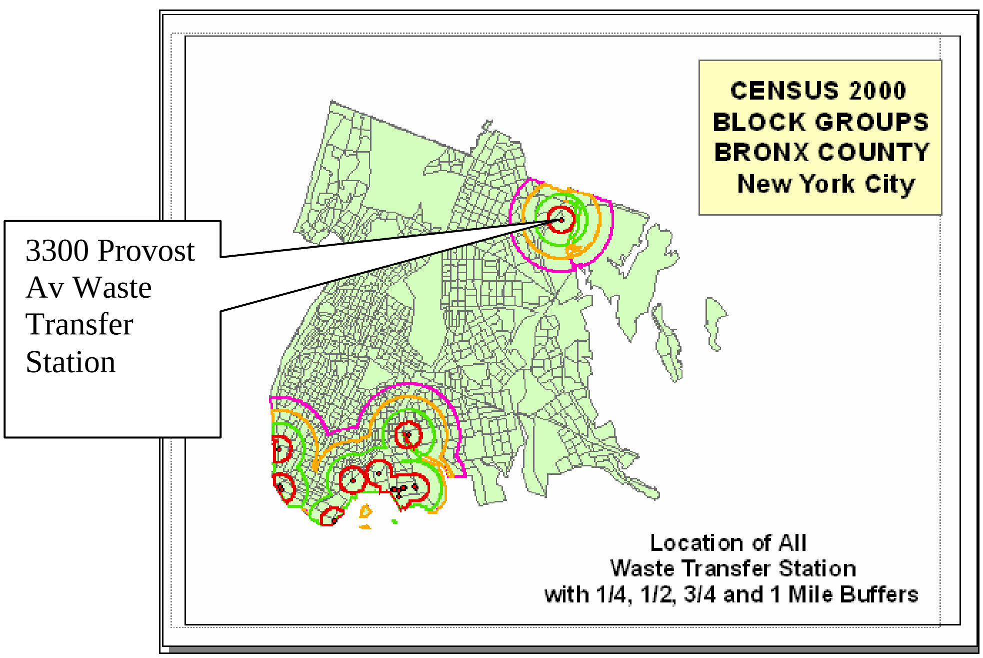
To calculate the mean values of owner-occupied housing two variables were used:

(1) The aggregate value is of owner-occupied housing is available in a field H086001

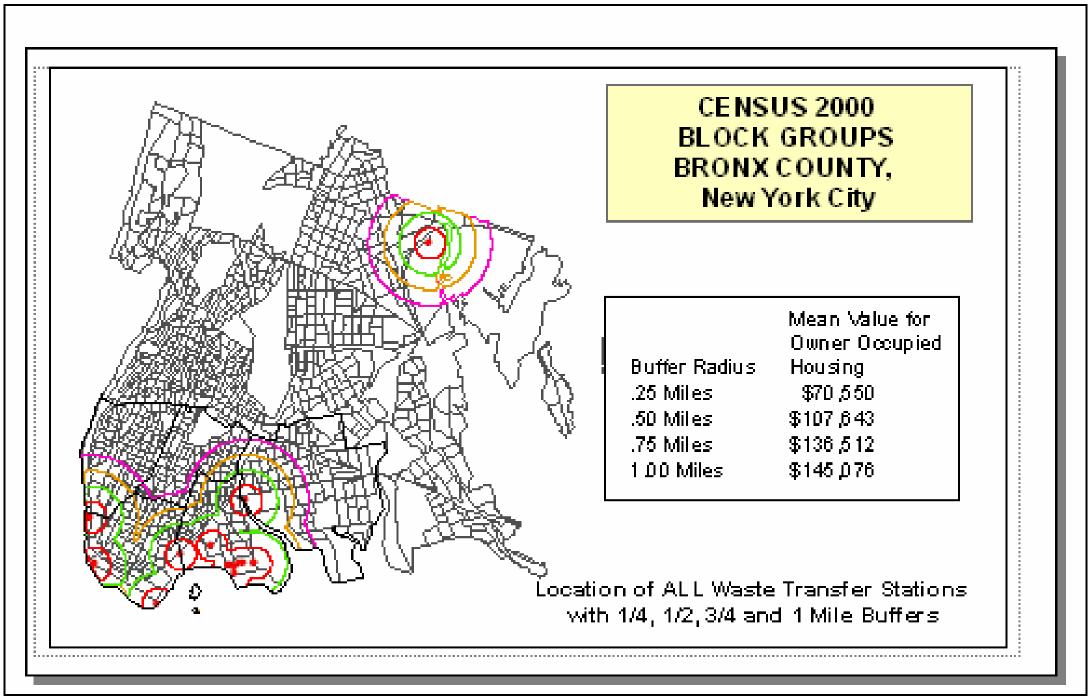
(2) The number of owner-occupied housing units is available in the field H007002.

In order to calculate the average value of owner occupied housing units in a defined region such as the Bronx, or the Study Area or a Buffer around a putrescible Waste Transfer Station, two numbers were calculated. The first number was the total value of the housing (which was calculated by summing the values of H086001 in each Census Block Group). The second number is the total of the number of owner-occupied housing units (which was calculated by summing the values of H007002) in each Census Block Group.

The average (mean) value of owner-occupied housing units in, for example, a buffer around a Waste Transfer Station, was calculated by dividing the total value of housing by the total number of units.



Four buffers around All the WTS



Buffers around ALL Waste Transfer Stations

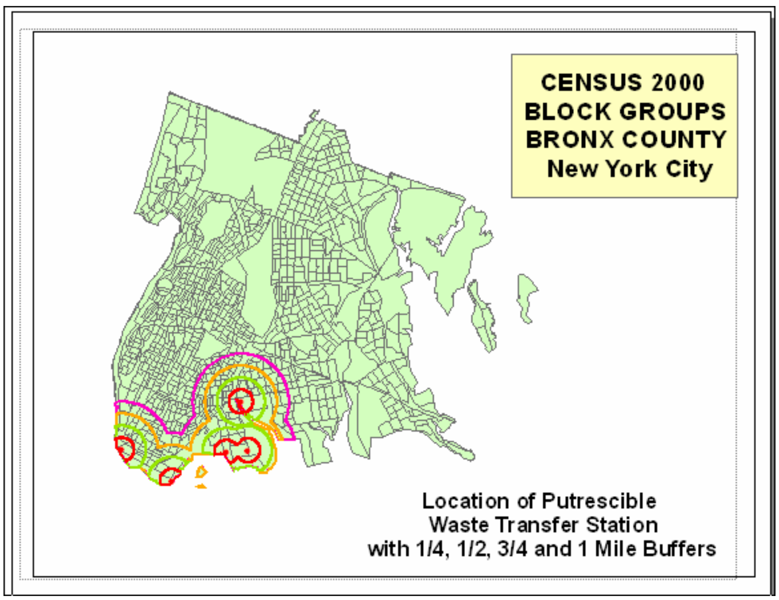
	Owner Occupied Housing	
Buffer Radius	Mean Value	Number
.25 Miles	$70,550	6,550
.50 Miles	$107,643	9,737
.75 Miles	$136,512	14,134
1.00 Miles	$145,076	21,535

Region	Owner Occupied Housing Mean Value	Number
Bronx	$189,527	90,522
Brooklyn	$270,737	238,290
Manhattan	$496,684	148,695
Queens	$225,399	334,894
Staten Island	$244,843	99,732
NYC	$280,034	912,133
Study Area	$164,028	19,792

In the buffers around ALL the WTS the mean value of Owner-Occupied Housing Units is below that of the Study Area and the Bronx as a whole. It is lowest in the buffer (the .25 mile buffer) closest to the Waste Transfer Stations.

It may be of interest to compare the number of owner-occupied housing units in the region of interest. Note that the number of housing units in the 1.0 mile buffer exceeds that of the Study Area. The reason is probably because the 3300 Provost Av Waste Transfer Station in the North-East of the Bronx is included in the buffers but it is not in the study area (see map on the previous page).

Four buffers around the Putrescible WTS



Note: The inclusion of Rikers Island in the buffers would not have affected the calculation since there are no owner-occupied housing units in the Block Group that includes Rikers Island.

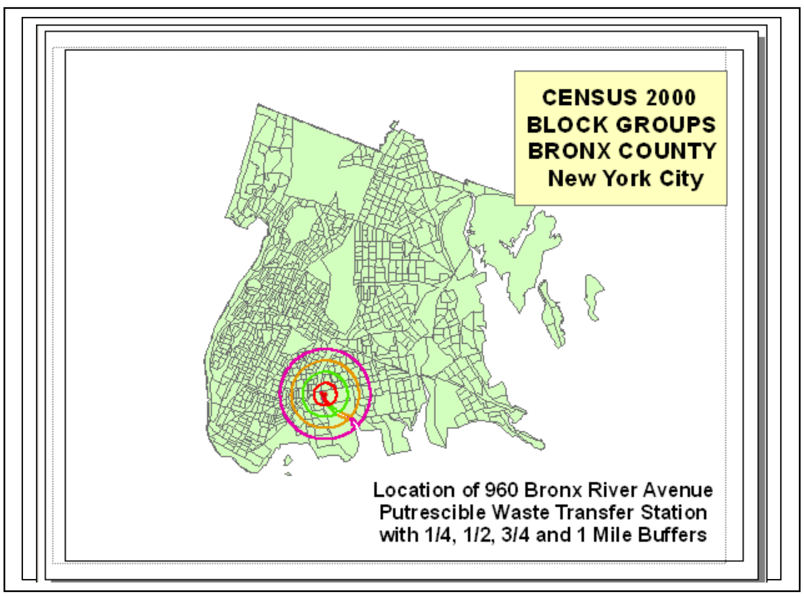
Four buffers around the Putrescible WTS

	Owner Occupied Housing	
Buffer Radius	Mean Value	Number of Units
0.25 Miles	$166,042	415
0.50 Miles	$173,663	1,700
0.75 Miles	$182,815	3,814
1.00 Miles	$176,065	8,614

Region	Owner Occupied Housing Mean Value	Number
Bronx	$189,527	90,522
Brooklyn	$270,737	238,290
Manhattan	$496,684	148,695
Queens	$225,399	334,894
Staten Island	$244,843	99,732
NYC	$280,034	912,133
Study Area	$164,028	19,792

In the buffers around the Putrescible WTS the mean value of Owner-Occupied Housing Units is above that of the Study Area but below the Bronx as a whole. It is lowest in the buffer (the .25 mile buffer) closest to the Putrescible Waste Transfer Stations.

Four Buffers around the
960 Bronx River Avenue Waste Transfer Station

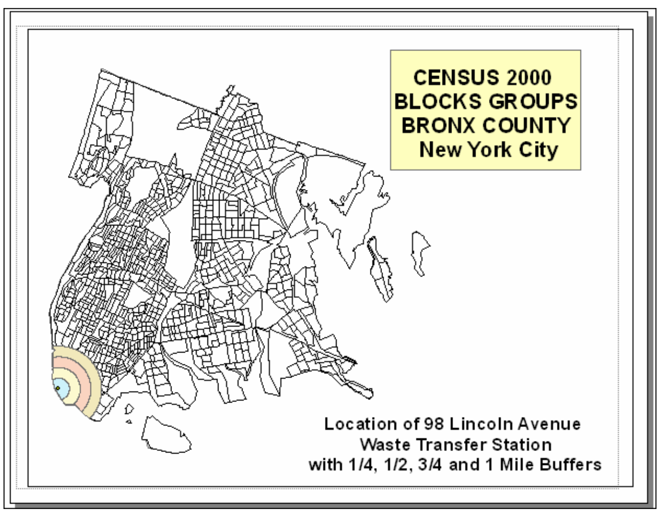


Buffer Radius	Owner Occupied Housing Mean Value	Number
0.25 Miles	$177,651	314
0.50 Miles	$183,357	1,322
0.75 Miles	$189,246	3,031
1.00 Miles	$197,136	6,092

Region	Owner Occupied Housing Mean Value	Number
Bronx	$189,527	90,522
Brooklyn	$270,737	238,290
Manhattan	$496,684	148,695
Queens	$225,399	334,894
Staten Island	$244,843	99,732
NYC	$280,034	912,133
Study Area	$164,028	19,792

In the buffer around the **960 Bronx River Avenue** Putrescible WTS the mean value of Owner-Occupied Housing Units is above that of the Study Area and the Bronx as a whole. It is lowest in the buffer (the 0.25 mile buffer) closest to the **960 Bronx River Avenue** Putrescible Waste Transfer Stations.

Four Buffers around the
98 Lincoln Avenue Waste Transfer Station



Buffer Radius	Owner Occupied Housing Mean Value	Number
0.25 Mile	$180,357	14
0.50 Mile	$144,078	244
0.75 Mile	$158,706	512
1.00 Mile	$114,285	2,085

Region	Owner Occupied Housing Mean Value	Number
Bronx	$189,527	90,522
Brooklyn	$270,737	238,290
Manhattan	$496,684	148,695
Queens	$225,399	334,894
Staten Island	$244,843	99,732
NYC	$280,034	912,133
Study Area	$164,028	19,792

The results are puzzling. There are very few owner-occupied housing units in the ¼ mile buffer and the mean value is the highest. It is higher than that of the Study Area. At the other distances, the mean value owner-occupied housing units lower than the study area and the Bronx as a whole. The results for the 1 mile buffer are also puzzling. However, note that the area is partially rail yards and unpopulated.

III. Results and interpretations

Conclusions and Recommendation for Future Work

RACE AND ETHNICITY

The analyses show that the percent Black is highest in the immediate vicinity (within 0.25 mile) of ALL the Waste Transfer Stations, and decreases as the distance from the WTS becomes larger, approaching the level of the South Bronx Study Area when the one-mile Buffer is examined. The percent Hispanic is lower in the 0.25 mile buffer, and increases with distance, approaching the level of the Study Area in the one-mile buffer.

This unexpected outcome – a higher percent of Blacks in the 0.25 mile distance from the Waste Transfer Stations and the lower percentage of Hispanics -- requires further investigation. One suggestion is that the composition of these groups of Blacks and Hispanics, their country of origin, immigration history, etc., are investigated in more detail.

The analysis of the race and ethnicity of the population living in close proximity to Putrescible Waste Transfer Stations shows the same pattern.

The analysis of the percent Blacks and Hispanics in the buffers around the 960 Bronx River Avenue Putrescible Waste Transfer Station shows the same pattern – in the 0.25 mile buffer the percent Black is higher (55%) than Hispanic (43.5%). At greater distances this reverses.

The analysis of the percent Blacks and Hispanics in the area near the 98 Lincoln Avenue Putrescible Waste Transfer Station is not conclusive because of the small number of people involved. There are not many people right around the waste transfer stations since they are usually located in M3 zoned areas, which are industrial areas. The 98 Lincoln Avenue Waste Transfer Station is surrounded by water and railroad yards.

INCOME

When all WTS are examined the median household income declines from the 0.25 mile buffer to the 1.0 mile buffer. It is greater than for the Study Area. It is greater than for the Bronx as a whole for the 0.25 mile buffer. This is unexpected. The inclusion of a WTS in the North East section of the Bronx, outside the Study Area, may account for incomes being higher than for the Study Area.

When only the putrescible WTS are examined, the median household income is again highest at 0.25 miles buffer and lower at greater distances. The median household income in all of the buffers is lower than for the Bronx as a whole. The median household income in the 0.25 mile buffer is at the same level as for the Study Area.

For the putrescible WTS at 960 Bronx River Ave. the median household income is slightly higher than for the Study Area, and at greater distances it is lower than for the Study Area. All the buffers have a median household income lower than for the Bronx as a whole.

For the putrescible WTS at 98 Lincoln Ave. the median household income is lower than for the Study Area at all distances. It is slightly higher for the one mile buffer that for the buffers closer to the WTS.

It is surprising to find that the median household income in the 0.25 mile buffer is usually higher than for greater distances from the WTS, except for the WTS at 98 Lincoln Ave. This, as discussed earlier, is an exceptional area with low population and includes the railyards and the waterfront.

POVERTY

The data on poverty levels has a pattern which is consistent with the data on median household incomes. The percentage of the population with incomes below the poverty level is lower in the 0.25 mile buffer around the WTS and rises as the buffer radius increases to 1.0 mile. The percent in poverty rises to a level higher than the Bronx as a whole, and approaches the level of the Study Area. When the focus is on the WTS handling putrescible waste, the percent in poverty is found to exceed the level of the Bronx as a whole in the 0.25 mile buffer, and at greater distances the poverty level increases, and becomes higher than in the study area.

VALUE OF OWNER-OCCUPIED HOUSING UNITS

In the buffers around ALL the WTS the mean value of Owner-Occupied Housing Units rises as the distance from the WTS increases. At all distances it is below that of the Study Area and the Bronx as a whole.

In the buffers around the putrescible WTS the mean value of Owner-Occupied Housing Units is lowest in the 0.25 mile buffer, and increases as the distance from the WTS increases, up to the 0.75 mile buffer, then declines slightly for the one-mile buffer. At all distances it is below that for the Bronx as a whole. At all distances, it is higher than for the Study Area.

In the buffers around the putrescible WTS at 960 Bronx River Ave. the mean value of Owner-Occupied Housing Units rises as the distance from the WTS increases. It is below the value for the Bronx as a whole for the buffers up to 0.5 miles, and exceeds the value for the Bronx at greater distances. At all distances, it is higher than for the Study Area.

In the buffers around the putrescible WTS at 98 Lincoln Ave. the mean value of Owner-Occupied Housing Units drops sharply from $180,357 to $114,285 (with fluctuations) as the distance increased from 0.25 miles to 1.00 miles.

At the distance of 0.25 miles, the mean value of Owner-Occupied housing is slightly below the level of the Bronx as a whole ($189,527) and higher than for the Study Area ($164,028).

This WTS, as discussed many times before, is unusual in that it is surrounded by railyards and the waterfront. The reason for including it is to emphasize the fact that not only this WTS but others are located in areas of low population density and railyards, the Hunts Point Market, areas zoned for industrial activity, and the waterfront.

Chapter 9
South Bronx Potential Environmental Improvement Strategies

Cary Hirschstein

In light of the air quality and environmental health problems that threaten the South Bronx, a number of steps are currently being taken to improve conditions in the area. These measures include the retrofitting of trucks and buses, the use of cleaner fuels, idling prevention strategies, truck rerouting, best practices for waste transfer station operations, and the adoption of green building technologies for homes, schools and community facilities in the study area. These strategies provide examples of future programs, incentives and regulations that may potentially hold value to enhance the air quality of the South Bronx. Nonetheless, the expansion of these solutions is imperative if we wish to attend to area environmental health concerns.

To accomplish these goals, it is crucial to address the environmental impacts of the trucks that travel along the South Bronx's expressways and major arterials to destinations ranging from Hunts Point and Port Morris in the South Bronx to Manhattan, Connecticut and New Jersey. Two main avenues exist for doing so: pollution control devices and cleaner fuels. As an example, the New York City Department of Sanitation (DOS) actively mitigates the environmental impacts of its fleet by mandating the use of ultra-low sulfur diesel fuel for all on-highway DOS trucks by 2006, utilizing computerized engine controls, equipping a portion of their fleet with diesel oxidation catalysts and diesel particulate filters, and purchasing 28 clean natural gas refuse collectors and 255 light duty bifuel vehicles (using a mix of gas and clean natural gas).[38] However, DOS currently holds no control over the emissions of private waste transfer vehicles; perhaps policies can seek to provide incentives for private waste industries to improve their fleets with similar measures. Likewise, any adoption of pollution control technology and cleaner fuels by trucks serving the Hunts Point Cooperative Market and other South Bronx destinations could have a positive impact on air quality in the study area.

The idling of trucks at South Bronx waste transfer stations, the Cooperative Market and other facilities also present adverse impacts on air quality in the area. In June 2003, the Hunts Point Produce Marker entered into an agreement with New York State Attorney General Spitzer to minimize emissions from idling trucks. The market agreed to educate drivers regarding idling laws, issue summonses for violations, explore anti-idling technologies and report to the State Attorney's office twice a year over the coming three years.[39] Furthermore, under a Clean Air Communities grant, Sustainable South Bronx, the New York Power Authority and IdleAire Technologies Corporation have worked together to install a system that provides amenities including heat and ventilation to 32 trucks around the clock, thus preventing the need for engines

[38] Spiro Katan, Bureau of Motor Equipment, New York City Department of Sanitation.

[39] Office of New York State Attorney General Eliot Spitzer, "Hunts Point Market to reduce diesel fumes in the South Bronx," Department of Law, June 20, 2003. Accessed 11 February 2004: http://www.oag.state.ny.us/press/2003/jun/jun20a_03.html

to remain on. This project is expected to reduce emissions by 2,000 tons per year.[40] The latest IdleAire in-cab model provides temperature control, ventilation, electric utility and internet access.[41] Expansion of the use of such technology can result in a significant decrease in the emissions of idling vehicles.

Similarly, the retrofitting of school buses and reduction of bus idling possess benefits for the health of South Bronx schoolchildren. In December, 2001, The New York Power Authority (NYPA) announced a $6 million program to retrofit 1,000 city school buses with particulate filters, in an effort to offset emissions from their gas-fired turbines across the city's outer boroughs.[42] No retrofits were completed as of 2003.[43] A $1.25 million state grant to the New York City Department of Education in 2003 allowed for the addition of emissions-reducing equipment to 2,194 city school buses.[44] Several programs seek to minimize engine idling in front of schools, including Real World Foundation's Asthma Free School Zone campaign[45] and successful agreements initiated by Connecticut, Maine and New Hampshire with school transportation associations.[46] Most recently, New York State Attorney General Spitzer negotiated agreements with four major school bus fleets to limit idling times, add particulate filters and utilize ultra-low sulfur diesel fuel, to be financed by NYPA. Combined, these efforts can reduce a school bus's emissions by up to 90%.[47]

The adoption of best practices for waste transfer stations can also be a valuable tool in directing environmental health improvement in the study area. Key components include measures to mitigate dust from garbage debris and the requirement for ventilation in indoor facilities.[48] City and state regulations seek to enforce some of these management practices, but however fall short in some respects. For instance, many private waste transfer trucks do not travel with full capacity loads, increasing the total number of trips necessary for a given amount of solid waste. Equally as important, waste transfer truck routes are not regulated, and experts suggest that a change in transfer routes and garage locations can significantly reduce the number of vehicle miles traveled. In a study for Environmental Defense, Sam Schwartz Company found that changing the location of only *one* district's garage could eliminate 200,000 vehicle miles

[40] Clean Air Communities, "EPA Administrator Christie Whitman Joints in Announcing First Clean Air Communities Project," Northeast States Clean Air Foundation, August 6, 2001. Accessed 11 February 2004: http://www.cleanaircommunities.org/newsroom/pr010806huntspoint.html
[41] IdleAire Technologies Corporation, http://www.idleaire.com/
[42] New York Power Authority, "New York announces Clean School Bus Program," DieselNet, December 5, 2001. Accessed 11 February 2004: http://www.dieselnet.com/news/0112nyc.html
[43] Office of New York State Attorney General Eliot Spitzer, "School bus fleet agree to reduce urban air pollution," Department of Law, January 23, 2004. Accessed 11 February 2004: http://www.oag.state.ny.us/press/2004/jan/jan27a_04.html
[44] Officer of the Governor of the State of New York, "Governor announces clean air initiative for school buses," State of New York, September 17, 2003. Accessed 11 February 2004: http://www.state.ny.us/governor/press/year03/sept17_1_03.htm
[45] Real World Foundation, Asthma Free School Zone http://www.charityadvantage.com/afsz/home.asp
[46] United State Environmental Protection Agency, "Anti-idling," updated October 22, 2003. Accessed 11 February 2004: http://www.epa.gov/otaq/schoolbus/antiidling.htm
[47] Office of New York State Attorney General Eliot Spitzer, "School bus fleet agree to reduce urban air pollution."
[48] United States Environmental Protection Agency, "Waste Transfer Stations: A Manual for Decision-Making," Office of Solid Waste, US EPA, 2002.

traveled per year.[49] Furthermore, the consideration of marine transfer stations could significantly reduce vehicle miles traveled due to waste transfer, drastically reducing waste transfer transportation emissions.[50]

Lastly, the adoption of green building technology has the potential to improve indoor air quality in homes, schools and community facilities throughout the South Bronx. Primarily, improved ventilation systems and use of non-toxic building materials improve conditions that lead to the aggravation of respiratory illnesses. An affordable housing project, the Melrose II Complex, features low-VOC paints and acrylic seals throughout the house among a number of other "green" features.[51] An improvement in the quality of the South Bronx's school buildings would be an improvement in the health conditions of their children. The adoption of green building techniques in affordable housing projects would likewise provide health benefits for it residents.

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[49] Adam Lubinsky, Sam Schwartz Company, "Management of truck flow and queuing," Presentation at *Waste & Recyclables Export from Manhattan: Design and Siting of Export Facilities*, October 27, 2003.
[50] Ibid.
[51] Northeast Sustainable Energy Association, "2003 Northeast Green Building Awards: Melrose Complex II," NESEA, 2003. Accessed 11 February 2004: http://www.nesea.org/buildings/buildingawards/Melrose.pdf

Chapter 10
Policy Recommendations and Conclusions

Carlos Restrepo and Rae Zimmerman

The Phase II & III report of the NYU-Wagner/ICIS component of the South Bronx Environmental Health and Policy Study has continued to pursue the overall objective of the study, which is to identify relationships between air quality and transportation patterns in the South Bronx and their association with waste transport as a basis for understanding potential health effects.

Air quality is measured in three different ways in the *South Bronx Environmental Health and Policy Study*. First, the project examined data from the network of air quality monitoring stations maintained by the New York State Department of Environmental Conservation (NYSDEC). This analysis was carried out in Phase I of the project. Second, the project looks at air quality by using sophisticated computer models that use traffic count estimates to model the contribution of transportation to concentrations of pollutants such as particulate matter and nitrogen oxides. These models are described in chapters 3-6 of this report. These models were also used to examine the impact of some hypothetical scenarios involving the removal or relocation of three waste transfer stations in the area to examine impacts on traffic and air quality. Third, the project looks at air quality in the study area by taking air samples through the use of a mobile laboratory. Chapter 2 of this report examines air quality in the area by comparing air quality data provided by the Nelson Institute of Environmental Medicine (NIEM), which is a participating partner in this study, with data provided by the New York State Department of Environmental Conservation (NYSDEC). These were real-time measurements carried out at different heights above the ground.

Chapters 7 and 8 of the report include detailed analyses of various socio-economic variables around the waste transfer stations following an environmental justice framework. Conclusions and some preliminary policy recommendations drawn from the analyses described above are discussed in this final chapter of the report. A more comprehensive discussion of policy recommendations will be included in the following phases of the project.

I. Air quality

The air quality report included in chapter two of this report compares ambient air quality data measured by the Nelson Institute of Environmental Medicine's mobile van with data provided by the air quality monitoring network of stations maintained by the New York State Department of Environmental Conservation (NYSDEC). This comparison was carried out because the intake of the mobile van is about 4 meters above the ground whereas the NYSDEC's monitoring stations are located 15 meters above the ground. The participating community groups expressed an interest in knowing if there was a significant difference between these sets of data since community residents are more likely to be impacted by air pollution closer to ground level. The comparison was done for three week intervals when the mobile lab was located in the South

Bronx. The data from the van were compared to all available monitoring stations in Bronx County for sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3) and fine particulate matter ($PM_{2.5}$).

The findings indicate that for $PM_{2.5}$ the ground-level measurements are similar in value and trend with those of NYSDEC stations. In the case of O_3, the concentrations recorded close to ground level by the project's mobile van were generally lower than those recorded by NYSDEC stations. For the other pollutants the concentrations measured by the project were substantially higher than those recorded by NYSDEC's monitoring stations. For NO_2 the daily average concentrations recorded at ground level are over twice as high as those recorded by NYSDEC stations. If the van's data are representative of concentrations of NO_2 in the area for the whole year, EPA's annual standard would be exceeded. NO_2 measurements taken by the van at Hunt's Point Avenue in 2003 show values that are lower than those taken at other locations in 2001 but higher than NYSDEC values taken in that year. In the case of SO_2, ground level measurements recorded by the project's van are also substantially higher than NYSDEC measurements. However, the van's measured concentrations as well as NYSDEC's data suggest concentrations that are well below EPA's 24-hour average standard for SO_2. Similarly, CO concentrations measured at ground level tend to be higher than those recorded by NYSDEC's stations. As with ozone, 1-hour average maximum values were selected each day in order to compare the data with EPA's 1-hour standard. Both the project's mobile lab and NYSDEC's measurements suggest concentrations of CO that are well below EPA's standard.

The most significant difference between the two sets of data appears to be for NO_2. The US EPA has set a one-year standard for this pollutant. This means that one year's worth of data would have to be collected close to ground level to compare it to the standard. Because ambient NO_2 concentrations do not show strong seasonal variations, these preliminary results suggest that more monitoring of NO_2 concentrations close to ground level should be carried out by NYSDEC to ensure that the standard is being met. Current federal regulations indicate that monitoring stations can be located at heights between 2-15 meters and it would be valuable to obtain more information about the vertical profile of this pollutant to ensure that residents in the area are not being exposed to dangerous levels of NO_2.

II. Transportation and air quality modeling

Another tool used during phases II & III of the project to gain a better understanding of the relationship between transportation, waste transfer activities and air quality was computer modeling. A simulation-based model called VISTA was implemented for the South Bronx network for the morning (6:00am – 10:00am) and evening peak periods (3:00pm – 7:00pm). The VISTA model was integrated with the MOBILE6 air quality software in order to produce emission estimates of nitrogen oxides (NO_x), carbon monoxide (CO), and total organic gas (TOG) for all the roadway segments of the network.

The traffic volume results from the traffic modeling were also used with US EPA emission factors to generate PM emission rates for roadway links in the South Bronx. The EPA ISC3ST dispersion model was used for this purpose. The model shows detailed variations in the ground level patterns of ambient air concentrations. Given the assumptions made, the results of the model indicate that traffic volume and vehicle-miles traveled (VMT) of trucks are about 5% of the total. Particulate matter (PM) emissions from trucks were estimated to be about 18% of the total for all vehicles and PM emissions from diesel engines were estimated to be 4 to 20 times greater than those from gasoline engines for similar sized vehicles per VMT. The predicted concentrations are highest along the main traffic arteries and maximum annual average concentrations are consistently in the range of 0.1 $\mu g/m^3$. Maximum 24-hour average concentrations are in similar areas and range from 0.3 to 0.5 $\mu g/m^3$.

The model was also used to estimate nitrogen oxide (NO_x) emissions from trucks. The results suggest that for the entire study area, on average the total NO_x emissions from cars are about a factor of three larger than the truck emissions. This ratio of car emissions to truck emissions is lower than that found for PM which suggests that diesel trucks are a larger contributing source to NOx concentrations than to PM concentrations relative to gasoline powered vehicles. In addition, the model estimates that the morning NO_x emissions from cars are greater than afternoon emissions. For trucks, the afternoon NO_x emissions are greater than those during the morning.

III. Waste Transfer Scenarios

The transportation and air quality models were also applied to scenarios where three waste transfer stations were removed or relocated. The selection of these waste transfer stations was done simply to gain a better understanding of what the impact of such changes could mean in terms of traffic volumes and air quality in the area. This kind of scenario analysis could be carried out in the future if changes to the current level of waste transfer activity in the area are sought. The selected waste transfer stations for the scenarios are ones that are currently located in M1 or M2 zoned areas, which are intended as buffers between heavy industrial land use areas (M3) and residential areas. According to current regulations all waste transfer stations should be located in M3 zoned areas, which are designated for heavy manufacturing/industrial uses. Waste transfer stations may be located in M1 and M2 areas provided they take extra measures to mitigate the impact of their activities.

The results of the scenario analyses suggest that removing or relocating three waste transfer stations in the area has a significant impact on the volume and distribution of traffic in the area. Relocating these stations to locations in M3 areas seems to shift traffic further south in the study area, and away from residential communities. One policy recommendation that emerges from these scenario analyses is that in the future the location of waste transfer stations or other facilities that are associated with large volumes of truck traffic should be restricted to M3 zoned areas.

IV. Environmental justice

The environmental justice analyses carried out in chapter eight of this report include detailed results for various socio-economic variables. The analyses use a methodology that is consistent with some of the more sophisticated analyses presented in the literature review of environmental justice studies, but are specific to areas surrounding waste transfer stations in Bronx County. The analyses examine how the socio-economic variables considered vary with distance from the stations by drawing concentric circles of different radii around the stations. The goal of these analyses is to examine whether minorities or other disadvantaged groups bear disproportionate burdens associated with proximity to these facilities.

The analyses show that the percentage of Black residents is highest in the immediate vicinity, or within 0.25 miles of all the Waste Transfer Stations, and decreases as the distance from the transfer stations becomes larger, approaching the level of the South Bronx Study Area when the one-mile Buffer is examined. The percentage of Hispanic residents is lower in the 0.25 mile buffer, and increases with distance, approaching the level of the Study Area in the one-mile buffer.

The Census uses many different ways to measure wealth such as family income, household income, individual income, median income, per capita income and percent below poverty. When all the waste transfer stations are examined as a set, the median household income declines from the 0.25 mile buffer to the 1.0 mile buffer. For the 0.25 mile buffer the median household income is greater than for the Bronx County as a whole. The data on poverty levels has a pattern that is consistent with the data on median household incomes. The percentage of the population with incomes below the poverty level is lower in the 0.25 mile buffer around the waste transfer stations and rises as the buffer radius increases to 1.0 mile. This finding is unexpected and the inclusion of a WTS in the North-East section of the Bronx, outside the study area, may account for this because incomes are higher in that area of the county than in the Study Area.

With regard to the value of owner-occupied housing units the results of the analyses suggest that in the buffers around all the waste transfer stations taken as a set the mean value of owner-occupied housing units rises as the distance from the transfer stations increases. At all distances it is below that of the Study Area and Bronx County as a whole.

These environmental justice analyses will be complemented with an analysis of asthma hospitalization rates by zip code relative to some of the socio-economic variables described above. The two sets of environmental justice analyses will serve as the basis for policy recommendations.

V. Strategies for environmental improvements in the South Bronx

A number of technologies and programs that could impact the health of residents in the area are described in chapter nine of this report. They include programs to reduce truck pollutant emissions and idling and technologies to improve housing and building indoor environments. Some of the overall patterns that emerge from the analyses carried out in this report indicate that traffic volumes and air pollution concentrations are much higher around highways in the study area. Future policies in the area should aim to separate sensitive receptors such as schools, nursing homes and hospitals, and sensitive populations such as asthmatics, children and the elderly from these areas. Improvements could be achieved by locating facilities and sites associated with heavy traffic exclusively in M3 zoned areas, and away from sensitive receptors and populations and by providing buffers such as green zones and parks.

The NYU- Wagner/ICIS portion of Phase IV of the South Bronx Environmental Health and Policy Study focuses on the following areas:

- Develop an environmental planning framework with the community for the South.
- Reassess and if necessary expand data where gaps exist for the purposes of the planning effort.
- Assemble, operationalize, and apply decision tools that provide the community with the capability of using the environmental planning framework and the data to address siting issues, impacts of extreme events, and similar questions. This will encompass education and communication strategies to transfer these skills and resources to the community.

When Phase IV of the project concludes in 2005, the results of Phases I, II, III & IV of the project will be used to provide a more comprehensive set of policy recommendations.