APPENDIX D.1

TRANSPORTATION—RIDERSHIP MODELING

A. INTRODUCTION

This Appendix describes the ridership forecasting methodology used by New York City Transit for this <u>FEIS</u>. The primary model is the Transit Demand Forecasting Model (TDFM) developed by NYCT.[1] A second model, the MTA Regional Transit Forecasting Model (RTFM), provided forecasts of commuter rail and other suburban transit trips that included a NYCT subway transfer and mode shifts between transit and non-transit modes. The TDFM provided transit ridership forecasts for numerous alternatives and sub-alternatives proposed by the Second Avenue Subway Study. Transit ridership forecasts include projections of the number of transit trips by origin and destination and by subway and bus route. The main components of the methodology include the following:

- A computer model containing a detailed representation of New York City's subway and bus routes within the context of a geographic information system (GIS)

- A census tract based zone system for locating the origin and destination of trips

- A base year (2000) AM peak hour origin and destination trip table

- Future year (<u>2025</u>) AM peak hour origin and destination trip tables for projecting usage of existing and proposed routes using the subway and bus route computer model.

This modeling work has been closely coordinated with regional transportation modeling at the New York Metropolitan Transportation Planning Council (NYMTC), the federally designated metropolitan planning organization (MPO) and the Metropolitan Transportation Authority (MTA). The regional models developed at both of these organizations use NYCT's subway and bus network databases.

<u>Since the SDEIS was prepared, NYMTC has begun the process of updating socio-economic and travel forecasts to reflect actual 1990 to 2000 changes, 2000 Census results and new econometric forecasts for the region. This process will lead to a new set of forecasts around the end of 2003. In the interim, several steps were taken to update ridership forecasts.</u>

<u>The first step was to incorporate a preliminary NYMTC population and employment forecast update (adopted in December 2000) into MTA's Regional Transit Forecasting Model (RTFM). This forecast uses 2025 instead of 2020 as the horizon year, thereby maintaining a 20 year forecast period. From 2000 to 2025, Manhattan employment, the major determinant of peak hour ridership growth, is forecasted to grow by 12.5 percent, which is slightly less than the 2000 to 2020 growth of 13.6 percent from the previous set of forecasts. This reflects indications that part of the growth expected in the 2000 to 2005 period had occurred in the 1995 to 2000 period. The second step was to update the base year (2000) trip table in NYCT's Transit Demand Forecasting Model (TDFM) to better reflect the strong subway and bus ridership growth that also occurred between 1995 and 2000. Lastly, it was</u>

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[1] Modeling Transit Demand in the Big Apple from a Transit Agency Perspective, James J. Barry, Jeffrey Erlitz, Robert Newhouser and QiFeng Zeng; presented at the Seventh Transportation Research Board Conference on the Application of Transportation Planning Methods, March 1999.

determined that within NYC, the NYMTC 2000 to 2025 forecast does not differ substantially from the previous 2000 to 2020 forecast. Therefore, the 2020 trip table in the TDFM was used for 2025.

B. MODELS USED

TRANSIT DEMAND FORECASTING MODEL (TDFM)

The TDFM is NYCT's in-house model of all subway and bus routes in New York City. This model has been developed and enhanced over the past eight years using TransCAD, a software package that combines transportation demand modeling with a Geographic Information System (GIS). TransCAD is a travel demand forecasting package that is used by many highway and transit agencies, as well as Metropolitan Planning Organizations throughout the country (including the NYMTC, the Metropolitan Planning Organization for the New York metropolitan area). The TDFM has been used extensively at NYCT for short-range planning [e.g., Lenox Avenue Line and Williamsburg Bridge Reconstruction projects) and long-range planning (e.g., East River Crossings Study and the Major Investment Study (MIS) and Draft Environmental Impact Statement (DEIS) prepared for the Manhattan East Side Transit Alternatives (MESA) Study in 1999]. It has also been integrated into two TransCAD based regional models, the MTA's RTFM and NYMTC's Best Practice Model (BPM), which includes a full highway demand modeling capability in addition to transit modeling.

The GIS capability in TransCAD has enabled NYCT to include the spatial detail that is needed to accurately represent the interaction between transit travel demand and the location of bus stops and subway stations. For example, the model includes a walk "network" that allows it to predict trips that might use the street grid to access alternative bus and subway services, rather than more simplistically assuming that all trips are made from the center of an origin zone in a straight line to a single subway or bus stop. The model also represents the characteristics of individual transit routes (e.g., the Lexington Avenue 4 and 5 service) separately, rather than the characteristics of a whole transit line or service (e.g., the Lexington Avenue express service). Thus, the model can predict results for each route separately.

The TDFM estimates how people use the transit system in New York City during the morning (AM) peak hour. The AM peak hour was chosen because the travel demand is highest during this hour, and transit facilities and services are sized to accommodate this level of demand. (Typically, trips are made in a more concentrated time period during the morning rush; during the evening, trips are spread over a longer period.) Travel demand is represented in the model by transit "trip tables," which list trips made by subway, NYCT buses, and other local and express buses in New York City. The trip tables contain estimates of the origins and destinations of patrons using the transit system, by analysis zones, e.g. census tracts or split census tracts. The origin and destination trip tables were constructed from the journey-to-work data provided in the 1990 U.S. Census of Population and Housing, Census Transportation Planning Package (CTPP). These are the latest Census data of this information currently available. The trip tables were also updated using recent ridership counts, information on origins and destinations derived from MetroCard data, and a prediction of future growth in population, labor force, and employment by census tract in Manhattan prepared by AKRF, Inc. A more detail discussion on the prediction of future growth is in Chapter 6 of this SDEIS, "Social and Economic Conditions".

The TDFM estimates route choices using information on transit service (routes, travel time, frequency, transfer connections) to predict which route patrons will choose. It is used to produce forecasts of riders by subway or bus route. These forecasts are suitable for general planning analysis, such as comparing the No Build Alternative and Second Avenue Subway alignment options in this document. The model outputs from the TDFM provide information on the volumes (i.e., transit riders) on various subway and bus routes, including passengers boarding and exiting trains and transferring between subway routes at various stations, and summary statistics on passenger hours

and miles traveled by transit. These data were used to evaluate and compare the changes in ridership and service operations between the No Build Alternative and alternative alignments of the Second Avenue Subway. Potential improvements and decline in service were compared using such measures as station leave-load volumes[1] and volume-to-capacity (v/c) ratios.[2]

REGIONAL TRANSIT FORECASTING MODEL (RTFM)

The RTFM is a model of regional travel in the New York metropolitan area, including NYCT subway and bus riders; commuters using Metro-North Railroad, Long Island Rail Road (LIRR), and New Jersey Transit; automobile travelers; and people using other travel modes, including taxi, bicycle, and walk. The model divides such trips into three types: home-based work (i.e., a trip to work from home), home-based other (i.e., a trip from home to another destination), and non-home based (i.e., a trip that begins away from home). The RTFM (and its earlier versions) has been used for major transit studies in the region including the LIRR East Side Access Project, the MTA's Lower Manhattan Access Study, and Metro-North's Penn Station Access Study.

The RTFM network database includes NYCT's subway and bus network from the NYCT TDFM as well as the commuter rail system and is used by NYMTC for the MTA region portion of the BPM transit network. For this SDEIS, the RTFM was used to provide forecasts of commuter rail riders using the subway and estimates of changes in mode usage (e.g., from auto to transit). The RTFM provided station-by-station estimates of commuter rail riders who would also use the Lexington Avenue and Second Avenue Lines, as well as commuters who would shift to transit from other modes.

C. APPLICATION OF TDFM FOR SECOND AVENUE SUBWAY

The steps involved in applying the model for the Second Avenue Subway Project are described below and illustrated in Figure D.1-1. The transit modeling process entailed four basic steps: 1) development of the zone system and transit network for the entire city (including coding and validation); 2) the development of existing and future travel demand (origin and destination trip matrices); 3) inclusion of the RTFM forecasts of commuter rail to subway transfers and mode share shifts; and 4) assignment of future trips to the future networks.

TDFM PROCESS

The ridership forecasting process must account for both the supply of transit service and the demand for the transit service. A change in either one can change the forecast of ridership on a proposed route. Figures D.1-2, D.1-3, and D.1-4 contain charts of the process used in this model with transit service shown on the left side of each chart and transit demand shown on the right side. The current process was updated from 1995 base year networks and trip tables used in the MESA Study's MIS/DEIS. The base year (2000) process includes coding scheduled subway and bus service into the model and developing an origin and destination trip table to represent transit demand. This very detailed process must ensure that the travel choices faced by travelers are carefully simulated, including transferring from one subway route to another or between a subway route and a bus route. Similarly, sources of information on transit demand must be carefully selected and combined to ensure that an accurate origin and destination table of transit trips is developed for use in the model.

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[1] Leave-load volume is the estimated number of passengers on-board a subway train as it leaves a station, based upon field observations or TDF model outputs.

[2] Volume-to-capacity ratio is the ratio of passenger demand to capacity of scheduled subway or bus services during the analysis period (e.g. AM peak hour).

The calibration and validation process, shown at the center of Figure D.1-2, is used to accurately estimate the volume of passengers on each subway and bus route by adjusting parameters in the trip assignment model, updating the trip table and verifying coded service characteristics.

Figure D.1-3 shows the development of the future year (2025) No Build transit service and trip table. To ensure that the service and demand are interacting in a reasonable way, a checking and validation process is used. Major transit service improvements in the No Build alternative include the free bus-to-subway transfers that started July 1, 1997, and the opening of the 63rd Street connection with the Queens Boulevard Line in 2001. Additional transit trips from the commuter rail and mode choice model components of the RTFM are added to the trip table to produce the final 2025 No Build trip table.

With the No Build network completed and validated, the coding of build alternatives proceeds by adding new services and modifying existing services to accommodate use of existing lines by the Second Ave Subway service. The final build alternative is passed on to the RTFM Mode Choice Model, which estimates new trips attracted to transit. Figure D.1-4 outlines this process and shows the final product to be a set of alternative specific trip tables that include the new trips attributed to transit. Each of these trip tables is used as input to the transit trip assignment model. The model produces the final ridership forecasts for each alternative.

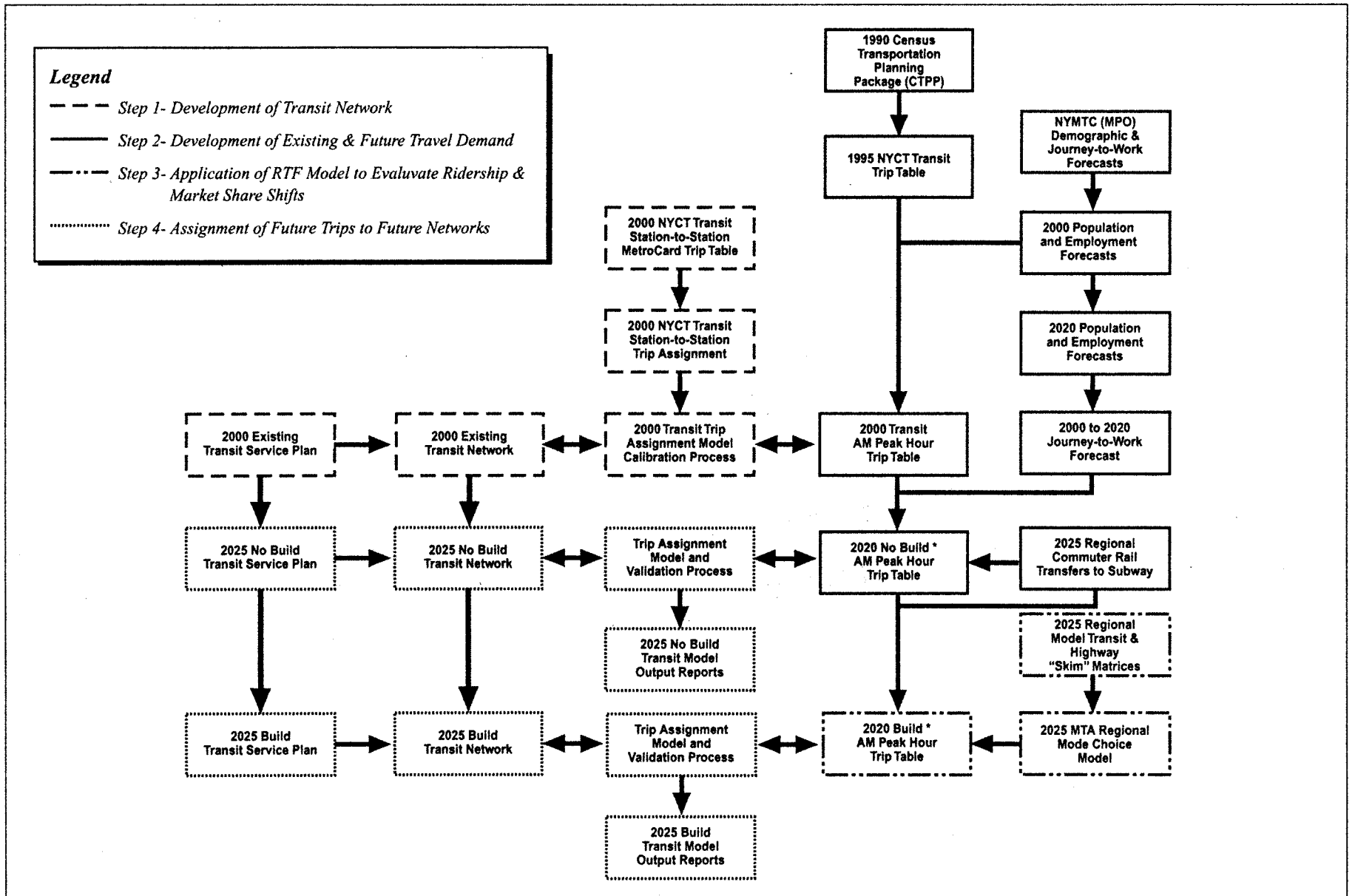## DEVELOPMENT OF ZONE SYSTEM AND TRANSPORTATION NETWORKS

DEVELOPMENT OF A ZONE SYSTEM

The TDFM evaluates a travel network made of different travel modes. For this evaluation, a zone system was created to represent the origins and destination of trips made in the network. These zones are used to build trip tables or origin and destination matrices that show the number of current (or future) trips that people typically make between each zone. Census tracts were selected as the zones for the study so that 1990 (and in the future, when data are available, 2000) census journey-to-work data could be used.

In this model, New York City is divided into 2,294 zones (see Table D.1-1). Each zone has a centroid that represents an approximate location in the zone where trips begin or end. Using over 2,000 zones reduces the size of the zones so that any errors due to this approximation are minimized. To provide greater detail close to the alternatives' routes, a number of the census tracts that straddled Lexington and Second Avenues were split into smaller units (census block groups).
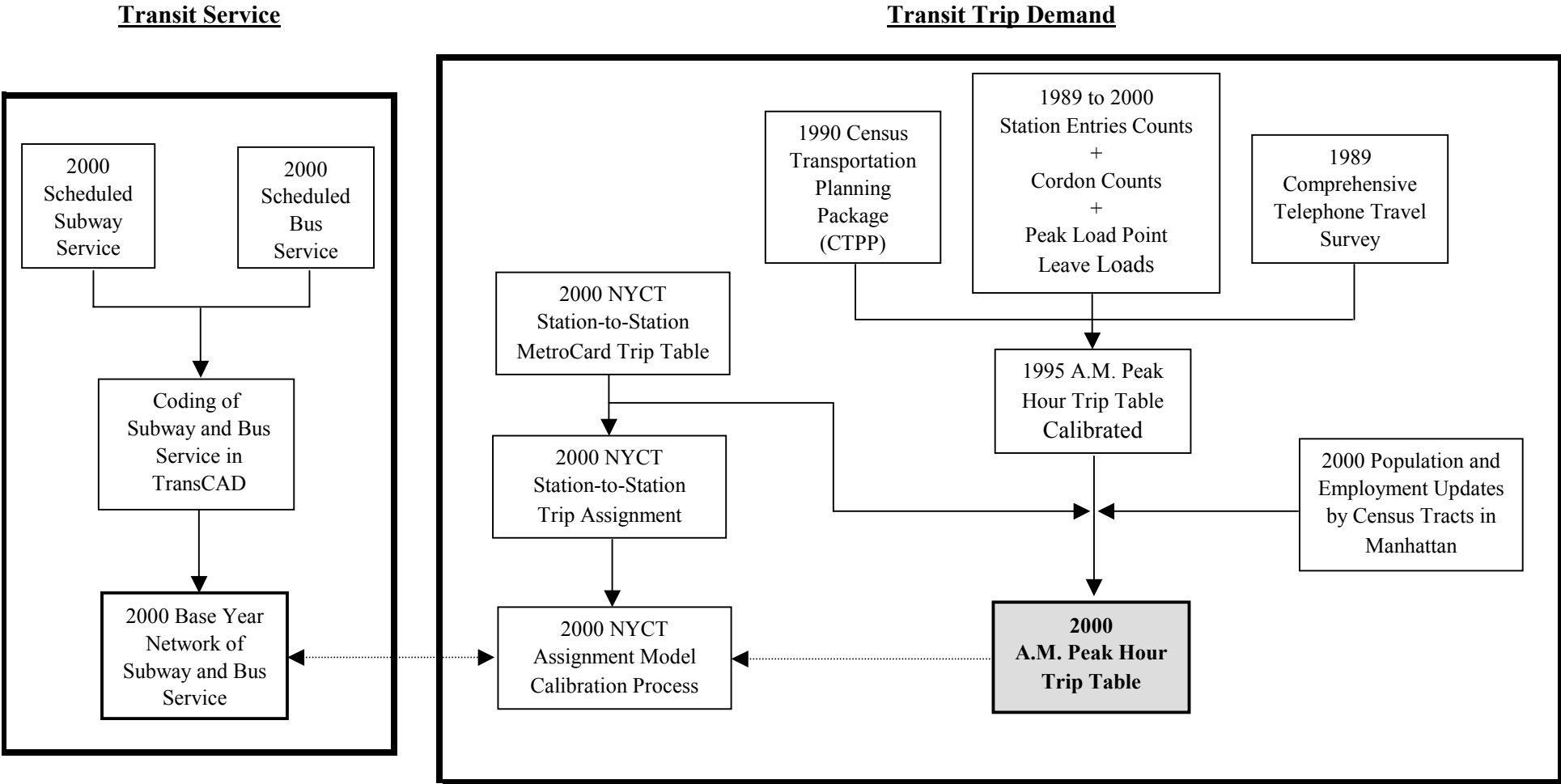
Table D.1-1
Zones by Borough

Borough	New York	Bronx	Kings	Queens	Richmond	Total
Zones	378	355	789	672	100	2,294

Legend

— — — Step 1- Development of Transit Network

———— Step 2- Development of Existing & Future Travel Demand

—··—··— Step 3- Application of RTF Model to Evaluvate Ridership & Market Share Shifts

············· Step 4- Assignment of Future Trips to Future Networks

1990 Census Transportation Planning Package (CTPP)

NYMTC (MPO) Demographic & Journey-to-Work Forecasts

1995 NYCT Transit Trip Table

2000 NYCT Transit Station-to-Station MetroCard Trip Table

2000 Population and Employment Forecasts

2000 NYCT Transit Station-to-Station Trip Assignment

2020 Population and Employment Forecasts

2000 Existing Transit Service Plan

2000 Existing Transit Network

2000 Transit Trip Assignment Model Calibration Process

2000 Transit AM Peak Hour Trip Table

2000 to 2020 Journey-to-Work Forecast

2025 No Build Transit Service Plan

2025 No Build Transit Network

Trip Assignment Model and Validation Process

2020 No Build * AM Peak Hour Trip Table

2025 Regional Commuter Rail Transfers to Subway

2025 No Build Transit Model Output Reports

2025 Regional Model Transit & Highway "Skim" Matrices

2025 Build Transit Service Plan

2025 Build Transit Network

Trip Assignment Model and Validation Process

2020 Build * AM Peak Hour Trip Table
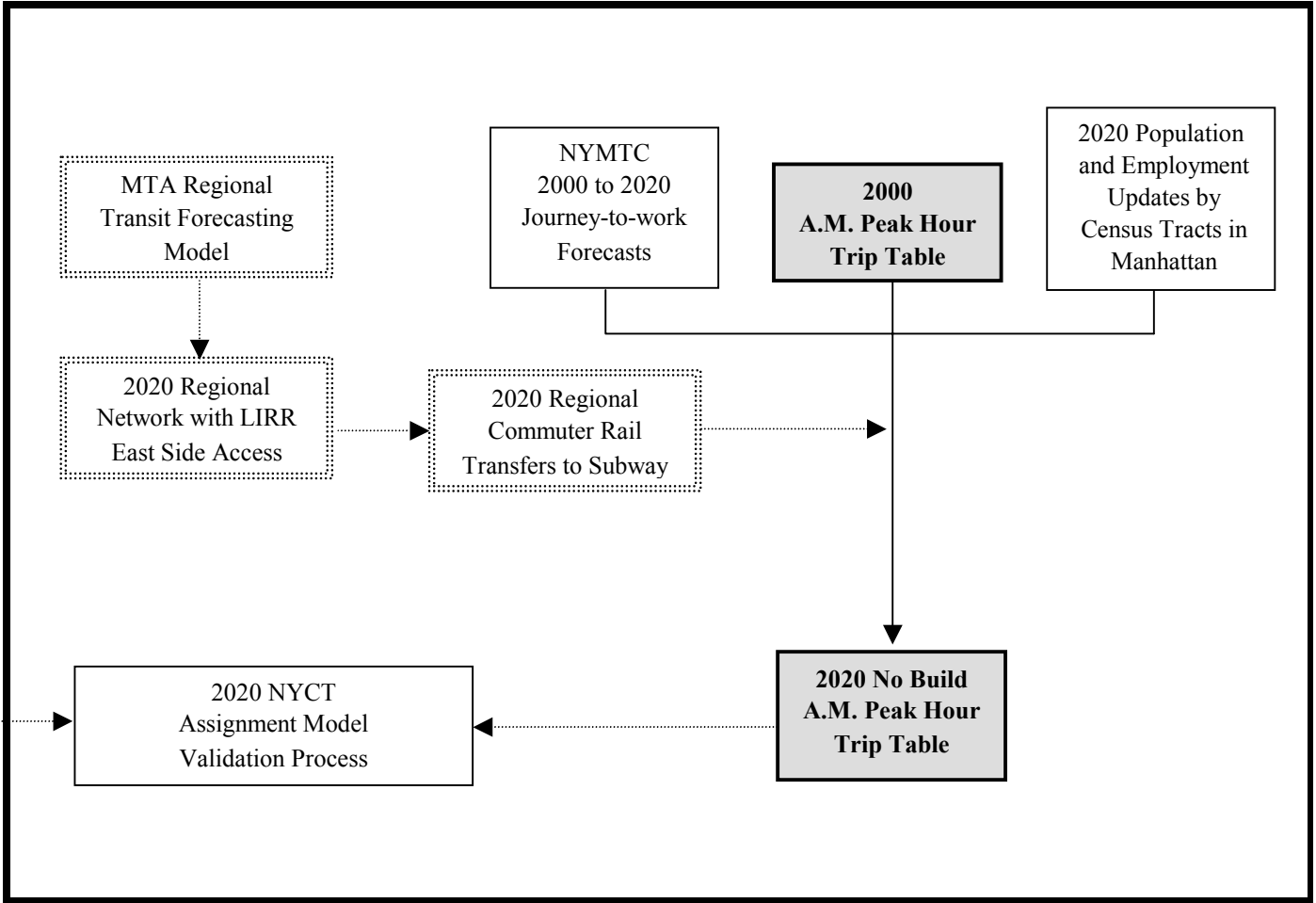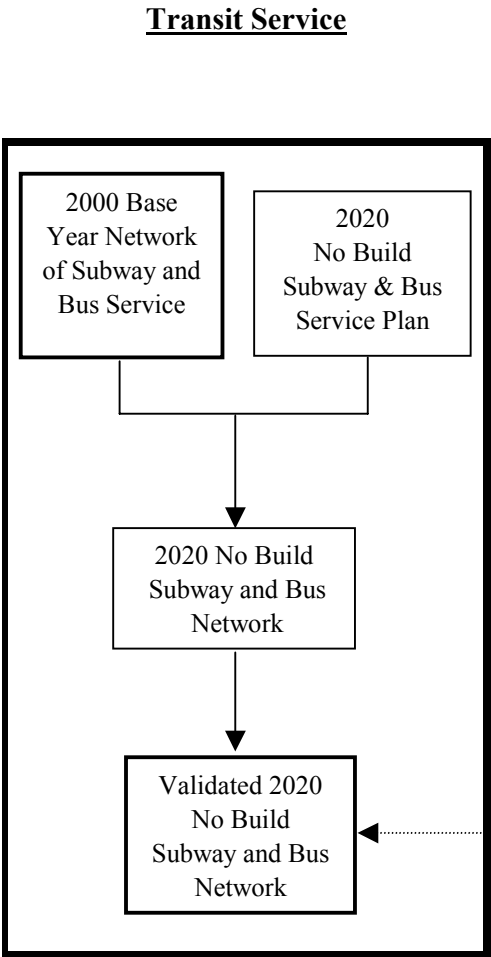
2025 MTA Regional Mode Choice Model

2025 Build Transit Model Output Reports

* Note: An updated 2020 trip table was used in NYCT Transit Demand Forcecasting Model (TDFM) for 2025.

Figure D.1-1

Second Avenue Subway Travel Demand Forecasting Process

Transit Service

Transit Trip Demand

Transit Service   **Transit Trip Demand**
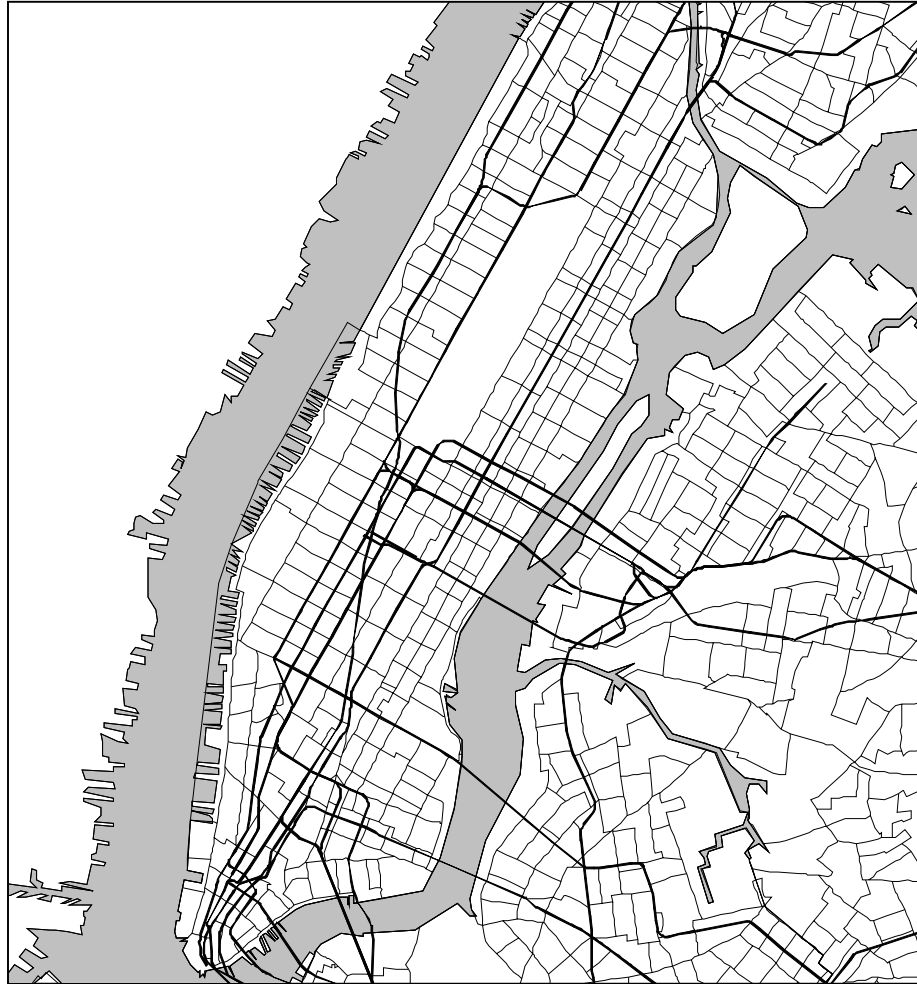
Transit Service

Transit Trip Demand
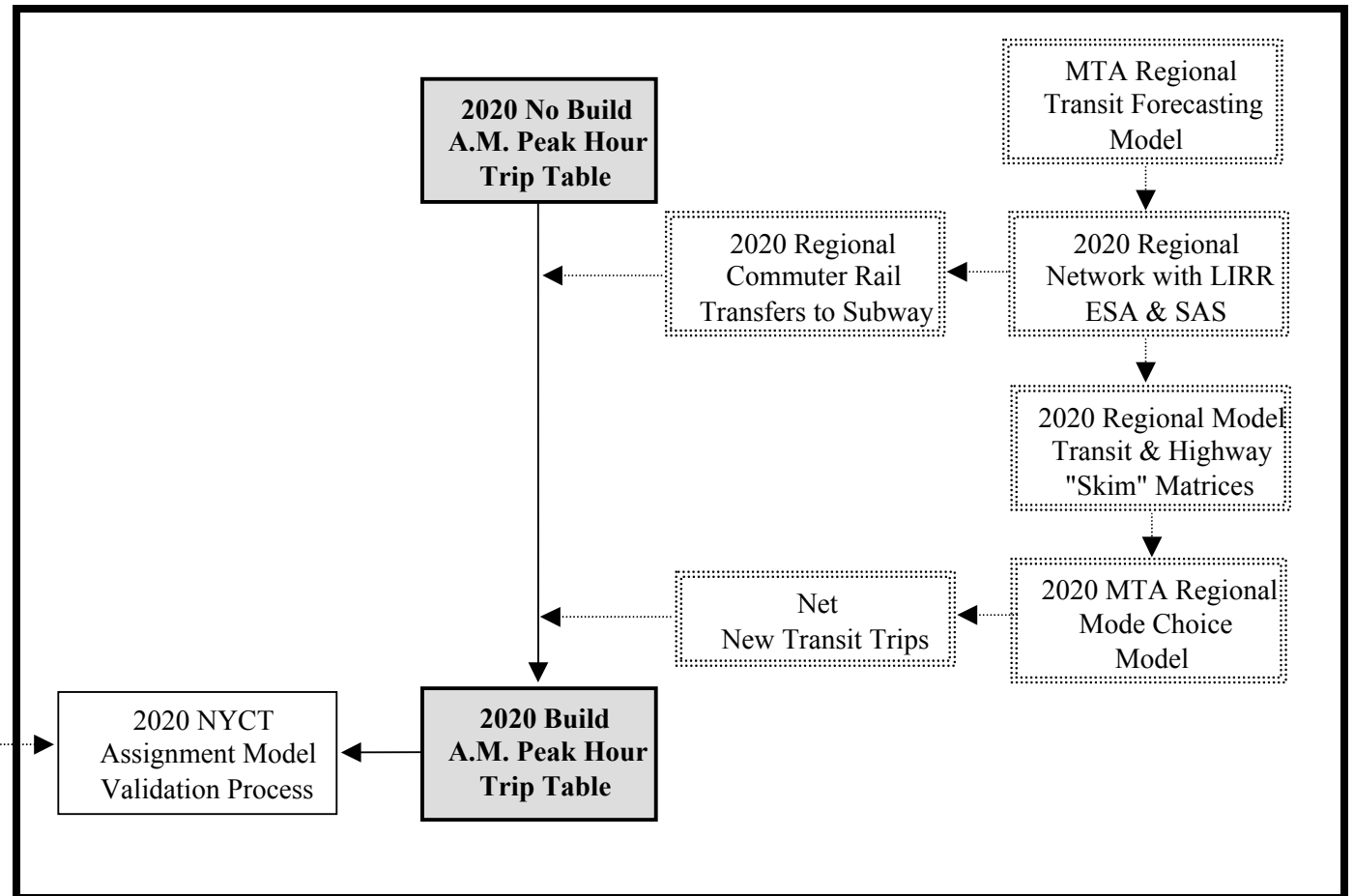
Figure D.1-5
Manhattan East Side Zone System with Subway Routes

ROUTE CODING AND NETWORKS DEVELOPMENT

NYCT has revised and enhanced the TDFM model to take advantage of computer speed and memory improvements and upgrades in the software package, TransCAD. Transit ridership forecasting for the long and short list of alternatives in the 1999 MESA MIS/DEIS was developed using the traditional trip assignment modeling approach with the following enhancements:

- A detailed NYC transit network with all NYCT subway and bus routes and all NYCDOT franchised bus routes, plus an extensive walk network covering most of Manhattan. All transit routes and related transfer passageway are re-coded into the "route system" format.

- A detailed zone system with 2,294 internal zones comprised of individual census tracts or census tracts split along block group lines. Two external zones were developed to account for Metro North users transferring to subway routes within or in the vicinity of Grand Central Terminal and 125th Street and Park Avenue.

- A Stochastic User Equilibrium Assignment procedure that accounts for crowding constraints as well as the multiple transit route choices available in many areas of New York City.

Transit Route Systems

Forecasting transit ridership changes resulting from major service changes or additions requires a model of New York City's large and complex transit network. It is important that this model not only be accurate and verifiable but that the updating process be efficient and the addition of proposed new routes be manageable. To achieve these objectives NYCT switched its route coding to the new "route system" feature in TransCAD. A route system is a collection of routes stored together in a map layer. Each route is composed of a series of line features that are stored in another layer in the map.

Bus routes are composed of line features from a layer containing all the streets in New York City. Subway routes are composed of line features from a layer containing all the subway, surface and elevated rights-of-way in the New York City subway system and the Staten Island Rapid Transit System. More than one route can operate over a single line segment, whether it is a street or a rail structure. Adding a bus route to existing streets or adding a subway route to existing lines is a relatively simple operation with this route system feature. When a route uses a new street or subway line, the street or subway line must be added to the line layer first.

CREATION OF AM PEAK HOUR TRANSIT NETWORKS

Transit networks were created for existing conditions in the base year (2000) and for the No Build scenario and each Build alternative in the future analysis year (2020), based on route-by-route service plans.

Transit Network

The transit network is a computer-based model of the transit travel choices available to passengers during the AM peak hour. It was designed with sufficient detail to represent accurately the numerous route choices available for travel to areas, such as Manhattan south of 60th Street and downtown Brooklyn. The components of the transit network include the following:

- All NYCT subway and Staten Island Railway (SIR) routes with AM peak hour service frequencies, travel times, and passenger-carrying capacities.

- A walk network with walking times and capacities for passageways between subway routes.

- All NYCT and New York City Department of Transportation (NYCDOT)-franchised local and express bus routes with AM peak hour service frequencies, travel times and passenger-carrying capacities.

- NYCDOT Staten Island Ferry route with AM peak hour service frequencies, travel times, and passenger-carrying capacities.

- Access and egress links for connecting zones with subway stations and/or bus stops or with street intersections in the walk network areas.

- Fares and transfer charges in accordance with the MTA's current fare policy.

For future conditions, the model's transit network was adjusted to reflect a future service plan for all routes expected to be operating in the analysis year. The No Build Alternative's service plan includes the recent completion of the 63rd Street Tunnel Connector in Queens and the future restoration of full subway service on the Manhattan Bridge. The No Build Alternative and the Second Avenue Subway build alternatives also include the LIRR East Side Access Project, which will bring LIRR trains into Grand Central Terminal.

Transit Network Specification

In order for TransCAD to assign trips to routes, a network file must be created and configured to depict the key features of New York City's transit system such as express/local subway services and numerous transfer passageways between subway lines. In creating a transit network one must specify the source of all attributes, i.e., the route layer, the stop layer, and the line layer. The route layer has descriptive information such as route name, mode, headway, passenger carrying capacity and fare amount. The line layer contains length, transit in-vehicle time, and walk time. For in-vehicle time, NYCT uses the travel time table look up option. The line layer includes all streets (see Figure D.1-6) in New York City, but in order to provide reasonable connectivity several link types were specified. These link types can represent either walking links or different types of station access or transfer links. Together these links are called non-transit links. The stop layer has subway stations and bus stop information. Listed below are definitions of the various non-transit links.

A transit network combines all the routes and associated model components described above into a model of the transit system as passengers would view it when choosing their "path" from origin to destination. Transit networks are used to solve "best path" problems and for performing transit trip assignments. Transit trip assignment (with capacity constraint) is a mathematical procedure that takes information from the transit network, computes the "best path" for all the trips in the trip table and checks the results for links with total passengers in excess of the specified passenger carrying capacity. Links over capacity are given a penalty value that makes the link less attractive for the subsequent iteration of the trip assignment.

Figure D.1-6
Infrastructure Layer (Streets) Sample
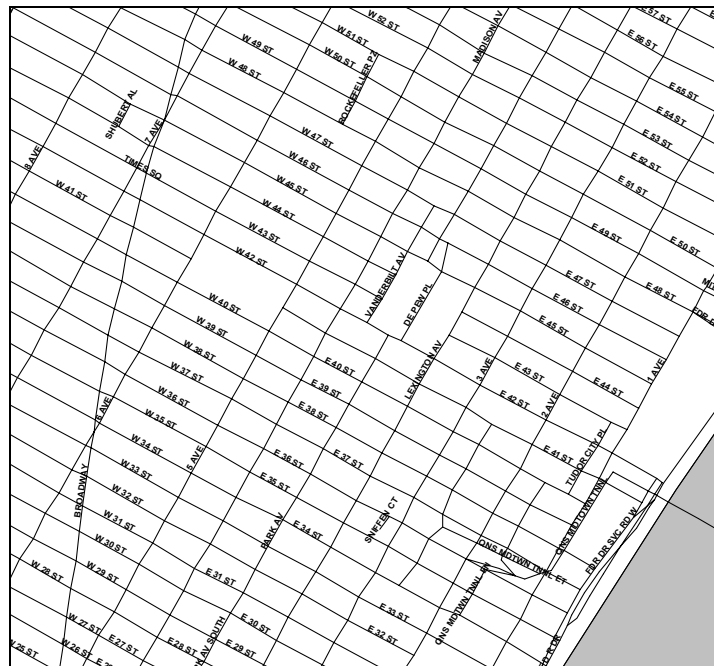
A walk network consists of street links included in the model to allow trips to go between zones and bus stops or subway stations. These streets can also be used to transfer between bus or subway routes if there is no better connection. Most streets in Manhattan and Downtown Brooklyn are included plus all other streets used by at least one bus route (Figure D.1-7). This walk network allows the model to account for the typical New York City practice of someone walking past the nearest subway station to access another nearby station on a route that provides more direct access to the person's destination.

Figure D.1-7
Walk Network Sample
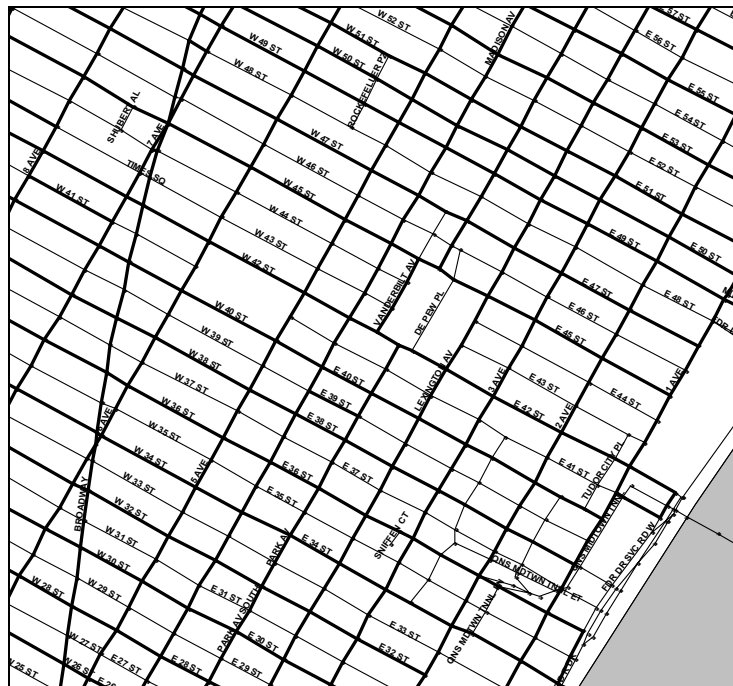
Using the line layer as a foundation, subway and bus routes and stops are coded into the model. Figure D.1-8 shows a sample of the coding for subway routes and stops in Manhattan.

Subway-to-subway transfers are special transfer links included in the model where two or more subway stations are linked by passageways. These transfer links contain measured walking times from the center of the platform or, in the case of proposed transfers, an estimated walking time based on the design layout. In corridors used by the proposed Second Avenue Subway and the Lexington Avenue Line, special " transfer routes" were created using these links so that more detailed information on transfer movements could be obtained from the model. See Figure D.1-9.

Access links provides a path between zone centroids and nearby transit stops or, in the case of walk access links, between zone centroids and nearby street intersections. See Figure D.1-10.

Figure D.1-8
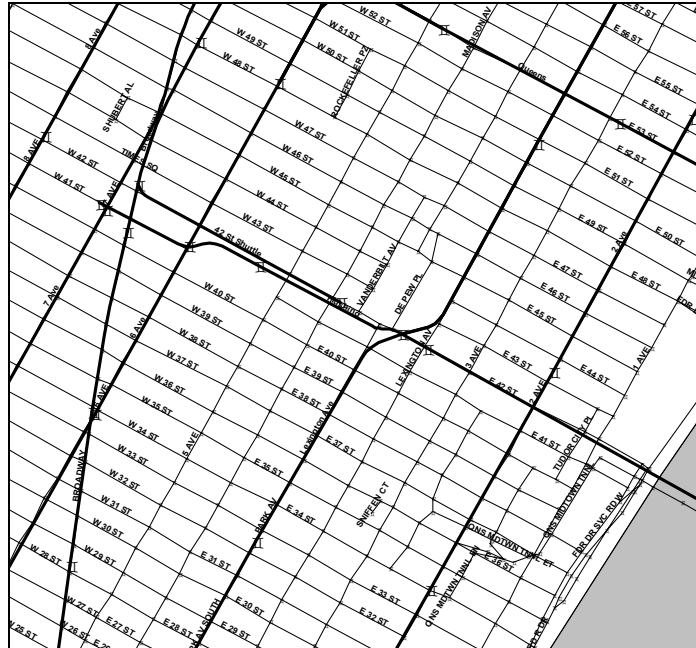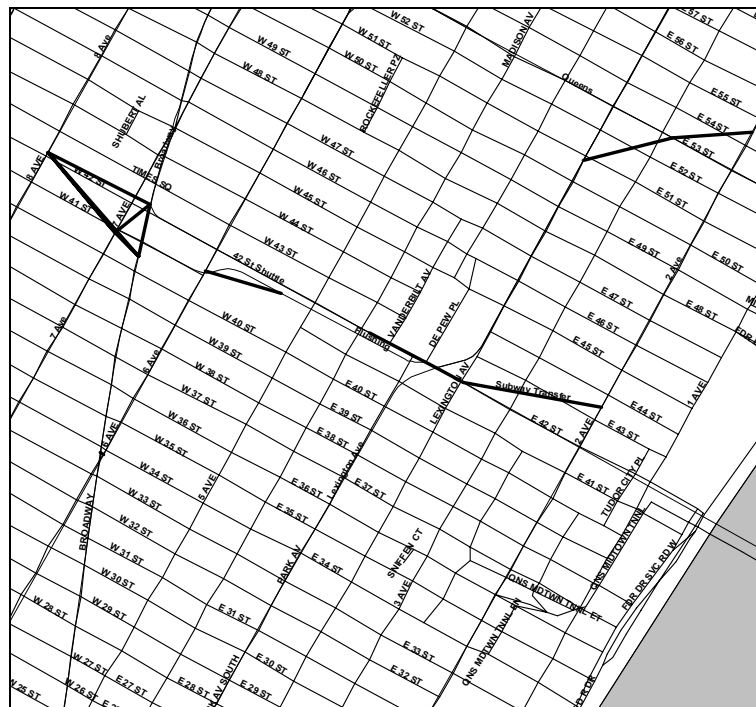**Subway Links and Stations Sample**

Figure D.1-9
Subway Transfer Links Sample

Figure D.1-10
Access Links and Zones

In addition to information provide above there are two other essential items that are needed before creating a network. One is a mode table, which allows the user to define a set of modes. For each mode, service parameters (such as headways, transfer times, etc.) are defined for all routes. This table can be used for both transit and non-transit modes. The second is a mode transfer table. This table controls mode-to-mode transfers. For instance, a passenger transferring from subway to local bus will have a free transfer, but will incur a second fare transferring from subway to express bus.

Transit Networks Building & Configuration

There are several steps in creating a transit network. First, several selection sets are made so that TransCAD recognizes the source of all necessary attributes:

- Select nodes that will represent centroids.
- Select appropriate non-transit links
- Select appropriate routes and stops

The next step is to configure the network.

NYCT used standard and optional features in TransCAD to customize the transit networks and route systems in the TDFM to account for the complexities of the New York City Transit system, e.g., express/local subway lines and intersecting subway lines with transfer passageways. There are several types of settings to specify:

- **General:** The general settings allow you to set the travel time field, path method, maximum trip cost, maximum transfers, maximum transfer time, value of time and centroids.

- **Mode:** The mode settings allow you to temporary enable or disable modes.

- **Fare:** The fare settings allow you to choose a fare system that represents flat fares, zonal fares, zonal fares by mode, or mixed fares. A fixed fare regardless of distance represents flat fares. To replicate NYCT fare system, we use the flat fare system. A transfer fare can also be set in a similar fashion. The fare settings also allow you to specify the number of free transfers and the number of free transfers before charging a full fare.

- **Weights:** The weights setting allows you to set weights or factors to account for riders relative perception of in-vehicle time, transfer time, waiting time, dwelling time and non-transit link time.

- **Other:** Allows you to set other time costs such as waiting times, transfer times, dwell times and layover times. It is also used to set minimum and maximum waiting times, maximum access, egress and travel times. Also, an inter-arrival parameter (determines the relationship between waiting times and headways) can be set.

- **Travel Time Tables:** These tables contain the time it takes to travel on each segment of a route based on scheduled running times for existing routes or simulated travel times for proposed routes.

In addition to the general settings above, Table D.1-2 below has details regarding all parameters used by NYCT and a brief explanation.

Highway Network

The RTFM characterizes the highway system using a network representation of all expressways, parkways, and arterial roadways in the New York metropolitan area. NYMTC, as part of its Best Practice Model (BPM), does the maintenance and processing of these networks. The BPM highway network is included in the MTA's RTFM in the form of matrices that represent peak-period congested travel time, distance, and tolls between each pair of transportation analysis zones in the modeling region.

Setting	Variable	Parameter	Explanation
General	Link Time	IVTT	In-vehicle travel time (VITT) required to traverse the link between two stops.
General	Path Method/Assignment Method	Shortest Path SUE	The method used to determine the best path between zones is the shortest path method which chooses the path that minimizes the total generalized travel cost. The assignment method is the shortest path based stochastic user equilibrium (SUE) procedure.
General	Maximum Transfers	5	The maximum number of transfers to another transit route permitted
General	Value of Time	$0.25 per minute ($15 per hour)	Converts path time to dollars for combination with fare in the generalized cost computation
General	Centroids	2,294	The geographical center of a zone from where trips begin or end
Fare	Fare	$1.50	Fare to board the first transit vehicle. Subsequent boardings within the one trip are free to reflect current MetroCard based fare policy.
Weights	Transit Link Time Weight	1.00	Travel time on an in-vehicle transit link is not weighed.
Weights	Transit Waiting Time Weight	1.25	Waiting time for a transit vehicle is weighed by a factor of 1.25 to reflect passengers' general dislike of waiting time relative to in-vehicle time.
Weights	Non-Transit Walking Link Time	1.50	Walking time to get to or from a transit vehicle is weighted by a factor of 1.50 to reflect passengers' general dislike for walking time relative to in-vehicle time.
Others	Headway	Combined Headway	Headway is the scheduled time between vehicles on a route and determines wait time which is set at one-half the headway. The headway on routes that share common links and stops for a substantial portion of the routes are partially combined (i.e., reduced) since most passengers can choose either route.
Others	Transfer Penalty Time (Minutes)	1	Intra-modal; used when transferring at a common node.
Others	Maximum Wait Time (Minutes)	60	Prevents wait time from exceeding a specified amount
Others	Minimum Wait Time (Minutes)	1	Prevents wait time from going below the specified amount
Others	Layover Time (Minutes)	0	Not used
Others	Maximum Access (Minutes)	30	Prevents access time from exceeding a specified amount
Others	Maximum Egress (Minutes)	30	Prevents egress time from exceeding a specified amount
Others	Maximum Travel (Minutes)	30	Prevents link travel time from exceeding a specified amount
Others	Interarrival parameter	0.5	Specifies the computation of wait time from headway, e.g., 0.5 times headway equals wait time
Assignment	Alpha Field	0.15	Parameter in the link cost penalty function
Assignment	Beta Field	3.5	Parameter in the link cost penalty function
Assignment	Capacity Field	AM Cap'y	The capacity used is the guideline passenger capacity for scheduling service. Capacity is used in a function that constrains boardings as capacity is exceeded.
Assignment	Link Probability Function Error Term	5%	This value specifies the average random error added to the link travel to reflect individual perception and choice
Assignment	Headway Probability Function Error Term	7%	This value specifies the average random error added to the headway to reflect individual perception and choice
Assignment	Link Function Distribution	Gumbel Distribution	Function used for the random link error probability
Assignment	Headway Function Distribution	Gumbel Distribution	Function used for the random headway error probability

DEVELOPMENT OF TRANSIT TRIP TABLES

A trip table is a matrix of passenger movement volumes between each origin zone and destination zone. It represents the transit travel demand. For the Second Avenue Subway, a transit-only trip table was developed, based on a table created initially for the MESA Study's MIS/DEIS.

For the MESA Study, origin and destination matrices were developed, based upon 1990 Census journey-to-work data, surveys and ridership counts to develop an accurate 1995 base year AM Peak Hour Trip Table. For the Second Avenue Subway, the 1995 zone-to-zone trip table was updated to 2000, with extensive checks and calibrations performed by NYCT using MetroCard data and field checks.[1] The MetroCard usage data was used to generate a station-to-station trip matrix, which NYCT used for model calibration and validation.[2] The 2000 trip table was updated to account for residential and non-residential land use changes that occurred within Manhattan between 1990 and 2000. The 2000 Population and Employment data compiled by AKRF was used as the basis for this update. The 2000 trip table was not updated to include changes in travel patterns that occurred following the events of September 11, 2001, because these changes were viewed as temporary in the context of long-range transportation planning. The 2000 trip table was the best available approximation of normal travel patterns in the region.

The 2000 trip table was then adjusted to reflect 2025 conditions in the future without the project (No Build Alternative). This was done using growth factors, which were based on journey-to-work forecasts developed by NYMTC as part of its population, employment, and labor force forecasts for the city's five counties. See Table D.1-3. The countywide forecast for Manhattan (New York County) was then allocated to specific census tracts in Manhattan, based on local development plans and projections also compiled by AKRF. This development forecasting process is described in more detail in Chapter 6, "Social and Economic Conditions."

For the future conditions with and without the Second Avenue Subway in place, the RTFM identified the number of commuter rail passengers transferring to the Lexington Avenue and Second Avenue subway lines at 125th Street and Grand Central Terminal. These additional transit trips were added to the 2025 Build trip table used for the No Build and Build Alternatives. In addition, the mode choice component of the RTFM produced forecast of new transit modes shifting from other primary modes (e.g., auto, taxi, commuter rail). These additional transit trips were also included in the 2025 trip table.

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[1] The journey-to-work data in the Census Transportation Planning Package (CTPP) from the 2000 Census is not yet available.

[2] "Origin and Destination Estimation in New York City Using Automated Fare System Data," James J. Barry, Robert Newhouser, paper presented at the 8th Transportation Research Board (TRB) Conference on the Application of Transportation Planning Methods, Corpus Christi, Texas, April 23-26, 2001.

Table D.1-3
Journey-to-Work Projections
2000 to 2020 Borough to Borough*

Residence	Workplace	2000	2020	2020/2000 Ratio
Bronx	Bronx	178,502	206,516	1.16
	Brooklyn	16,178	17,735	1.10
	Manhattan	150,805	174,946	1.16
	Queens	150,805	20,700	1.23
	Staten Island	988	1,155	1.17
	NYC Total	363,349	421,052	1.16
Brooklyn	Bronx	11,172	13,021	1.17
	Brooklyn	439,744	424,586	1.10
	Manhattan	310,942	363,338	1.17
	Queens	50,091	62,079	1.24
	Staten Island	6,222	7,332	1.18
	NYC Total	818,171	930,345	1.14
Manhattan	Bronx	22,395	24,575	1.10
	Brooklyn	27,706	29,168	1.05
	Manhattan	572,830	617,751	1.08
	Queens	19,680	22,443	1.14
	Staten Island	2,091	2,310	1.10
	NYC Total	644,702	686,247	1.08
Queens	Bronx	22,429	25,501	1.14
	Brooklyn	87,920	95,220	1.08
	Manhattan	336,789	380,610	1.13
	Queens	348,049	415,297	1.19
	Staten Island	4,459	5,117	1.15
	NYC Total	799,646	921,745	1.15
Staten Island	Bronx	1,216	1,468	1.21
	Brooklyn	26,382	30,055	1.14
	Manhattan	53,026	65,196	1.23
	Queens	3,848	4,943	1.28
	Staten Island	81,083	99,163	1.22
	NYC Total	165,555	200,825	1.21
NYC Total	Bronx	235,714	271,081	1.15
	Brooklyn	597,930	656,764	1.10
	Manhattan	1,424,392	1,601,841	1.12
	Queens	438,544	525,462	1.20
	Staten Island	94,843	115,077	1.21
	NYC Total	2,791,423	3,170,225	1.14

Note:	* These growth ratios have not been updated by NYMTC to 2025.
Source:	Journey-to-Work Flows CTPP Base, New York Metropolitan Council, 9/27/95

D. APPLICATION OF THE MODE CHOICE COMPONENT OF THE REGIONAL TRANSIT FORECASTING MODEL

The MTA's RTFM was used to predict travel mode choices made by travelers. The NYCT transit networks for the No Build Alternative and Second Avenue Subway were incorporated into the MTA's RTFM, so the model could accurately reflect the proposed improvements to the subway system.

The mode choice component is one of the most important aspects of the RTFM. This component predicts the shifts in market share for each mode of travel that would result from changes to the transportation network. These predictions are based on the characteristics of the trip makers, the trip purpose, and on the characteristics of each mode, including in-vehicle travel time, waiting time, fare, and number of transfers.

The mode choice component calculates the number of person trips on each zone-to-zone combination for each of nine modes:

- *Automobile (Drive Alone)*: Single-occupancy motorized trips that drive from origin to destination without using any transit service.

- *Automobile (Shared-Ride)*: Multiple-occupant motorized trips that drive from origin to destination without using any transit service.

- *Walk-to-Commuter Rail*: Trips that use commuter rail (i.e., LIRR, Metro-North, or NJ Transit rail) during some portion of the trip from origin to destination. This includes transit-to-commuter rail trips and commuter rail-to-transit trips where automobile is not used to access public transportation.

- *Drive-to-Commuter Rail*: Trips that use commuter rail (i.e., LIRR, Metro-North, or NJ Transit rail) during some portion of the trip from origin to destination. This includes transit-to-commuter rail trips and commuter rail-to-transit trips where automobile is used to access public transportation.

- *Walk-to-Transit (No Commuter Rail Use)*: Trips that use transit (subway, bus, PATH, ferry, or light rail transit) during some portion of the trip from origin to destination but do not use commuter rail (these trips would be characterized as commuter rail trips). This includes transit trips where automobile is not used to access public transportation.

- *Drive-to-Transit (No Commuter Rail Use)*: Trips that use transit (subway, bus, PATH, ferry, or light rail transit) during some portion of the trip from origin to destination but do *not* use commuter rail (these trips would be characterized as commuter rail trips). This includes transit trips where automobile is used to access public transportation.

- *Taxi*: Trips that utilize taxis from origin to destination without using any transit service.

- *Walk*: Trips that utilize walk only from origin to destination without using any transit service.

- *Ferry*: Trips that utilize ferry from origin to destination without using any other transit services.

Improvements such as the Second Avenue Subway change the relative attractiveness of these modes and result in mode shifts.

E. ASSIGNMENT OF FUTURE TRIPS

TRANSIT ASSIGNMENTS

The primary objective of the modeling is to forecast the number of transit passengers that will use the various subway and bus routes in the study area during the peak hour. The trip assignment model does this by using passenger trip forecasts with origins and destinations and the simulation of subway and bus routes to determine the most likely routes to be used in the future. Out of the six transit trip assignment methods available in TransCAD, NYCT choose to use Stochastic User Equilibrium (SUE). This method accounts for two key characteristics of the subway system: peak hour crowding and the availability of two or more similar route choices in many corridors. To perform an SUE transit assignment it is necessary to specify both congestion parameters and random error terms as shown in Table D.1-4.

Table D.1-4
Stochastic User Equilibrium Transit Trip Assignment Model

$$\text{cost}_t = \text{cost}_o \, [1 + A(V_{t-1}/C)^B]$$

where:

Cost is the combined measure of the cost of the fare and the time required to make a trip, and:

$$
\begin{aligned}
\text{cost}_t &= \text{Adjusted link cost} \\
\text{cost}_o &= \text{free flow link cost} \\
C &= \text{Practical capacity of a link} \\
V_{t-1} &= \text{volume on the link after the prior increment is loaded} \\
A &= 0.15 \text{ or other value set by user} \\
B &= 3.5 \text{ or other value set by user}
\end{aligned}
$$

At each iteration, adding a random component further modifies the link cost. This random component is the product of a random number (chosen from the Gumbel distribution) times user specified error terms. The terms used are as follows:

Error term	Value
Link	= 5%
Headway	= 5%

The **user equilibrium feature** distributes passenger trips between a particular origin and destination to different paths when crowding on part of the path increases beyond practical capacity.

The stochastic feature produces assignment results that accurately reflect behavioral responses of passengers to perceived differences in waiting or travel time on one route compared to another. This results in an assignment in which many reasonable paths may be used for each origin and destination pair even when congestion is not an issue.

The final step in the modeling process was the assignment of transit trips between an origin zone and a destination zone—a process that considers each possible route in the network. The trip assignment process includes the following steps:

- The shortest path between two zones is determined based upon the minimum combination of fare and time including walking, waiting, and transferring.

- In recognition that people perceive their travel time differently depending on whether they are walking or waiting, the model weights walking and transferring times by a factor of 1.50 and waiting time by a factor of 1.25.

- Capacity constraints to the subway route are applied by adding travel time when passengers per scheduled subway train exceed service guideline capacity by 15 percent or more. This reflects the fact that as average loadings exceed capacity, station dwell times increase and on-time performance declines and passengers choose not to board very crowded trains. The constraint value is set at 15 percent above guideline capacities to account for situations, such as on the Lexington Avenue Line, where additional trains cannot be added to meet demand and passengers are willing to squeeze into crowded cars.

- Average waiting times are estimated as headways (the time between arriving trains) divided by two. Approximate combined headways are estimated for cases where two or more routes serve the same corridor.

The transit model distributes passenger trips between a particular origin zone and destination zone to different paths when crowding on part of the path increases beyond practical capacity. A stochastic (random error) feature is included to account for choices between similar paths. This feature produces assignment results that more accurately reflect behavioral responses of passengers to perceived differences in waiting or travel time on one route compared with another. This results in an assignment in which many reasonable paths may be used for each origin-destination pair, even when congestion is not an issue. For each of the alternatives tested, the transit model assignment process forecast ridership for each portion of the transit system.

F. VALIDATION AND CALIBRATION OF TRIP ASSIGNMENTS

Validation and calibration are basic steps required to ensure that the model contains no errors and that it provides ridership by line estimates that are reasonably close to actual counts of passengers on trains at specific locations. Procedures are used to check for errors include:

- The GIS in TransCAD enables all components of the model including route coding to be observed as a map on a PC screen. This visual checking is used for troubleshooting as well as for continuous quality control.

- Shortest path routines are used to test for illogical paths between two points on a route that may indicate a coding error

- Running transit trip assignments for the entire system and analyzing the results compared to counts and other measures of actual train and bus loading

Calibration follows validation and focuses on the response of the model to actual or proposed service changes. A model's ridership projections should be reasonably close to actual ridership changes or demonstrate logical responses to proposed service changes.

NYCT's TDFM has produced accurate line-by-line ridership forecasts for completed projects including the 63rd Street-Queens Boulevard Connection and the Williamsburg Bridge and Lenox Avenue Line reconstruction projects. Numerous proposed projects have been coded into the model and tested for reasonableness, e.g., changes in headways and travel times on the

Lexington Avenue Line, restoration of full service on the Manhattan Bridge and new transfer passageways at the Broadway-Lafayette St-Bleecker St and Jay St-Lawrence St station pairs.

Both validation and calibration are limited by the accuracy of the input demand information, i.e., the trip table. The 1990 Census based trip table has proved to be generally reliable but it has gone through several interim updates and a complete update cannot be done until the 2000 Census journey-to-work data is released next year. This Census based trip table is a zone-to-zone trip table. NYCT has developed another source of origin and destination data, the MetroCard fare system. This MetroCard based trip table is a subway station-to-subway station trip table.

MetroCard based origin and destination data is derived from MetroCard transaction records that include the card's serial number, the time the card was used and the ID number of the subway turnstile or bus. Sorting these records by serial number and time produces a sequential list of the stations or buses where the card was used during the course of a day. This information provides the location where each trip begins (trip origins) and the sequence of the transactions provides the information needed to impute the trip destinations. Analysis of NYMTC home interview survey data showed that trip destinations could be imputed from the sequence of trip origins as follows[1]:

- A high percentage of a person's trips begin at the station where the previous trip ended and;

- A high percentage of a person's last trip of the day ends at the station where the first trip of the day began

Using this methodology, an AM peak trip table was produced using MetroCard transaction records for a weekday in September, 2000. This trip table is a station-to-station trip table which means that the stations used is known which is an advantage for calibration. In the zone-to-zone Census based trip table the model chooses the stations used for each trip. The MetroCard based trip table was used in the same model as the zone-to-zone trip table except that only the subway system was used. Since the subway trip input to the model is current and based on actual trip information, the results should show accurate loading distributions and peak load point volumes for each line. In the cases where the results looked wrong, further calibration or error checking was conducted.

G. RESULTS REPORTING

NYCT has developed a standard model run report for the TDFM. This report contains the following tables and charts for documentation and validation as well as for presentation of forecast results:

- Cover page documenting the name, date and time of the model run, the network and trip table used and key parameter settings for the network and the assignment model

- Convergence diagram by iteration for validation purposes

- Service performance (inbound cordon crossings and peak load point summaries)

- Manhattan Eastside subway ridership summaries

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[1] Origin and Destination Estimation in New York City Using Automated Fare System Data, James J. Barry, Robert Newhouser, Adam Rahbee, Shermeen Sayeda; presented at the eighth Transportation Research Board Conference on Applications of Transportation Planning Methods, April, 2001

- Subway boardings, alightings, and leave-loads for each station (by route and direction)
- Subway transfer summaries
    - Movement table showing passenger volumes transferring to and from subway routes and transfer routes
    - Diagrams showing detailed transfer diagrams and data tables for key locations
    - Non-transit link volumes for subway transfer links that are not routes, subway station entrance links, and subway mezzanine links
- Bus summaries
    - Bus cordon volumes
    - Bus peak load point volumes for selected Manhattan routes
    - On, off, and leave load volumes for selected Manhattan routes. ✴