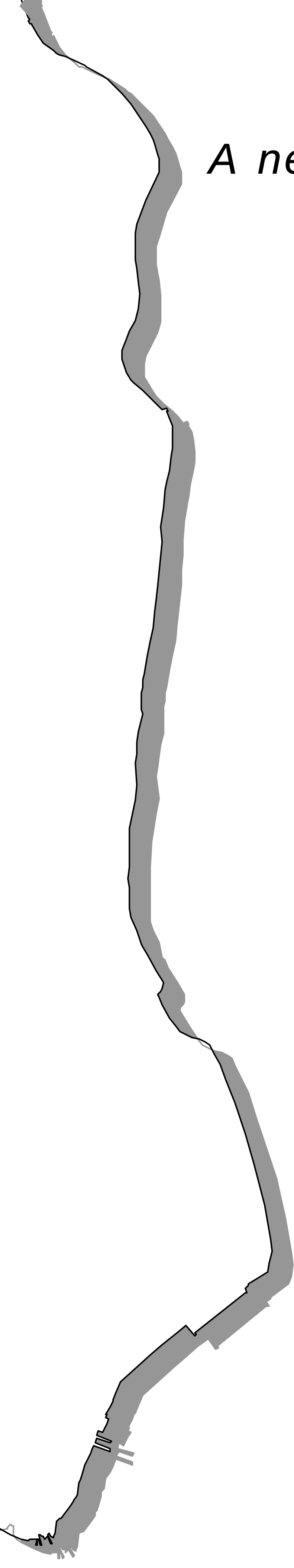
A new transit mode for New York City



The Case for Light Rail Transit on Manhattan's East Side

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RESEARCH STUDY - STUDIENARBEIT

"The Case for Light Rail Transit on Manhattan's East Side"

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List of Abbreviations

ADA	American Disabilities Act
APTA	American Public Transit Association
BMT	Brooklyn-Manhattan Transit
CBT	Committee for Better Transit
DEIS	Draft Environmental Impact Statement
FEIS	Final Environmental Impact Statement
GCT	Grand Central Terminal
IRT	Interborough Rapid Transit
IRUM	Institute for Rational Urban Mobility
ITS	Intelligent Transportation Systems
LES	Lower East Side
LIRR	Long Island Rail Road
LM	Lower Manhattan
LOS	Level of Service
LPA	Locally Preferred Alternative
LRT	Light Rail Transit
LRV	Light Rail Vehicle
MESA	Manhattan East Side Transit Alternatives Study
MIS	Major Investment Study
MTA	Metropolitan Transportation Authority (New York)
NYCDCP	New York City Department of City Planning
NYCT	New York City Transit
pph	Persons per hour
pphpd	Persons per hour per direction
QBB	Queensboro Bridge
QMT	Queens Midtown Tunnel
RPA	Regional Plan Association
TA	Transportation Alternatives
TEA 21	Transportation Equity Act for the 21st Century
TRB	Transportation Research Board
TSM	Transportation System Management
UES	Upper East Side
ULURP	Unified Land Use Review Procedure
UN	United Nations
USDOC	United States Department of Commerce
USDOT	United States Department of Transportation
VCTC	Village Crosstown Trolley Coalition
VDV	Verband Deutscher Verkehrsunternehmen
vph	Vehicles per hour

Chapter 1

Introduction

1 Introduction

In 1998, the Institute for Rational Urban Mobility, Inc. released its Livable City Plan - a four-year transportation plan for New York City. Transit improvements throughout the city were specified as a major element of this proposal and were the genesis that gave rise to this student study.

In the last few years, new and old concepts of this kind have been widely discussed, since the city experienced a strong economic boom. While one good news item follows another about new jobs, record visitor rates, and a reduction in crime not to mention the overall success and great popularity of New York City, nothing could be said about opening new transit infrastructure to the public since the 1940's. This lack of expansion continues although NYC accounts for about 20% of all public transit passenger miles in the US.[1]

However, improvements to the existing transit service have occurred due largely to the $ 20 billion invested since the early 1980's to upgrade the subways and return them to a "state of good repair". This is truly an outstanding accomplishment. This MTA program included overhauling the tracks and subway cars, renovating its stations, and keeping them free of graffiti as well as improving subway performance.

Together with the successful introduction of MetroCard, an innovative fare policy concept that replaces the famous token, last year's subway ridership recorded the greatest volume since 1970. With a 20% growth since 1985[2] and an daily increase of 400,000 riders from 1997 to 1998 alone, New York's subway system is among the most successful in the world.

[1] APTA, 1998

[2] Zupan/Weber, 1999, p. 6

Allied with these accomplishments, more and more people are of the opinion that long promised new transit infrastructure has to be built. Two efforts in this direction have taken place already: Funding for Long Island Rail Road Access to Grand Central Terminal seems assured and construction for a new rail access at JFK Airport started this year.

Less successful are transit proposals for the core of New York City, the Island of Manhattan. The place where most transit systems in America were first implemented, and where a revival of urban density in the late 20th century is taking place, today has experienced difficulties to begin a new era of transportation. With unusual high pedestrian traffic and minimal car ownership ratios (20% of the households) even for European Cities, Manhattan cries out for new transport strategies, expressed, amongst other things, by an increasing amount of taxis and limousine services. Despite a huge market, fashionable high-tech transit is missing, ignoring the fact that for many Manhattanites these kind of factors are important for a certain panache and lifestyle. Who likes to get off an MTA bus arriving at the Stock Exchange, the United Nations, the Odeon Restaurant, the Wintergarden Theater or a fashionable store on 5th Avenue?

Furthermore, this city of pedestrians has almost no pedestrian zones and interprets public space differently. Unlike Europe, these spaces are more likely to be thought of as places for drug addicts and one's unpleasant fellow human beings. Therefore, these locations have time restrictions and green spaces outside major parks are fenced. Some neighbors gladly welcome cars to take over public space.

The Institute for Rational Urban Mobility, Inc. identified these conditions and concluded that Light Rail Transit (LRT) would help to put things right, particularly by providing efficient surface transit. This initiative was encouraged by the great success of the revival of streetcars in the form of Light Rail Transit, not only in the US, but worldwide.

Chapter 1 - Introduction

After new initiatives and movements dealing with the inadequacy of public transit on Manhattan's East Side evolved in the last three years, several Light Rail Transit possibilities were discussed. Unfortunately, most of them were rejected at public hearings so that only one segment in Lower Manhattan and the Lower East Side was considered for further analysis. At least this one segment is included in one of three transit improvement alternatives proposed by New York City Transit in the form of its Manhattan East Side Transit Alternatives (MESA) Study.

The study in hand intends to identify the neglected possibilities for Light Rail Transit on Manhattan's East Side and examines a comprehensive line that would serve the entire East Side of Manhattan.

The study is divided into two major sections. The first section, Chapter 2, provides general information about LRT including the history in the US in general - and New York City in particular - as well as its revival in the last 20 years. In this context, existing plans for street railways in Manhattan are presented. The last part of this chapter fulfills the urgent need to provide more details about the characteristics of LRT.

The second section, Chapter 3, deals with the actual case for light rail on Manhattan's East Side. It begins with the description of the Study Area, identifies and examines existing problems, formulates objectives and proposes solutions. The core of this section consists of the description and evaluation of alignment alternatives. Finally the role of an East Side LRT Line in a broader context is discussed.

Chapter 2

The Light Rail Transit Mode

2.1 The History of Trolleys in the US and in New York City

The following two subchapters provide an overview of the history of trolleys in the US and in New York City. The first part also includes more general information about the development of trolleys outside the US.

2.1.1 Trolleys in the US[1]

When studying the history of trolleys, streetcars and trams,[2] particularly the one in the U.S., one gets a clear example of a phenomenon, which economists explain by the Theory of Product Life Cycle. Tracing the development of streetcars from their beginnings in the first half of the 19th century through their heyday which lasted from the turn of the century until World War I, and ultimately until their decline in the first half of the 20th century, the rise and fall of the transportation system is shown in an impressive way.

The Need for Public Transit

With the onset of industrialization at the beginning of the 19th century, city size was no longer limited by supply problems. New transportation possibilities changed the structure of cities. For the first time in history, the pedestrian mode became insufficient in terms of developing the city and demand for public transportation occurred. This mode was unavailable to the mass public until the development of large-scale public transportation. The first of its kind was the horse-drawn omnibus, a coach adapted to urban mass transit.

The Beginning of Street Railways: Horsecars

Two factors attributed to the emergence of rail guidance technology (tramways). The omnibuses could not meet growing passenger demands and the consensus amongst the populace leaned toward improved comfort. Engineers began thinking about technology previously used exclusively in the mining industry, the technology of rail guidance.

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[1] Carter, 1961, p. 87; Cudahy, 1990, p. 40; Hilton / Due, 1960, pp. 4-5; USDOT, 1977, p. 13; Vuchic, 1981, pp. 14-20

[2] These expressions are used synonymously

This basic concept found its first urban application with the tramway, an omnibus running on rails. As a result of the low rolling resistance, due to steel-on-steel contact, tramways had given several marked advantages over the omnibus. The most noteworthy one is the more efficient use of horsepower; vehicles could now use smaller wheels and run conveniently low to the ground. Previously, in order to guarantee acceptable rolling resistance on cobblestones omnibuses required much larger wheels.

Although as early as 1832 the first horse-drawn "street railway" opened in New York, running from Harlem to Lower Manhattan, it took another 20 years for other cities outside of New York and New Orleans to begin operating their streetcar lines. The breakthrough of street rail technology resulted with the introduction of grooved-rails in New York in 1852, which were developed by a French engineer, Alphonse Loubat. In just four years from 1856 until 1860, the following cities opened their horsecar systems to the public: Boston, Baltimore, Chicago, Cincinnati, Philadelphia and Pittsburgh.[3]

In most American cities, particularly in the North, tramway lines soon appeared on major streets and became a major component in the suburban landscape of the post-Civil War boom.

The Effort to Mechanize Street Transit

The limitations of the existing transit system, with its uneconomical dependency on horses as the power source, resulted in pressure to seek further development. Using live animals for power presented many disadvantages such as the high cost of purchasing, feeding, and stabling horses. In addition to the inevitable problems stemming from derailments, gradients, operation in snow, and a scheduled speed of under six miles per hour, the transit operators were confronted with a high rate of equine death caused by disease: In 1872, the Great Epizootic, an equine-influenza epidemic, caused the death of 18,000 horses in New York alone.[4]

The search for a replacement to horses quickly turned towards a well-established power source, the steam engine. Historians point out that at various times there may have been as

[3] Vuchic, 1981, p. 14

[4] Hilton / Due, 1960, p. 5

many as 700 steam trams in the US, most of them used as light railways in sparsely populated rural areas.

Since the steam trams emitted a great amount of noise and dirt, citizens and policy-makers were not at all enthusiastic about this technology. Furthermore, the high frequency of stops required by the tram's system contradicted the efficiency of using a steam engines. In 1873, the introduction of a fireless steam engine in New Orleans, which used pressurized steam generated in a stationary boiler, illustrated another major handicap: It could not operate longer than about 9 miles or about 15 km.

The concept of cable cars turned out to be the most promising development. This technology is characterized by a system of ropes, pulleys, and stationary steam engines. In 1868, the hauling mechanism previously used in the British mines was further developed into a propulsion system and ultimately incorporated into New York's urban transit. However, the world's first cable-operated street tramway opened in 1873 on San Francisco's Clay Street Hill. The tramways wide appeal quickly caught on and by 1880, approximately 800 km of cable tramway covered high-volume routes in 16 U.S. cities. At the time, Chicago's network was the largest system of its kind with 84 miles or about 135 km of track used by 496 grip cars and approximately 1000 trailer cars. [5]

The Success of Electric Tramways

In 1879, the first electrically-propelled streetcar, which remains today's technology, ran as a demonstration at Berlin's Trade Fair. Developed and built by Werner von Siemens (1816-1892), this technology was a result of research and development conducted for the dynamo and electric motor during the 1870's. Along with Werner von Siemens, Z.T. Gramme, C.F. Brush and Pacinotti contributed to this development.

In 1881, the world's first regular operating electric streetcar line developed by Siemens & Halske, opened at Lichterfelde near Berlin.[6] An important improvement of Siemens' electric streetcar system was demonstrated at the Paris Exposition of 1880. This line was equipped

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[5] Vuchic, 1981, p. 18

[6] Carter, 1961, p. 87

with an overhead cooper-wire conductor, that replaced the dangerous usage of the running rails as positive and negative conductors. This system found its first operational application with the streetcar in Charlottenburg, Berlin.

In the US, electric streetcar development began in 1880 with Thomas Edison's experimental rail conductor tramway in his Menlo Park New Jersey factory. In 1884, the first regular electric streetcar service opened in Cleveland, Ohio. The system in Cleveland used a small "plough" to draw current from a pair of copper wires, which were laid in a slotted underground conduit between the rails. In other cities, the streetcars used the overhead wires and overrunning trollers, just like the one designed by Siemens for Charlottenburg. While designs differed from city to city, they had one thing in common: All the systems faced serious technical problems; however, they continued operating for years during this implementation period.

The landmark of vast growth of electric tramways was set in February 1888, when the world's largest electric tramway network, designed by Frank Sprague (1857-1934), opened in Richmond, Virginia. This 12 mile or 19 km line awakened the attention of American railway officials, who were still looking for a reliable and efficient substitute of horse traction. [7]

The following numbers illustrate the acceptance and effectiveness of tramways with electric traction at the turn of the century. Estimates state that the streetcar network in the US by 1880 was about 2050 miles (3300 km), almost all of which still used horse traction. By 1890 the length had increased to 5783 miles (9305 km), with 500 miles (800 km) using cable and 1180 miles (1900 km) using electric traction.

By 1902, virtually all of the total length of 16,605 miles (26,782 km) of lines was equipped with electric traction, and by 1912 the total length of lines increased to 30,365 miles (48,975 km).[8] The growth period of trolleys peaked around the time of World War I.

[7] Cudahy, 1990, p. 40

The last major trolley development in the first half of the 20th century resulted from the efforts of the street railway officials in the US who recognized the necessity for an advanced, less costly, and standardized rail vehicle. In the 1930's their committee developed guidelines for the PCC (Presidents' Conference Committee) car. Their basic design features were simple: a single-body car about 50 feet long and weighing about 20 tons. The car had two powered trucks and ran on 600-volts DC electric power obtained from an overhead trolley wire.[9] First built in 1935, approximately 5000 PCC cars were delivered in North America by 1952.

The Decline of Trolleys

After World War I, the advanced development and mass production of automobiles resulted in their increasing availability to a broader social stratum. Likewise, the development of the motor bus experienced equal advancement. Subsequently through the 1920's, the demand for urban transportation service was shared among electric railways, buses, and automobiles.

Due to their slow performance in mixed street traffic and with the dramatic increase of automobile ownership, trolley ridership levels began to steadily fall: "In Kansas City in 1930, cars and trolleys moved at the same speed through downtown's rush-hour traffic, but at two miles from the city center, cars had gained a five-minute advantage, which expanded to 15 minutes at seven miles (Interrante 1983)."[10]

As a result, street railway companies were confronted with a decline of profitability, which could not be balanced with the increase of fares due to franchise restrictions.[11] Due to many corruption incidents, a widespread distrust erupted against the mass-transit companies resulting in lack of public support (Bottles 1987).[12] Equipment conditions deteriorated because of deferred maintenance causing passengers to look elsewhere for their transportation needs. Between 1916 and 1923, a third of all transit companies went

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8 Vuchic, 1981, p. 20

9 USDOT, 1977, p. 13

10 Gordon, 1991, p. 10

11 USDOT, 1977, p. 5

12 Gordon, 1991, p. 10

bankrupt (Yago 1984). Since trolley lines were often used to promote suburban real-estate ventures, the promoters of these lines did not provide long-term financial commitments after the sites were sold.[13]

In addition, trolley operators were faced with further economic problems due to the great depression in the 1930's, so that by the end of 1950's, only a few cities in the US and Canada were still operating the streetcar. Although not fully proven, many transportation planners believe that automobile and bus manufactures conspired to acquire trolley operations in the US and hasten their conversion to buses.

In conclusion, the decline of trolleys in the late 20th Century can attributed to its inability to yield a profit in an era when urban public transportation existed mostly in the private sector. In general, the transportation sector is often claimed to function as a private enterprise. In reality, substantial subsidies interfere with this market based concept. Due to this misperception by both the public and political leaders, allocations of subsidies in the 1920's and 1930's to private modes of competing vehicular transportation on public roads and highways led to the decline of the trolley.

[13] Gordon, 1991, p. 10

2.1.2 History in NYC[14]

The history of surface railway in New York City is a virtual overview of the US street railway's technological development and operation dating from the early 1830s to the middle of the 20th century. During this period, all major technologies found applications in New York City. As America's first industrial metropolis, and to this day the epitome of a Megacity, New York's demand for transit improvements grew rapidly. Consequently, during the heydays of mass-transit, this pressure resulted in a high willingness to implement new technologies.

1832 - Putting Tracks onto the Streets

The history of New York's street rail began with the opening of a horsecar line on 4th Avenue by the New York Harlem Railroad in 1832. However, the major wave of converting former omnibus lines to street railways did not occur until the 1850's, when the stage companies invested in major lines running along the Avenues as street railways. This conversion transpired during the following timeframe: 6th Avenue in 1851, 2nd Avenue and 3rd Avenue in 1853, 8th Avenue in 1855, and 9th Avenue in 1859 and continues through 1885 when tracks were installed on the cross-town routes. Soon, the vast increase of passenger ridership confirmed horse railway's success. In the 1860's, the number of passengers almost tripled, reaching 115,000,000 by 1870.[15]

Operating omnibuses and horse railways became a profitable business resulting in numerous companies battling for its concessions. At the time, a fragmented and sometimes corrupt city government awarded inadequate franchises: "By 1880, going by horsecar from river to river on 14th Street meant to ride on four different lines, each with a change of cars and another fare."[16] During this period, seventeen surface and elevated companies operated independently until 1890, when their number ultimately increased to twenty-four.

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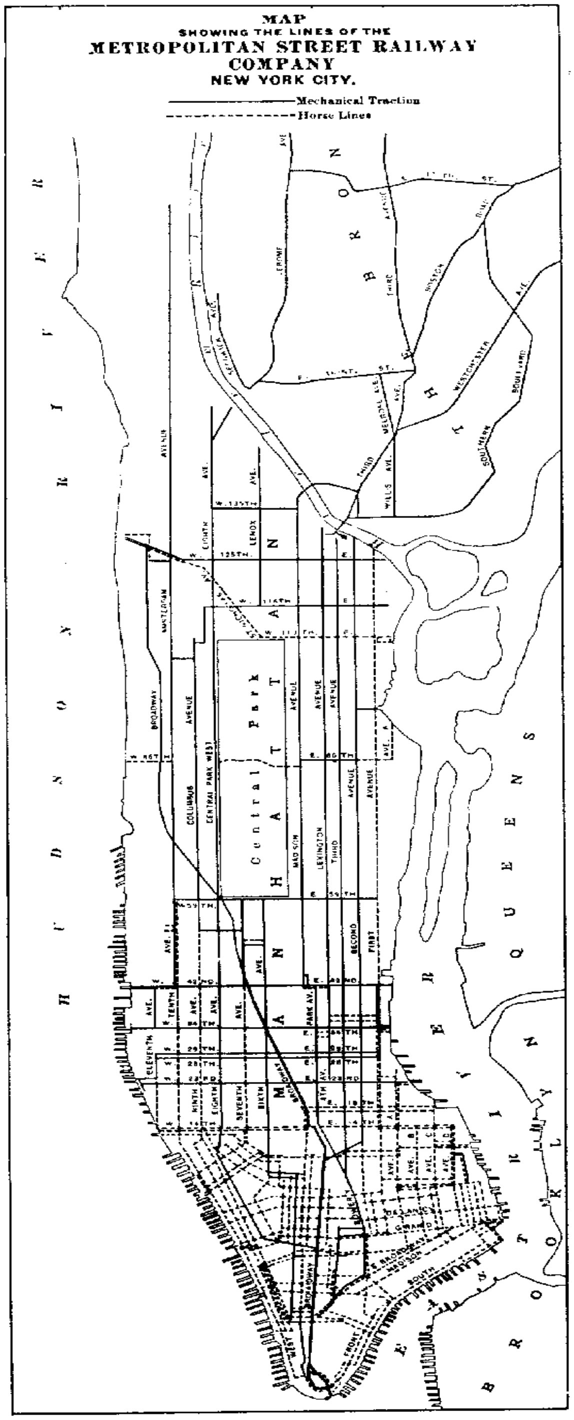
[14] The principal sources for this chapter are: Cheape, 1980, p. 25-61; Jackson, 1995, p.1128-1129; Kahn, 1973, p.1; N.J. International, 1994, p. 4-5

[15] Cheape, 1980, p. 25

[16] Cheape, 1980, p. 40



Conditions did not improve until the Metropolitan Street Railway syndicate started to take over smaller operators. By the time it acquired the large 3rd Avenue system in 1899, it achieved a virtual monopoly controlling a network extending from South Ferry to Tarrytown and White Plains in Westchester (Map 2.1-1).

Besides the above mentioned problem which was caused by privately run transit companies, another well known transportation issue emerged: the betterment of facilities generates greater traffic and in turn this diminishes improvement. In Lower Manhattan, which at the time was considered the center of retail, travel speeds of more than 5 miles per hour were unattainable for horse cars. This was caused by heavy traffic already blocking the streets.[17]

Map 2.1-1: Trolley Network of the Metropolitan Street Railway Company at the turn of the century

Source: New York Railways, The Green Line

[17] Cheape, 1980, p. 26

Even with the construction of an extensive network of elevated railways the existing bottleneck of surface railways coupled with the increase of short haul traffic in the downtown area not only restored, but further expanded street railway traffic. Horse car operation remained in Manhattan on light traffic routes along with the mechanized lines until 1917, when the last horse-car operation discontinued on Bleecker Street.

1893 - Cable Cars

The first mechanizing application of street railways was cable car technology. Due to their danger to pedestrians from a high risk of explosion and their capacity to frighten horses, the alternative of steam propulsion was unfeasible; it was even forbidden below 42nd Street.

By 1893, transit service on Broadway became New York's pioneer for the second time: first with the omnibus line and now with the first cable car line running from Battery to 59th Street. Even as capital costs reached more than a million dollars per mile, twenty times as much as the horse railway, investments grew dramatically. However, the advantages were considerable: operating costs on Broadway dropped from 66 to 38 percent of gross revenue and ridership rose by 25%.[18]

The major investment costs needed for cable car service became questionable due to their short period of operation. By 1901, the Broadway cable line was replaced, and the last line operating in New York City, in Brooklyn Heights, was discontinued by 1909. Nevertheless, the choice of technology was not simply the result of cost, practicality, and previous experience. Expansion of the cable system, instead of converting to trolleys by 1892 when electric technology was already widely available, was more accepted by the public because of its perceived safety and reliability.

[18] Cheape, 1980, p. 60

1895 - The Electric Streetcar

Picture 2.1-1: Trolleys at Times Square

The quick demise of cable cars in New York City can be attributed to the electric streetcar's fast development and rapid public acceptance. In addition, its superior machinery surpassed cable cars' continuous technical problems such as shredding cables which inevitably limited their longevity. In 1895, the Metropolitan Street Railway opened an experimental segment on Lennox Avenue; and by the late 1890s, it began the electrification of its north-south roads and some of its cross-town lines. By 1902, more than 114 miles were powered by the electric conduit and, shortly after the turn of the century, the company converted its cable lines to the new technology. [19]

Through the rapid addition of new and better equipment, the electric streetcar obtained major advantage over the horse and cable cars: The increase of capacity exceeded both, and by 1901, electric streetcars turned out to be even cheaper to operate than the cable cars.

A Manhattan Feature - The Conduit

A special regulation complicated the implementation of an electric streetcar system in Manhattan; a prohibition against putting up poles for trolley wires. Particularly in Manhattan, with its high business and population density, the increase in electric utilities for lighting, telegraph and the telephone wiring above the streets resulted in public pressure for their relocation underground. The blizzard of 1888 which caused many of the wires to collapse into the streets led to legislation forcing their removal.

[19] Cheape, 1980, p. 61

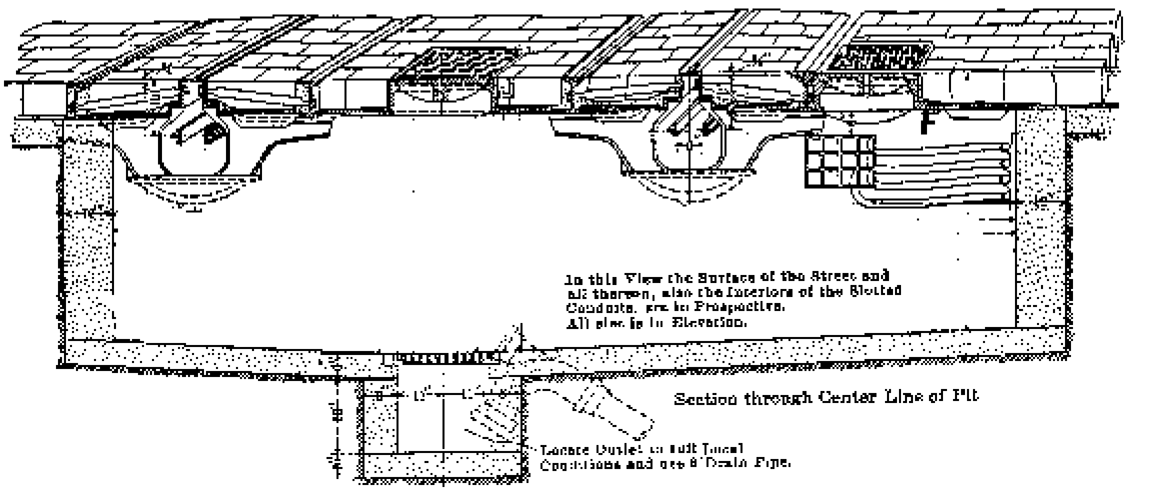


Figure 2.1-1: The Electric Conduit Source: New York Railways, The Green Line

The engineers adapted the electric conduit system already used in Budapest. This method of current collection used a "plow" suspended from the undercarriage of each streetcar. This plow drew electricity from an underground electric conduit (Figure 2.1-1) which was reached through a slit between the rails.[20]

This technology was never fully satisfactory because major problems with the conduit remained unsolved. The problems included: daily flooding of the conduit, broken insulators, loose or broken train or slot rails and closure of the slot due to extreme heat or cold.[21] The effort to keep the conduit clean was another monumental challenge.[22] The high investment cost of this system allowed it to operate only on heavy traffic lines leaving some of the cross-town lines, which were distinguished by lower ridership, served by horse cars. Cross-town lines operated in this matter for a long time the last disappearing in 1917. Some even converted to battery operation but this technology still was unsatisfactory.

[20] Kahn, 1973, p. 1

[21] N.J. International, 1994, p. 4

[22] N.J. International, 1994, p. 5

1907 - The First Bankruptcy

The subway system was opened on October 27th, 1904 and due to the enormous volume of passengers that it attracted, trolley businesses began to diminish for the first time in that year. In 1907, the Metropolitan declared bankruptcy and ultimately was forced to relinquish its 3rd Avenue system on January 6, 1908. At the time its 47 lines carried over 571 million passengers in 3,280 cars on more than 300 miles of track. In addition, it employed more than 8,000 workers.[23] In December 1911, the Metropolitan Street Railway was reorganized as the New York Railway Company.

Although the city's streetcar system peaked at 1344 miles (2162 km), and streetcars carried more passengers than both the elevated lines and the subways, the New York Railway Company went bankrupt again in 1919. The reason for its economic problems included higher wages and escalating material costs resulting from inflationary conditions imposed by World War I and the City's decision to deny a fare increase of two cents.[24]

Post 1920 - The Decline of NYC's Trolleys

The decline of trolleys in New York began with the arrival of the automobile and by the efforts by General Motors and the Omnibus Corporation to replace streetcars with petroleum powered motor buses in the 1920s. Importantly, operating costs for bus operation were less expensive, due to low petrol prices and deteriorating conditions of the trolley fleet.

In 1930, when New York Railways decided to substitute all of its remaining trolley lines with motor bus service, operating costs of trolleys were 53 cents per mile versus the costs of buses which were 45 cents per mile. Revenues generated averaged 66 cents per car mile leaving trolley service only 13 cents per car mile to service all operational costs and debt.[25] However, the fact that more buses were needed to provide the same level of service remained overlooked.

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[23] Kahn, 1973, p. 1

[24] Jackson, 1995, p. 1129

[25] Cheape, 1980, p. 61

In 1936, New York Railways closed its last line. The 3rd Avenue system resisted, but pressure from the City government forced its closing. Lines in upper Manhattan and the Bronx were motorized in 1946-48, and the Yonkers system closed in 1952. The once extensive street railway system in Brooklyn operated as a subsidiary of the Brooklyn Manhattan rapid transit system and was converted to bus operation in 1956. The Queensboro Bridge local ended its service on April 6, 1957. It was the last streetcar operation in both New York City and the State.[26]

Picture 2.1-2: Tearing up Trolley Tracks

[26] NY Streetcar News, 1995, Issue 3, p. 5

2.2 The revival of Streetcars: Light Rail Transit

Although the efforts to reintroduce surface railways at the end of the 1970's is widely quoted as a "revival" or a "renaissance", it is in many ways an introduction of a new system. This is emphasized by the use of a new term. What once had been known as a trolley, streetcar or tramway is now considered to be "Light Rail Transit" (LRT).

2.2.1 The Worldwide Interest in LRT

During the second half of the 20th century, the economy of industrial nations has been going through an extended period of structural change and the professional or "information" services sector (e.g., finance, marketing, research, media, executive offices) has expanded rapidly. The rapid growth of the auto has led to a dispersal of industrial, commercial and residential activities outward from the central cities, especially in the US. But public attitudes about cities began to change. Along with these new professional activities, a tendency to cluster and a strong desire for an attractive environment has resulted in new investment in downtown areas. Planners and architects began to lay out these areas in a fashion more amenable to walking. This new urban design is also well suited to LRT.[1]

During the 1960's, interest in public transportation was still concentrated on conventional rail rapid transit. As this service is capital-intensive and best suited for high ridership ranges, it was applicable for only a limited number of American cities. Similarly unsuitable for widespread use were new transit modes such as monorails, rubber-tired guided cars, and personal rapid transit systems, as shown by generally unsuccessful experimentation.[2]

[1] Landgraf, 1985, p. 3

[2] USDOT, 1977, p. 5

In the 1970's, along with other services and techniques, such as demand-responsive transportation and preferential treatment for buses and carpools, interest in LRT grew as a quickly-implementable transportation solution which made more efficient use of existing transportation infrastructure.[3] Additionally, the national interest in energy conservation as a result of the energy crisis, combined with the rising concerns about the quality of urban life and the environment at the end of the 1970's, stimulated a renewed interest in various transit alternatives even more.[4]

Summarized, the success of LRT has resulted from its ability to meet three major needs: low-cost capacity, service quality, and environmental appeal.[5] Definitions of LRT show clearly that this mode should be distinguished from the "old-fashioned" trolley, particularly with reference to its use in mixed traffic: "..., light rail transit, a generic name for a transit mode consisting of electrically powered steel-wheeled rail vehicles <u>operating predominantly on exclusive rights-of-way</u>."[6]

While street railway systems virtually disappeared in many of the world's largest cities like London, Tokyo and New York, other cities retained their systems and expanded them. Today, 80% of the world's LRT systems operate in European and North-American countries. With 73 systems, Russia has the greatest number of cities with LRT systems, followed by Germany with 57 and the Ukraine with 25. The country with the highest density of LRT systems, as expressed by systems per inhabitant, is Switzerland, with one system for each million persons. The US is in first place when comparing openings of new systems in the last 10 years.[7]

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[3] USDOT, 1977, p. 5

[4] USDOT, 1977, p. 1

[5] Landgraf, 1985, p. 3

[6] USDOT, 1977, p. 2

[7] Röhleef, 1999, LRT Conference Berlin

2.2.2 LRT Revival in the US

In the 1970s only eight LRT systems in the US, as Map 2.2-1shows, had survived the wave of trolley abandonments from the 1920's to the 1960's. With the exception of the system in New Orleans and Philadelphia's Red Arrow Division, only PCC cars were used to provide streetcar service. In 1977 about 1,300 of them were still in service and waited for replacement through state-of-the-art light rail vehicles. [8]

The Introduction of LRT

The first new LRT vehicles in the US were ordered by Boston and San Francisco in the 1970's to replace their existing light rail fleets, both of which were well over 20 years old. These jump-started the beginning of light rail transit revival in the US and led to the development of the US Standard Light Rail Vehicle (SLRV) which was built for both transit systems by the Boeing Vertol Company.[9] In 1979, the opening of the new LRT line in Edmonton, Canada began the trend for new LRT systems in North America. [10]

LRT Systems in the US

Map 2.2-1 to Map 2.2-3 illustrate the development of LRT in the US in the last 20 years, including an overview about future projects. Much progress has been made in two decades. The eight older systems have been thoroughly renovated, and new LRT systems are operating in 12 US urban areas.

Table 2.2-1 provides more information about the existing systems. The latest LRT systems are configured to provide service both on city streets and on exclusive alignments. As expected, the portion of semi- and non-exclusive alignments is greatest in cities with older LRT systems (Boston: 42%, San Francisco: 74%).

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[8] USDOT, 1977, p. 13

[9] USDOT, 1977, p. 2

[10] USDOT, 1977, p. 2

Except for Seattle, where new LRT lines are in a detailed planning stage, Map 2.2-3 shows extensions to all existing systems that are in a final design or construction phase, as. Additionally, this map portrays seven cities without an existing Light Rail System where projects for implementation are in the final design or construction phase.

Map 2.2-1: US Cities with LRT Systems in 1979

Map 2.2-2: US Cities with LRT Systems in 1999

Map 2.2-3: Future Development of LRT Systems in the US

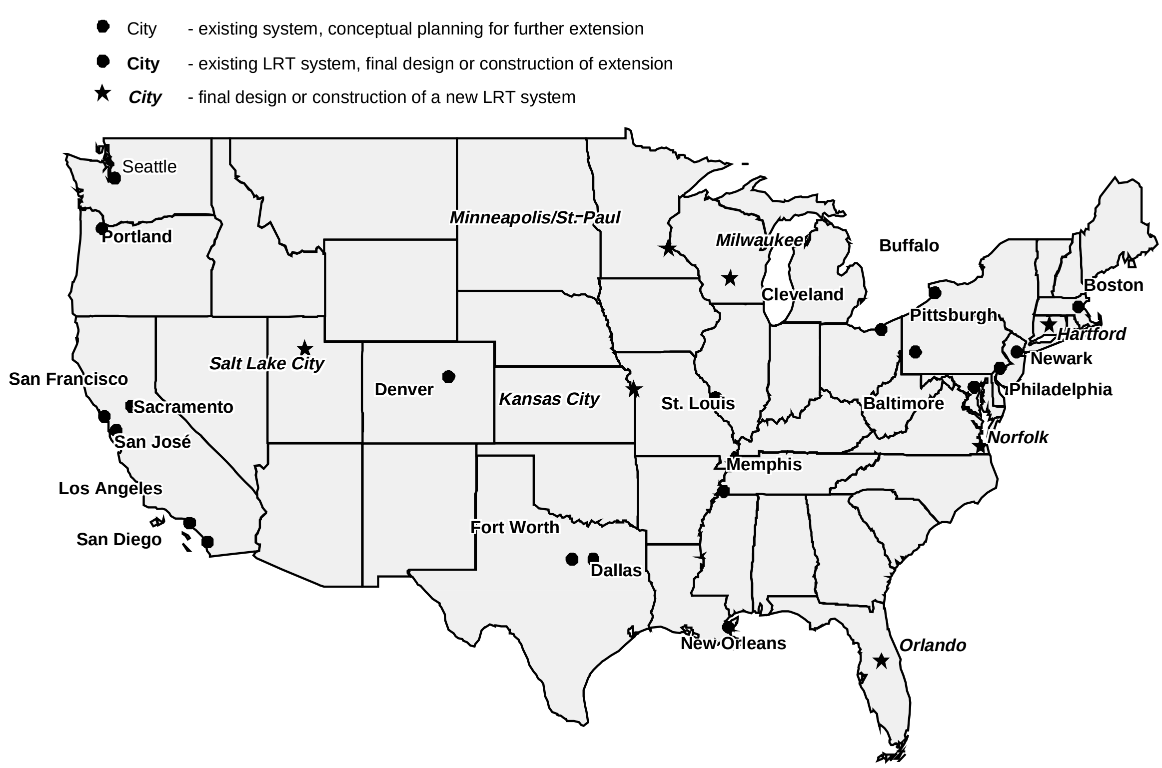


Table 2.2-1: LRT Systems in the US

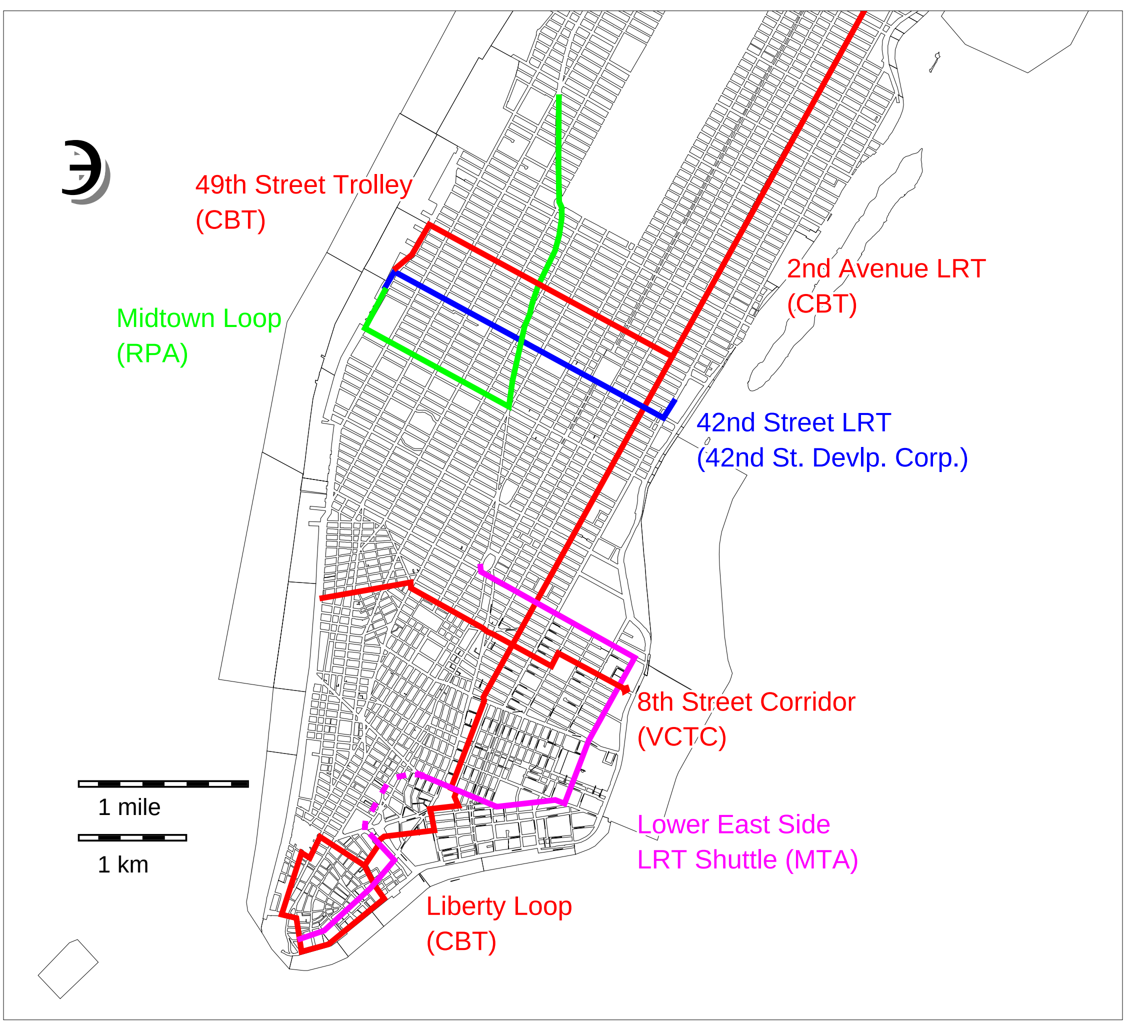
Town/City[11]	Transit Agency	Year of Opening	Year of Extension	Manufacturer of the latest LRT vehicles	System length in route-miles in 1976 (USDOT)	One-way Line in km, 1995 (TRB)	One-way Line in miles, 1995 (TRB)	Number of cars in operation, 1995 (TRB)	Percentage of Semi-Exclusive and Non-Exclusive under 35 MPH, 1996 (TRB)
Baltimore MD	Mass Transit Administration, Maryland DOT	1992		Adtranz		35.4	22	35	18%
Boston MA	Massachusetts Bay Transportation Authority	1856		Kinki-Sharyo	28.5	40.1	24.9	220	42%
Boston MA	Mattapan Ashmont			-		4.3	2.7	12	-
Buffalo NY	Niagara Frontier Transit Metro System	1984		Tokyu Car Corp.		10.3	6.4	27	20%
Cleveland CH	Greater Cleveland Regional Transit Authority	1913	1996	Breda, Tokyu Car Corp.	13.1	21.1	13.1	48	-
Dallas TX	Dallas Area Rapid Transit Authority	1996		Kinki-Sharyo	-	-	-	-	-
Denver CO	Regional Transportation District	1994		Siemens		8.5	5.3	11	-
Fort Worth	-			-	1.2	1.6	1	8	-
Los Angeles CA	Los Angeles County Metropolitan Transit Authority	1990		Siemens		35.4	22	54	23%
Memphis, TN	Memphis Area Transit Authority	1993		-	-	*4.3*	-	-	-
New Orleans LA	Regional Transit Authority of Orleans & Jefferson	1835	1990	CKD T6C5 Double-Ended Tram	6.5	14	8.7	41	-
Newark NJ	New Jersey Transit Corporation	1935		Kinki Sharyo, Alstom	4.2	6.9	4.3	24	-
Philadelphia PA	Southeastern Pennsylvania Transportation Authority	1906		Adranz	27	19.2	11.9	29	-
Philadelphia PA	-	1858		-	82	35.9	22.3	112	-
Pittsburgh PA	Port Authority of Allegheny County	1859	1985	Siemens	24.9	31.2	19.4	71	-
Portland OR	Tri-County Metropolitan Transportation District of Oregon	1986		Bombardier, Siemens		24.3	15.1	26	52%
Sacramento CA	Sacramento Regional Transit District	1987		Siemens		29.5	18.3	36	26%
San Diego CA	San Diego Trolley	1981	1991	Siemens		55.4	34.4	71	11%
San Francisco CA	San Francisco Municipal Railway	1860	1980	Breda	36	39.1	24.4	128	74%
San Jose CA	Santa Clara Valley Transportation Authority	1987		UTDC (Bombardier)	32.2	20	50		47%
Seattle WA	King County Department of Transportation	1982		-	-	*3.7*	-	-	-
St Louis MO	Bi-State Development Agency	1993		Siemens		29	18	31	-
Total					255.6	469.2	324.2	984	

[11] General Source: TRB, LRT news, p.4; Internet: www.tramway.com; www.apta.com

2.2.3 Existing Plans for New York City

To this day, New York City has refrained from participating in the worldwide renaissance of light rail transit. Nevertheless, for almost twenty years there has been a continuous effort to introduce this system to New York City. Repeatedly, transit and planning agencies, private developers as well as community groups, released numerous proposals (Map 2.2-4) and led information sessions about implementing LRT in Manhattan. The following chapters describe the most recent LRT drafts, plans and proposals introduced for implementation by various organizations.

Map 2.2-4: Existing LRT Plans for Manhattan



The 42nd Street LRT Line

The most advanced proposal to reintroduce streetcars on Manhattan's streets is, unquestionably, the 42nd Street Light Rail Transit Line project. From the beginning of LRT's resurgence in North America, and thirty three years after streetcar service on 42nd Street was replaced by the bus in 1946, studies began to rethink the value of streetcars, which are now called light rail transit. The New York City Department of Planning released a report called "Light Rail Transit Financial Feasibility 42nd Street Case Study" in January 1979.[1]

Since 1979, several follow-up studies were proposed resulting in 13 revisions to the LRT plan and an expenditure of more than $2 million.[2] In 1994, the Final Environmental Impact Statement (FEIS) on the 42nd Street LRT line was finished and the Unified Land Use Review Procedure (ULURP) began. On June 9, 1994, the City Council approved the plan to build the LRT line.[3] To this day, the proposal is stalled with further progress impeded by the lack of political support particularly from the Mayor.

The proposed project intends to implement a crosstown LRT line on the 2.2 mile stretch between United Nations Plaza on the east side and Jacob K. Javits Convention Center on the west side of Manhattan. For the majority of 42nd Street, the study proposes a two track right-of-way on the street's south side. Therefore, the three eastbound traffic lanes would be closed, converting 42nd Street into a westbound one-way street. The FEIS forecasts the following: the highest demand for LRT service would occur in the AM peak hour heading in the eastbound direction with up to 3,260 riders between Seventh and Sixth avenues.

This proposal aims for light rail vehicles to operate during weekday peak hours on a 3 minute headway in each direction (20 trips per hour per direction), and a service capacity of

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[1] Habib/Rosen, 1994, p. I-6

[2] NY Streetcar News, 1994, Issue 1, p. 4

[3] NY Streetcar News, 1994, Issue 4, p. 3

4,000 passengers per hour, in each direction, would be provided, assuming a typical LRV capacity of 200 passengers.[4]

Proposed to be funded entirely by private investments, the 42nd Street LRT line was expected to cost $75 million (in 1994 dollars). An additional $60 million was set aside for street refurbishing and replacement of water and sewer lines to be paid by federal, state and city funds.[5] As a result of recovering its operating and capital costs, the 42nd LRT service was expected to be implemented and managed without any subsidies.

Fred Papert, President of the 42nd St. Development Corporation, was responsible for the project's headway in the first half of this decade. His not-for-profit corporation persistently promoted the implementation of a LRT line on 42nd Street.

The Lower East Side LRT Shuttle

In 1996, for the first time in its 44 year history, New York City Transit (NYCT) released a study, including a draft proposal for LRT.[6] The so called "Manhattan East Side Transit Alternatives Study" (MESA) proposes, in one of three alternatives, an LRT shuttle for the Lower East Side.

This LRT line would start at Union Square, at a stub terminal or small loop. From there, a double track line would run eastbound along 14th Street to Avenue D, continuing south on Avenue D, turning southwest onto East Broadway. Once on Canal Street, the line will drop from grade and enter a tunnel west of Allen Street.

The LRT tunnel would then turn west beneath Canal Street before joining the existing (four track) Canal Street subway, just west of Chrystie Street. The line would use two of the four tracks to proceed west, bearing south into the Centre Street Subway using a presently

[4] Habib/Rosen, 1994, p.I-52

[5] NY Streetcar News, 1994, Issue 4, p. 3

[6] NY Streetcar News, 1997, Issue 2, p. 4

unused connection between Canal and Centre Street subways. The LRV´s would use the eastern-most platforms in the Nassau Subway's Chambers Street Station and continue along Frankfort Street, beneath the approaches to the Brooklyn Bridge, before surfacing just west of Pearl/Water Streets. The line would turn south on Pearl/Water Street and proceed to a terminus near Whitehall Street. The entire route is five miles long and estimated to cost about $1.3 billion including the tunnel, cars, tracks and wires.[7] With the tunnel segment proving to be quite expensive, transit advocates developed an alternative alignment without the necessity of a tunnel.

LRT Plans by the Committee for Better Transit

The civic advocacy organization, *Committee for Better Transit* (CBT), released a newsletter every second month from 1994 to 1997, entitled "New York Streetcar News". In many of their issues, one possible new route for LRT in New York City was presented and discussed. The following drafts for Manhattan were included in the newsletter:

The Liberty Loop[8]

As a trolley line circling in Lower Manhattan, the Liberty Loop should link business, residential, tourist and transportation hubs in Manhattan's downtown. In the shadow of the World Trade Center, this 3 miles long line would serve New York City's oldest neighborhood, which is today considered to be one of the world's major centers of finance. About 375,000 people work in the area; only some 14,000 people live south of Chamber Street.

[7] NY Streetcar News, 1997, Issue 2, p. 5

[8] NY Streetcar News, 1995, Issue 3, p. 4

Next to residents and workers, this Light Rail Line would provide an appropriate transport facility for tourists visiting the numerous attractions and historical sites of Lower Manhattan. One of New York City's rare pedestrians zone, the Fulton Promenade, would be served as well as Battery Park, South Ferry, the World Trade Center and the Financial District.

Second Avenue LRT

CBT's most extensive LRT proposed for Manhattan is the plan for a Second Avenue LRT. This line would serve the entire East Side of Manhattan, which is, in terms of subway accessibility, is the least transit developed area in Manhattan. The suggested line would run from the Metro North Commuter Rail Station at Park Avenue and 125th Street in Harlem along the entire length of Second Avenue, through the Lower East Side and Chinatown ending at Fulton Street, where it would connect with CBT's Liberty Loop.

The total length of this line would be 8.4 miles with about 40 stops. CBT suggested that Second Avenue be converted to a pedestrian mall, serviced by the LRT line with two tracks in the middle of the Street. As a consequence, First Avenue would be restored to two way operation to provide space for the diverted southbound vehicular traffic.

49th Street Trolley

CBT suggested another cross-town line on 49th street. This one would be routed from the proposed 42nd Street LRT terminus on 12th Avenue north to 49th Street, where it would head eastbound along a pedestrianized 49th Street to Second Avenue to connect with the proposed Second Avenue LRT.

VCTC-Plans for 8th Corridor

In 1995, the *Village Crosstown Trolley Coalition* (VCTC) was founded by a group of neighborhood residents to develop plans, and gain community support, for a river-to-river trolley line through the 8th Street corridor, linking the East Village, West Village and Greenwich Village.

This community group distributes their newsletter "Making Tracks" every three months mainly to community leaders and to retail businesses located along the proposed LRT line.

"Making Tracks" provides information about the proposed trolley line, as well as the history of trolleys in the area, and general technical information about LRT.

VCTC's plan is to close the 8th Street corridor, including Christopher Street and St. Marks Place, for car traffic and transform it into a pedestrian-only crosstown transitway. The line, which would follow and replace the nearly identical M8 Crosstown bus line, would begin at the Hudson River, continue through Christopher Street, continuing onto West 8th Street and St. Marks Place on a dedicated, double-track transitway, then travel east of Avenue A along East 10th Street all the way to Avenue D, near the East River Park.

By providing direct access to every north-south subway line serving Manhattan and two PATH stations, this LRT line integrates well into the existing transit system. Accordingly, VCTC argues that the proposed auto-free LRT corridor "...will provide both convenient transportation to and between existing retail shopping areas and access from transit-starved residential areas to rapid transit lines serving the entire city."[9]

The line would serve major concentrations of small shops, galleries, boutiques, off-Broadway theaters, restaurants and cafés. Additionally it would link the East River Park, Tompkins, Washington and Sheridan Squares as well as educational institutions, such as New York University, Cooper Union and the New School.

[9] Making Tracks, 1995, Issue 1, p. 3

The Crosstown Loop[10]

The *Regional Plan Association* (RPA), one of the major non-governmental planning organizations in New York City, proposed in its "Third Regional Plan" an LRT line for the first time in February 1996. Based on the idea to extend the 42nd Street LRT line, which at the time still awaited final clearance from City Hall, this plan would result in an ambitious Light Rail system in Midtown Manhattan.

The proposed Line would run along Broadway, starting at Lincoln Center (West 66th Street), circling Columbus Circle, crossing Times Square and turning east into 34th Street at Herald Square. It would follow 34th Street to the Hudson River and continue along 12th Avenue northbound to 42nd Street where it would connect with the 42nd Street LRT line.

The section along Broadway, from Lincoln Center to Herald Square, would be realized by the implementation of a transit mall, closed for vehicular traffic. On 34th Street and 12th Avenue, the LRT line would run on the street along with existing traffic.

This crosstown LRT loop would "serve to connect all the elements of the existing transit system" at street level. Beside all 16 Midtown subway lines, this includes Metro North at Grand Central Terminal; Amtrak, Long Island Railroad and Jersey Transit at Penn Station as well as the PATH train on 33rd Street.

In addition to LRT service on 42nd Street, the Loop would also serve the Javits Convention Center, the planned Hudson River Esplanade, Macy's, Madison Square Garden, the Empire State Building, Central Park and Lincoln Center. Therefore the "Crosstown Loop" would encompass all business, residential, transportation, entertainment and cultural elements in Manhattan's Midtown.

[10] Yaro/Hiss, 1996, p. 120

2.3 Characteristics of Light Rail Transit

The introduction of the new term "Light Rail Transit" - being used for what once was known as a trolley, streetcar or tram - caused not only curiosity and interest in this "modern" transit technology, but also confusion. Therefore, it seems necessary to provide a definition as well as a description of the Light Rail Transit Mode.

One LRT definition has been proposed by the Transportation Research Board:[1]

> Light Rail Transit is a metropolitan electric railway system, that operates with single cars or short trains, runs along exclusive rights of ways at ground level, on aerial structures, in subways or, occasionally, in streets, and boards and discharges passengers at track or car-floor level.

The following subchapters describe major technical elements of Light Rail Transit, such as vehicles and infrastructure as well as possible alignments and the role of LRT compared to other means of transportation.

2.3.1 Light Rail Vehicles

Appearance and features of light rail vehicles differ a great deal from each other, depending on their specific assignment and operation. Vehicle standards for a metropolitan LRT Line, operating on an exclusive right-of-way with long distances between each stop are quite distinct from those for an urban street railway, operating in city streets with sharp curves and frequent stops.

There is a general difference between LRV's in the US and those in Europe. Those in North America are usually heavier and designed for exclusive right-of-way with higher speeds. In Europe, operation with 100% low-floor, lighter and slower vehicles is more common.

[1] Schumann/Tidrick, 1995, p. 3

Picture 2.3-1: The Grenoble LRV

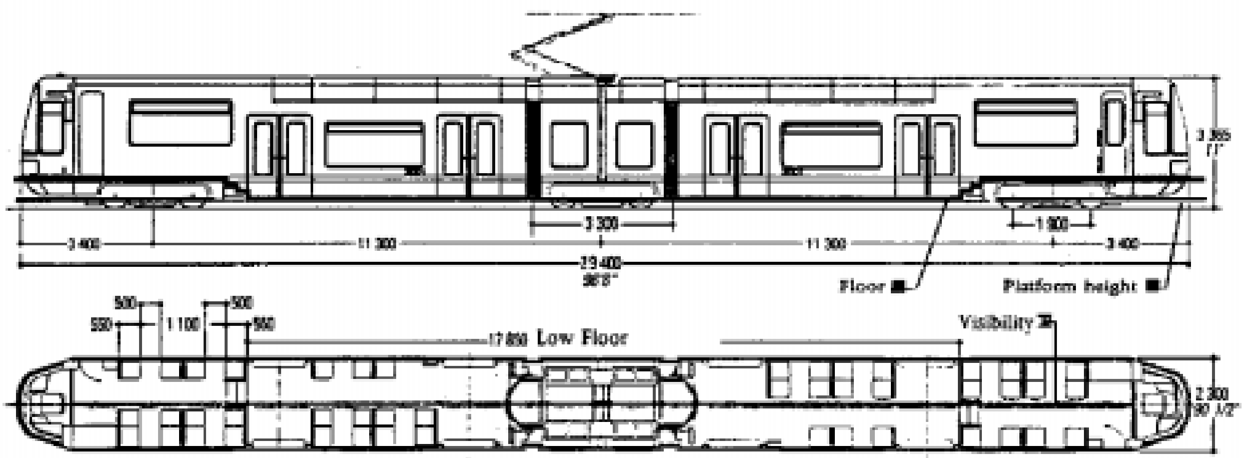

Figure 2.3-1: Dimensions of the Grenoble LRV

Dimensions and Weights

The following Figure 2.3-1 shows a typical example of an European low-floor LRV (see Digression: Low Floor at the end of this chapter). A length between 80 to 100 feet (24 to 30 meters) is also common for US LRV's (compare with Figure 2-2). Vehicles are typically 8.1 to 8.7 feet (2.4 to 2.7 meters) in width and do not exceed 12.2 feet (3.7 meters) in height. Vehicle weights usually vary from 40 to 50 tons.

Capacity and Entrances

According to the vehicle's length, capacity of LRV's varies extensively. Shorter Vehicles provide space for up to 120 passengers with 50 seats; long trains carry up to 500 passengers with 130 seats. A typical maximum capacity of a single articulated light rail vehicle is 200 to 250 passengers.

Most LRV's have doors on one side, which allows only one operating direction. These vehicles have to be operated around a loop track at the terminus. Typically a vehicle has from 3 to 6 doors. Alternatively, light rail vehicles may be bi-directional, with doors on both sides.

Propulsion

Light rail vehicles are typically electrically powered. This type of propulsion provides an "excellent dynamic performance of vehicles",[2] in particular a smooth and rapid acceleration. Further advantages of electric motors are their cleanliness, durability and low-maintenance and low negative side effects, such as noise levels and air pollution in the service area. Additionally, electric motors can recover energy during braking (regeneration). Most common is the use of a 750 volt direct current power supply.

Negatives of this technology are higher investment costs for fixed power supply facilities and operation of vehicles being limited to the extent of electrified lines only. Power failure may disable the whole system rather than individual vehicles.

Driving Performance

A typical 100% low flow LRV can operate at speeds up to 80 km/h (50 mph). The average service acceleration and deceleration rate is 1.3 m/sec² (2.8 mphps). For emergency braking, a deceleration of 2.5 m/sec² (5.8 mphps) is made possible through two brakes, a physical one and a electromagnetic one.

Turning radii range from a minimum of 39.5 feet (12 meters) to a maximum of 82 feet (25 meters).[3]

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[2] Vuchic, 1981, p. 303

[3] Habib/Rosen, 1994, p. I-28

DIGRESSION: Low floors - an important quality

Example of an 70% Low Floor Light Rail Vehicle, Portland (Siemens)

Picture 2.3-2: LRV in Portland

Dimensions and Weights	
Length:	92 feet (28 m)
Width:	8 feet 9 inches
Floorheight:	14 inches - 39 inches
Weight:	48 t
Performance	
Maximum Speed:	55 mph (88 km/h)
Service Acceleration:	3 mph/s (1.3 m/s²)
Capacity	
Number of Seats:	72
Total Passengers:	252

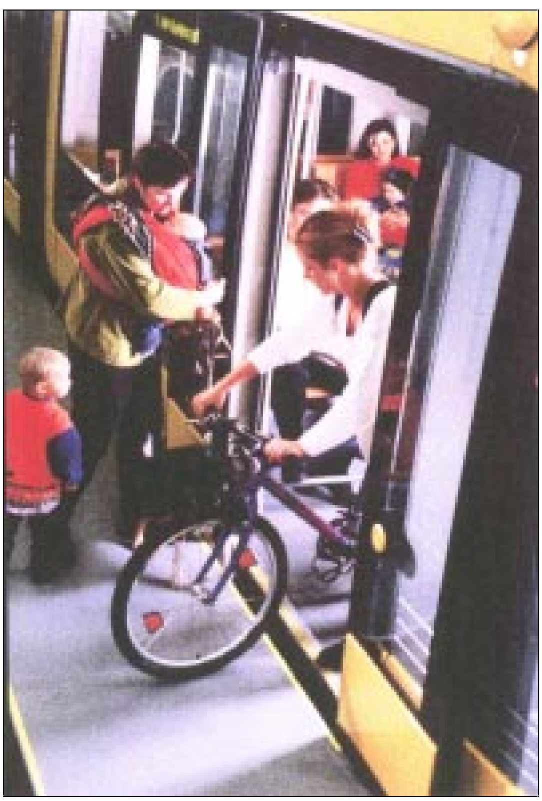
Example of an 100% Low Floor Light Rail Vehicle, Incentro (Adtranz)

Picture 2.3-3: Incentro LRV (Adtranz)

Dimensions and Weights	
Length:	54 feet (18m) - 152 feet (52m)
Width:	7.3 feet (2.4m) - 8 feet (2.65m)
Floorheight:	11 - 14 inches (285 - 350 mm)
Weight:	22 t - 48 t
Performance	
Maximum Speed:	45 mph (70km/h)
Service Acceleration:	3 mph/s (1.3 m/s²)
Capacity	
Number of Seats:	28 -126
Total Passengers:	131 - 509

Modern low floor rail vehicles (LFLRV´s) first entered revenue service in Europe during the mid-1980's.[4] In the US, manufacturers were concerned whether LFLRV's could meet the requirements for both higher carbody strength and higher operating speeds. In 1992, Portland was the first US city to operate LFLRV's,[5] although not 100% lowfloor.

Low floors are typically 13.8 inches (350 mm) or less above the top of rail (TOR) compared to 35.8 inches (910 mm) or more for high floors. Only a single step is needed to board LFLRV's from curb level compared with three or four steps for conventional LRVs. Installing platforms, which might be something as simple as a raised curb, can provide level boarding of the LFLRV. [6] Furthermore, wheelchair access as well as baby carriage and bike access is significantly improved.



Picture 2.3-4: LRT and Bike Access

Picture 2.3-5: Wheelchair Access

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[4] Porter, 1995, p. 175

[5] Porter, 1995, p. 175

[6] Zebarth, 1995, p. 184

The importance of the low floor concept is also expressed by the most common distinction of LRV's. Three classes of LFLRV are highlighted:

Category 1 vehicles with 9% to 15% low floor area: Two unit vehicles use conventional powered and trailing trucks. To provide a low floor area, a new body section is added leading between the two units and providing a low floor area between two conventional axles.

Category 2 vehicles with 50% to 70% low floor area: Vehicle propulsion axles are not affected by low floor. Non-powered trailing trucks might use smaller wheels, cranked axles or independent wheels to accommodate the low-floor area above.

Category 3 vehicles with 100% low floor area. Standard modules are used to create vehicles with multiple articulations, and running gear and drive technologies are substantially different form those used on conventional vehicles.[7]

LFLRV's currently cost 10% more than traditional LRV's. The higher cost may be offset by less capital cost for stations not requiring high platforms and lower operating cost due to reduced round trip times because of faster boarding. Furthermore LFLRV's are appreciated by the public so that an increase in ridership is possible.[8]

Obstacles for the Introduction of 100% Low Floor LRV to North America:

Operating speed

Many European LFLRVs, like the "Incentro" LRV (Picture 2.3-3), are designed for operating speeds up to 70 km/h (45 mph), which is substantially lower than some North American transit systems. When operating entirely in city streets with frequent stops, as is common in Europe, higher speeds are not necessary.[9]

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[7] Zebarth, 1995, p. 185

[8] Zebarth, 1995, p. 185

[9] Zebarth, 1995, p. 185

Compliance with North American Specifications

So far, implementation of Category-3 low floor LRVs in North American cities, has not taken place, because of difficulties to achieve the North American specifications. Two aspects are considered to be the most expensive to meet, buff load and fire resistance.

A - Buff Load and Compression Strength

As the static longitudinal force that a rail vehicle "must be capable of withstanding without permanent deformation,"[10] buff loads in North America vary from 150% to 200% of the vehicle's tare weight. This is due to the requirement to interact with any other vehicle, using the same right-of-way. Buff loads of most low floor LRV are between 50% and 100% of tare weight.

New exclusive right-of-way LRT systems are free to specify lower buff loads. There is no technical reason to make LRVs stronger than the heaviest vehicles with which they share their operating space, namely buses or trucks. However, transit operators "will probably not want to degrade the compression strength standard of previous vehicle specifications for fear of legal repercussions in the event of an accident that causes injury."[11]

B - Fire Resistance

The most difficult challenge with North American specifications for fire resistance seems to be the floor fire resistance of European LRVs. Aluminum, the principal material used for these floors has a low melting point and, to date, cannot meet the pertinent requirements.[12]

[10] TRB, 1995a, S. 53

[11] TRB, 1995a, S. 53

[12] TRB, 1995a, S. 54

2.3.2 LRT Infrastructure

In contrast to bus service, LRT service demands considerably more infrastructure. On the other hand, these components provide many of the positive characteristics of LRT. Therefore transit vehicles and infrastructure could not be assessed independently. Only together they represent two integral parts of a transit solution. An overview about LRT infrastructure components is given in the following paragraph.

Tracks

Like all rail vehicles, light rail vehicles are physically guided by their track. Therefore the driver's dominate function is to control the vehicles speed. The main principle of rail technology are the vehicle's flanged, conical shaped steel wheels running on two steel rails.

The type of rail guidance used for LRT provides the following advantages:[1]

- Lowest energy consumption per ton of weight, due to extremely low rolling resistance of steel-on-steel contact
- Greater performance and stronger identity, which is important for high passenger attraction and impact on urban development
- The only guidance technology that allows both at-grade crossings and on-street running
- Low maintenance requirements and high durability
- Relative independence from weather conditions
- Stable, smooth riding comfort
- Simplest, fail-safe and fastest switching of all guided technologies
- Permits utilization of electric traction

[1] Vuchic, 1981, S. 302 f.

Negatives of this technology are: [2]

- Rail guidance requires higher investment costs
- The guideway network restricts movement of vehicles
- The lower adhesion coefficient of steel-on-steel compared to rubber on dry concrete surface results in a diminished gradient and braking performance.

In most cases, the standard railroad gauge of 4 feet 8.5 inch (1.435 m) is used for LRT systems. To dampen sound and vibration, usually LRT tracks in roadway pavement are laid on a concrete base with an intermediate layer of asphalt for a flexible connection.[3] Different types of flexible tracks in pavement are shown in Figure 2.3-2.

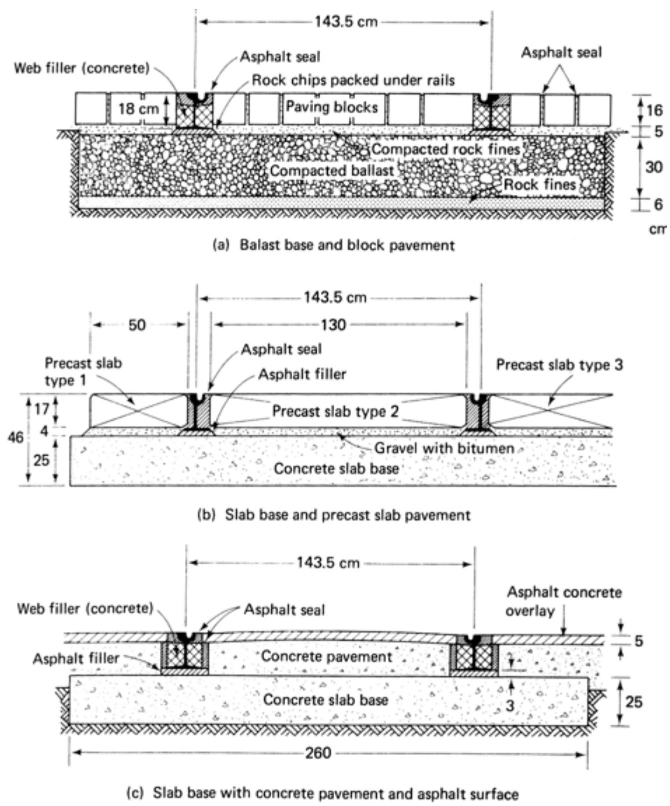


Figure 2.3-2: Different types of flexible tracks in pavement
Source: Vuchic

[2] Vuchic, 1981, S. 302 f.

[3] Vuchic, 1981, S. 378

Electricity Supply

To provide electricity for the electric powered LRVs, a power distribution system is essential. This system contains three major elements: traction power substations, feeder cables and the overhead wire system (Figure 2.3-3).

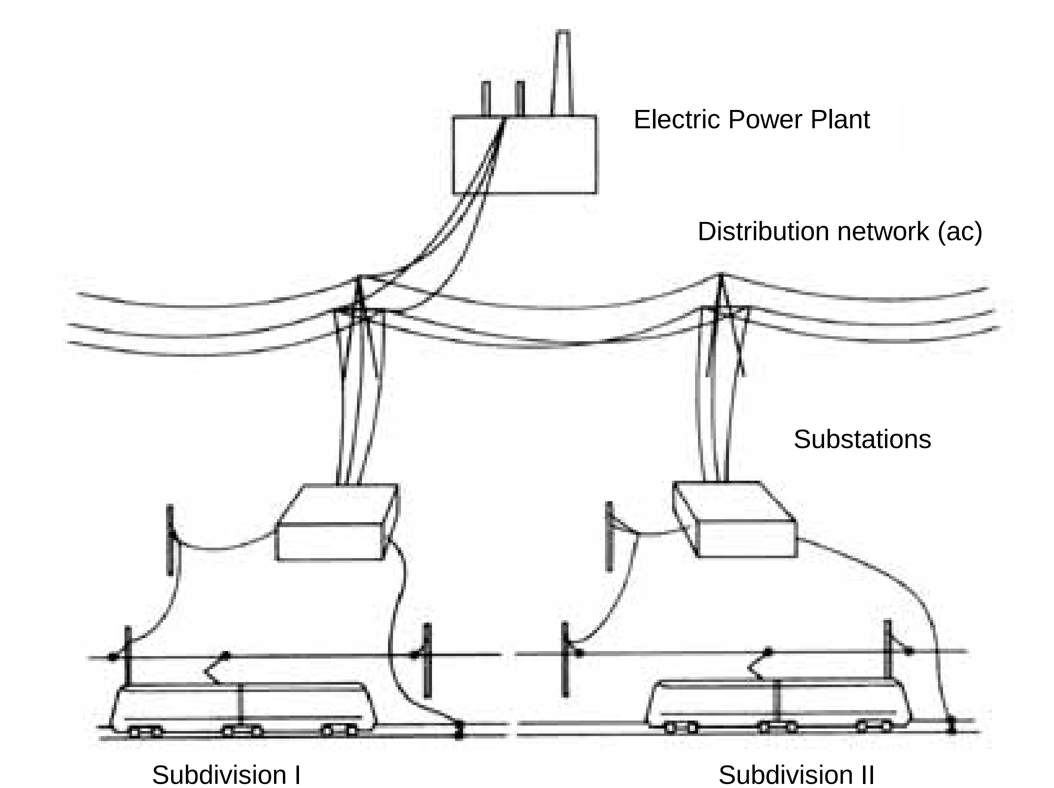


Figure 2.3-3: Transit Line Power Distribution System
Source: Vuchic

The traction power substations convert the typically 12,000 to 13,000 volts (high voltage is more efficient for transport over long distances) alternating current generated by an electric power plant into 600 to 750 volts direct current used for LRT operation. The required space for substations vary from 250 to 500 square feet, depending on model and manufacturer. They could be either located underground or above-ground.

Feeder cables connect the substations with the overhead wires. These cables are usually located beneath the street or sidewalks.

The most noticeable element of the power systems for the public eye is the overhead wire system that supplies electrical power to the light rail vehicle via pantographs mounted on the roof of each LRV.

Two different overhead wire systems are used. The more economic, simple catenary system consists of a contact wire supported from a parallel one, called the messenger. The messenger maintains the contact wire in a level position and acts as an electrical feeder to it. This wire system allows wider spacing of the support poles, typically 200 feet to 220 feet (60 m to 67 m) apart.[4]

On LRT lines running through aesthetically sensitive locations, such as downtown areas, a single contact wire is used. This requires relatively closely spaced poles, typically 100 feet to 120 feet (30 m to 37 m) apart. In both cases more poles are necessary, for curved sections of track.

Pole designs vary depending on the environment. In aesthetically sensitive locations, they are designed to match with the existing fluted poles used for street lighting. Implementing poles that provide both street lighting and overhead wire attaching is another possibility.

The height of the contact wire varies from 22 feet 6 inch (6.85 m) on railroad rights-of-way to 19 feet (5.80 m) in mixed street traffic. A lower 15 feet 6 inch (4.72 m) height is used in segregated rights-of-way in which only light rail vehicles operate. Exceptions to these height requirements are at existing low clearance locations, such as at overpasses.[5]

[4] Habib/Rosen, 1994, p. I-35

[5] Habib/Rosen, 1994, p. I-37

Stations

The design of LRT stations depends predominantly on the LRVs floor characteristics. With a 100% low-floor LRV a curbheight of 7.87 inches to 9.84 inches (200 mm to 250 mm) above rail level is recommended in order to take full advantage of the easy wheelchair accessibility. This curb height also provides an at grade access from the sidewalk. Typically, a proof-of-payment fare collection scheme allows an open station without specific entrances in contrast to methods where fares are collected at the station.

Picture 2.3-6: Modern LRT station in Strasbourg

Marking the start and the end of every LRT trip, stations should be easy to recognize and clearly arranged. They should also include a shelter with detailed transit and travel information. Special station features, such as dynamic schedule information, further increase the attractiveness of not only the station but the whole transit system.

Storage and Maintenance Facility

Layout of the storage and maintenance facility corresponds to the size of the LRT system and the amount of facilities. In addition to vehicle maintenance, inspection and cleaning, this facility might include the LRT operations and control center. For an LRT fleet of 13 vehicles (100 feet/30 m long vehicles), this facility could be accommodated within a 60,000 square-foot site.[6]

[6] Habib/Rosen, 1994, p. I-37

2.3.3 LRT Operation

In this section several important light rail transit operating factors are specified and described. Further operating factors are qualified under Chapter 2.3.4 in comparison with other means of transportation.

Boarding and Alighting

One important benefit of low floor LRVs, is the shorter station dwell time due to more efficient boarding, moving through and alighting. This is primarily a result of quicker ingress and egress by passengers, who do not need to ascend or descend steps. This takes an especially long time if they are carrying bags or pushing strollers. Furthermore, wheelchairs passengers are able to board the LRV independently and almost as fast as everybody else. Therefore the schedule reliability increases and boarding for disabled persons is less embarrassing and more convenient.

Picture 2.3-7: Multiple entrances, LRV in Berlin

Fare Collection

There are three general types of fare collection available for LRT passengers: first a proof-of-payment fare collection scheme, similar to that in most European cities and in most new LRT systems in the US, second to collection of fares at stations and third, to utilize the vehicles, which normally limits entry to the first entrance.

Picture 2.3-8: Touchless checking on board an LRV

Vehicle Travel Control

Most LRT systems use visual vehicle control as the control method. The driver's vision is utilized to control speed, driving or stopping. Therefore this method is only as safe as the driver's capabilities and judgment. The driver can choose any distance to the vehicle driving ahead and consequently, a high capacity can be achieved through short headways. This however leads to low speeds, when capacity level is approached. [1]

Switch-Point Positioning

In contrast to most other rail systems, where switch-point positioning is either done remotely by a central control train dispatcher or automatically by preprogrammed signals from vehicles, the LRV driver usually operates switches through a remote electrical control, that starts an electric motor on the switch-point mechanism.[2]

[1] Vuchic, 1981, p. 437

[2] Vuchic, 1981, p. 382

2.3.4 LRT Alignment

As a result of very specific conditions at each section of an LRT line, alignment types could vary extensively. This reflects a high adaptability of this rail mode to performance requirements, cost and community acceptance. In general, LRT alignment should comply with objectives such as serving the greatest number of potential riders, minimizing operating costs, minimizing operating conflicts, and maximizing operating speeds.[1]

In addition, alignments of LRT could be used selectively to recover street space from vehicular traffic and function as a part of traffic calming measures. The advantage of this measure is that, with its implementation, an attractive alternative to private car use is offered, so that transportation by itself is improved. This is not the case with other traffic reducing strategies.

The following division of alignment classes and categories, recommended by the TRB[2], are based on access control. They reflect similar conflict conditions between light rail vehicles and motor vehicles and pedestrians. Three basic alignment classes are distinguished; each is subdivided into different categories, as outlined in Table 2.3-1a/b. Figure 2.3-4 to -6 give a visual impression of how these alignment categories could appear.

Alignment classes are characterized as follows:

Type a:. "Exclusive Alignments use full grade separation of both motor vehicle and pedestrian crossing facilities, thereby eliminating grade crossing and operating conflicts and maximizing safety and operating speeds."

[1] TRB, 1996a, p. 13

[2] TRB, 1996a, p. 13

Type b: "Semi-exclusive alignments use limited grade crossings, thereby minimizing conflicts on those segments where conflicts cannot be eliminated entirely. Operating speeds on segments other than those where automatic gates are installed are governed by vehicle speed limits on the streets or highways. On segments of this type of alignment where the right-of-way is fenced, operating speeds are maximized; however, these higher speeds are typically maintained for shorter distances, often on segments between grade crossings."

Type c: "Non-exclusive alignments allow for mixed flow operation with motor vehicles or pedestrians, resulting in higher level of operating conflicts and lower-speed operations. These alignments are often found in downtown areas where there is willingness to forgo operating speeds in order to access areas with high population density and many potential riders."

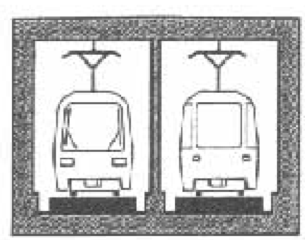
Table 2.3-1a: LRT Alignment Classification

CLASS	CATEGORY	DESCRIPTION OF ACCESS CONTROL
Exclusive	Type a	A right-of-way without at-grade crossing that is separated or protected by a fence or substantial barrier as appropriate to the location (includes subways and aerial structures). Pedestrians, bicycles, and motor vehicles are prohibited within this right-of-way.
Semi-Exclusive	Type b.1	A right-of-way with at-grade automobile, bicycle, and/or pedestrian crossings, protected between crossings by fencing or substantial barriers if appropriate to the location. Motor vehicles, bicycles, and/or pedestrians cross this right-of-way at designated locations only.
	Type b.2	An LRT alignment within a street right-of-way but protected by 6-inch-high curbs and fences between crossings. The fences are located outside the tracks. Motor vehicles, bicycles, and pedestrians cross this right-of-way at designated locations only.
	Type b.3	An LRT alignment within a street right-of-way but protected by 6-inch-high curbs between crossings. A fence may be located between the tracks. Motor vehicles, bicycles, and pedestrians cross this right-of-way at designated locations only.
	Type b.4	An LRT alignment within a street right-of-way but separated by mountable curbs, striping, and/or lane designation. Motor vehicles, bicycles, and pedestrians cross this right-of-way at designated locations only.
	Type b.5	An LRT alignment within an LRT/pedestrian mall right-of-way adjacent to a parallel roadway that is physically separated by a 6-inch or higher curb. The LRT right-of-way is typically delineated by discernible visual and textural pavement markings and/or striping. Motor vehicles and bicycles cross the LRT/pedestrian mall right-of-way at designated locations only; pedestrians cross the LRT right-of-way freely and cross the parallel roadway at designated locations.

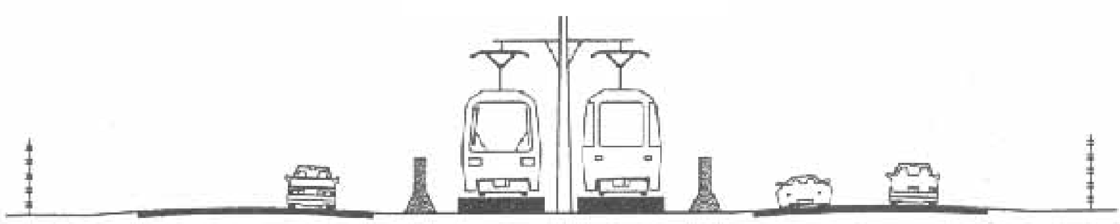
Table 2.3-1b: LRT Alignment Classification

CLASS	CATEGORY	DESCRIPTION OF ACCESS CONTROL
Non-Exclusive	Type c.1	Motor vehicles and bicycles operate with LRVs on surface streets. Pedestrians cross this right-of-way at designated locations only.
	Type c.2	Transit vehicles may operate with LRVs in a transit-exclusive area for transporting, embarking, and disembarking passengers. A raised curb separates the transit/LRV right-of-way from the pedestrian way. Nontransit motor vehicles and bicycles are prohibited in this right-of-way; they, as well as pedestrians, cross at designated locations only. Delivery vehicles may be allowed at certain times.
	Type c.3	LRVs and pedestrians share this right-of-way. Motor vehicles and bicycles are prohibited from operating on or adjacent to the LRT tracks. The LRT right-of-way is typically delineated by discernible visual and textural pavement markings and/or striping. Motor vehicles and bicycles cross this right-of-way at designated locations only; pedestrians my cross it freely.

Figure 2.3-4: Exclusive Alignments
Source: TRB



Exclusive, Type a
(Subway)



Exclusive, Type a
(Freeway Median)

Figure 2.3-5: Semi-Exclusive Alignments
Source: TRB

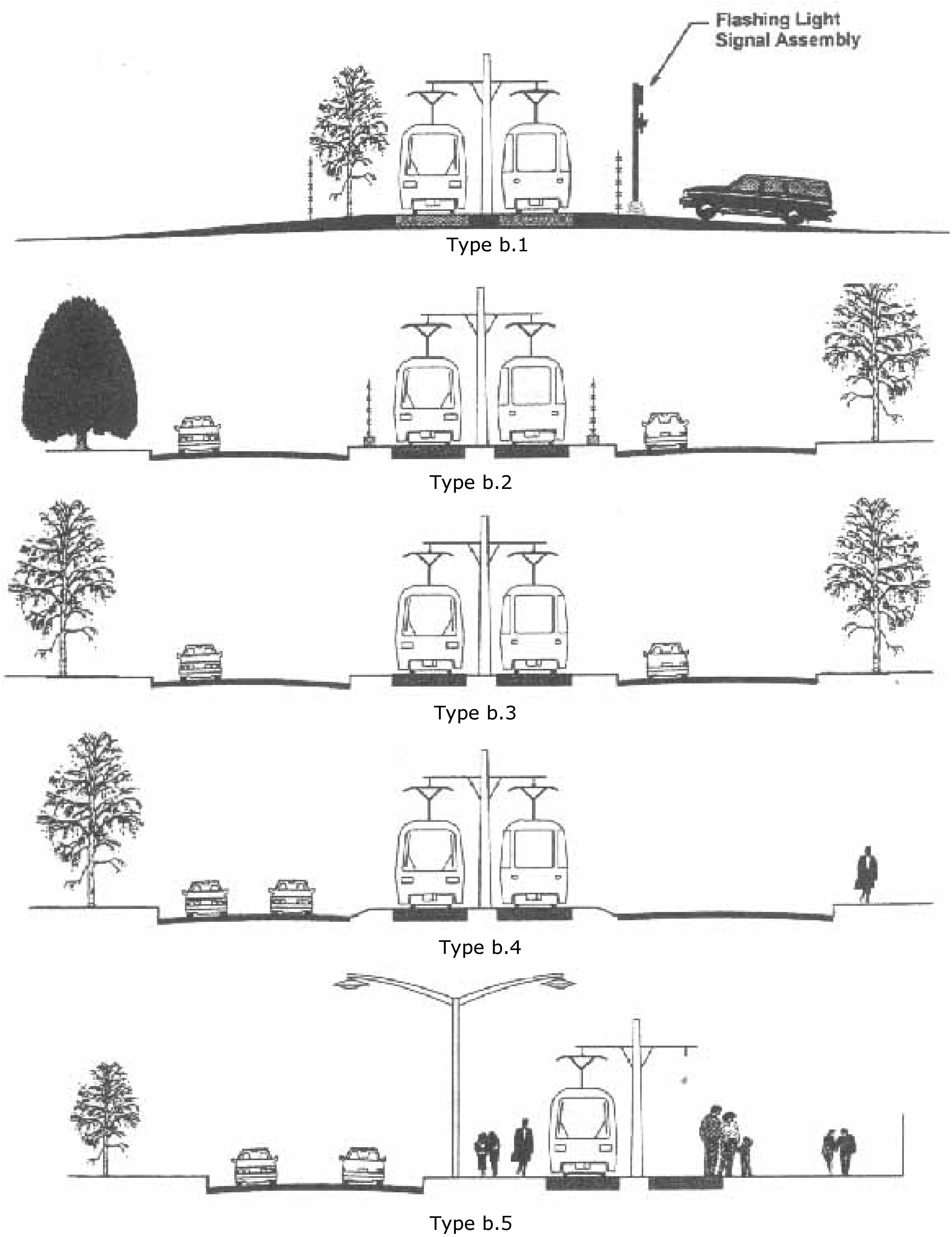
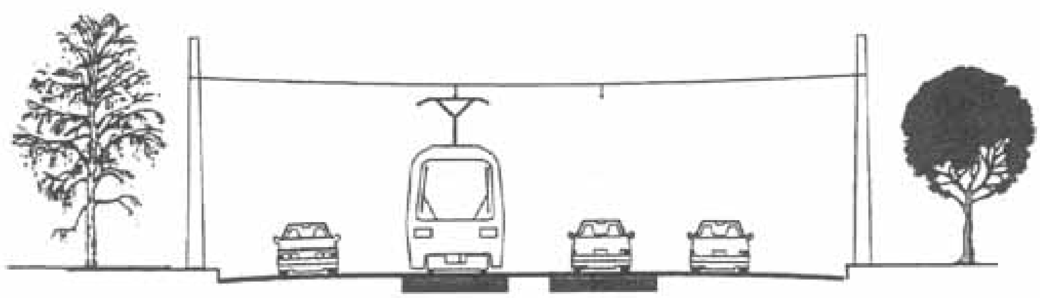
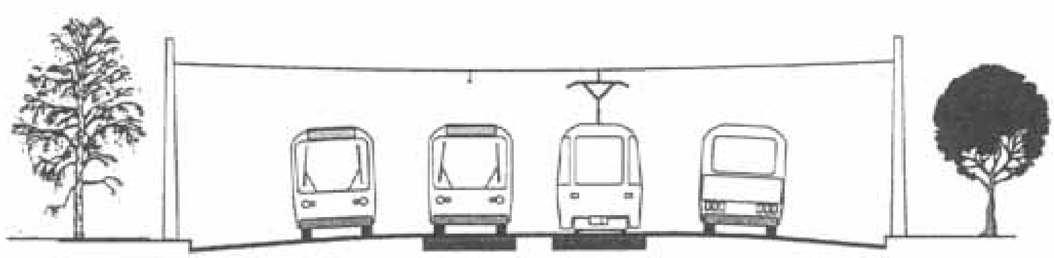


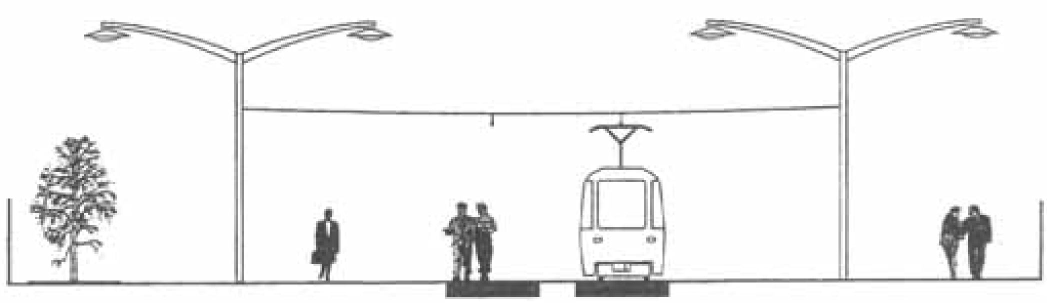
Figure 2.3-6: Non Exclusive Alignments
Source: TRB



Type c.1 (Mixed Traffic)



Type c.2 (Transit Mall)



Type c.3 (LRT/Pedestrian Mall)

2.3.5 The role of LRT as part of a transit system

To better describe the further characteristics of light rail transit, a comparative description was chosen. According to the already described features, the advantages and disadvantages of LRT as a transit component becomes obvious through a comparison with the two most common transit modes: the bus and the subway. This comparison is done for the following categories: capacity, service, environment, economy, traffic issues, safety, security and social issues. This chapter is summarized in Table 2.3-3 and 2.3-4 at the end of this paragraph.

In general, a major advantage of LRT over the **bus** is its popularity. In Europe, an increase in ridership of 30% to 80% is usually realized after replacing bus service with LRT.[1] Unquestionable, less flexibility is its major disadvantage.

Compared to the **subway**, LRT offers the advantages of a surface transit system, but requires changes in street use.

CAPACITY

A key characteristic of a transit mode is capacity, defined as the amount of persons that could be served in one direction within a certain time period (normally an hour or a day).

Typical, the maximum capacity of LRT is between 11,000 to 24,000 passengers an hour, depending on the train length.[2] LRT service becomes less costly to operate than bus service when passenger demand reaches 5,000 or more passengers per day (Table 2.3-2).[3] However, operating costs for buses in the US are less expensive compared to Europe because of three times lower gasoline prices.

As experience has shown, **bus** systems operation in surface streets have difficulty operating efficiently when passenger volumes exceed 4,000 to 6,000 persons per hour per direction

[1] Ludwig, 1991, p. 33

[2] TRB, 1996b, p. 96

[3] Ludwig, 1991, p. 31

(pphpd), while the minimum passenger demand to warrant a **subway** system is reported to be 20,000 to 24,000 pphpd. LRT fits into the capacity gap between bus and subway (Vuchic, 1972).[4] In contrast to the subway, train control with LRT is by "visual control", that allows shorter headways with up to 60 trains per hour.

Capacity characteristics already place LRT somewhere between bus and subway service, in a manner similar to LRT's other distinctive features.

Table 2.3-2: LRT comparison with other means of transportation

	Bus	**LRT**	**Subway**	**Automobile**
Vehicle Capacity	60	120 - 400	1,400	1.3
Vehicles/ Hour/Direction	120	60	30	700
Passengers/ Hour/Direction	7,200	7,200 - 24,000	42,000	900
Typical Range of Ridership	up to 5,000	500 - 20,000	up from 20,000	-
Average Speed	5 - 7 mph	12.5 mph	18.6 mph	12.5 mph
Operating Speed	15-50 mph	15 - 70 mph	55 mph	15 - 50 mph
Required Lanes to serve 100,000 pphpd	14	4	3	110

[4] USDOT, 1977, p. 4

SERVICE

For passengers, the most important service quality of a transit mode is the journey time. This is the time which a person spends travelling between the point of departure (e.g. home) and destination (e.g. place of work). When using public transit, this typically breaks down into the time for walking or driving from the point of departure to the station, the waiting time at the station, the riding time, where applicable the transfer time and finally the walking or driving time from the last station to the destination.

Independent of the trip length, the journey time by LRT is less than the one with the **bus**. With the same distance between each stop, LRT provides a faster service due to better driving performance and less station dwell time, resulted by faster boarding due to multiple entrances. Vehicles are also easier to board (low floor), especially for seniors and disabled. Furthermore, access for strollers and bikes is provided as well as easier access with packages. State-of-the-art LRV's also guaranty a convenient *smooth ride*. Weaving and jerking as occurs with buses changing lanes does not happen, and acceleration and braking are smoother, due to electrical propulsion.

However, LRT service in city streets is more likely to be *interrupted*. While a bus could easily drive around a potential obstacle, the LRV, tied to its tracks, has to wait until it is removed.

For trips up to 2.5 miles (4 km), the actual journey time with LRT is less than with the **subway**.[5] This is, above all, due to shorter walking trips to LRT stations, which are more closely-spaced and located on the surface.

[5] Brändli, 1987, p. 148

Taking into account the "subjective" journey time,[6] which is determined through surrounding situations, attractiveness and attitude - passenger preference for LRT even exceeds 2.5 miles (4 km). This, due to the fact that walking times are felt longer than riding times, the waiting environment on the surface is generally more pleasant and a ride through the city's landscape is more attractive, than one through a dark tunnel. Furthermore access for seniors and disabled is easier and faster, avoiding stairclimbing, elevators or escalators.

A journey time advantage for subways takes effect for *longer trips* of more than 2.5 miles (4 km). Subway service also provides greater *reliability*, due to less potential for interruption.

ENVIRONMENT

Compared to the **bus**, LRT provides a more efficient use of *space*, especially when operating vehicles with a narrower profile of 8.1 feet (2,4 metes). LRV's with the same width than buses as 8.2 to 8.7 feet (2.5 to 2.7 meters) are superior because they do not need as much space for curves.[7] Due to a lower rolling resistance, LRT is a more efficient user of *energy*.[8] Since LRV's are electrically powered, they offer a clean quite ride, ensuring no *emissions* at the operating location and providing a wide choice of energy sources. Noise absorbers and the use of the latest track technology guaranties less *noise* impacts than motor buses [9] and reduce *vibration* so that residents are minimally impacted.[10] On the other hand *visual impacts* of LRT, particularly due to overhead wires and *impacts during construction*, like dust and noise, are more substantial.

Differences with the **subway** are, on the one hand, less *energy consumption* for LRT construction but, on the other hand, more *surface disruption* when operating LRT.

[6] VDV, 1997, p. 224

[7] Monheim, 1990, p. 433

[8] USDOT, 1977, p. 4

[9] USDOT, 1977, p. 4

[10] Ludwig, 1991, p. 37

ECONOMY

On the one hand, LRT service has lower *operating costs* than **bus** service, on the condition that ridership is already in the range of LRT efficiency. The fact that LRT handles the same amount of passengers with less staff, seems important when considering that typically 60% of operating costs are staff related.[11]

Understandably, on the other hand, LRT has *higher capital costs* than bus systems. But still, these costs are substantially lower - only 10% - 20% of than those for a **subway**. A mile of LRT construction is usually quoted with 20 to 80 million dollars, while a mile of subway may cost around 500 million dollars. LRT is proven to be more economical also because of lower *station maintenance cost* and due to the fact that it is easier to add or change routes. LRT is less efficient because of its limited potential for automation.

TRAFFIC ISSUES

LRT rights-of-way are more enforceable than **bus** lanes,[12] though they reduce space for cars and complicate deliveries.

The possibility to organize street traffic, can be thought of as an advantage over the **subway**, as much as a disadvantage by interfering with street traffic.

[11] Monheim, 1990, p. 432

[12] Apel, 1990, p. 231

SAFETY

An important safety advantage of LRT over the **bus** is that *movement* of LRV's is *more predictable*. Up to a certain distance from the tracks, there is almost no risk of an accident with LRV's. In case of a collision, the possibility of *running over* a pedestrian is minimized, due to safety devices. Experiences in Europe have shown that five times fewer accidents happen in transit malls with LRT than with bus service.[13] However, LRT provides a *greater risk* for autos in case of a collision due to the heavier weight of LRT vehicles and their *limited maneuverability*.

Major safety advantages over the **subway** are the elimination of accidents at stairways as well as those at high platforms. Moreover, the potential for collision with large vehicles, like trucks or buses, does not exist with the subway as well as danger to car traffic, bicyclists and pedestrians.

SECURITY

As a surface transit system, LRT passengers do not have to walk underground, which is subjectively a less safe walk. Riding closer to the driver provides less security risk as compared with the **subway**. Furthermore, access of police to above ground LRT stations is easier. On the other hand, subway stations can be more easily kept under surveillance, due to controlled access.

SOCIAL ISSUES

Important social advantages of LRT over the **subway** are that LRT allows passengers to *experience the city* while riding and *increases the presence of people in the streets*. This *contribution to urbanity* could be even bigger when the implementation of LRT is used to create a pleasant street scape, amenable for walking and resting. Furthermore, the positive image (panache) of LRT provides incentives to attract car and taxi users.

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[13] Ludwig, 1991, p. 34

Table 2.3-3: LRT compared to Bus systems

CATEGORY	ADVANTAGES OVER BUS	DISADVANTAGES OVER BUS
GENERAL	• Positive image	• Less flexible
SERVICE	• Shorter journey time • Faster to board (multiple entrances) • Easier to board (low floor) for seniors and disabled • Access for strollers and bikes • Potential for goods movement • Smoother ride, no lateral movement	• Potential for disruption
ENVIRONMENT	• More efficient use of space • Less energy consumption • Less noise • No emissions at the operating location	• Impacts during construction • Visual impacts
ECONOMY	• Lower operating cost	• Higher capital cost
TRAFFIC	• More enforceable than bus lanes	• Reduces space for cars • Complicates deliveries
SAFETY	• Movement is more predictable • Cuts possibility of running over • Works better in pedestrian zones	• Greater risk for autos in case of an accident • Limited maneuverability

Table 2.3-4: LRT compared to Subway systems

CATEGORY	ADVANTAGES OVER SUBWAY	DISADVANTAGES OVER SUBWAY
GENERAL	• Stays on Surface	• Requires changes in street use
SERVICE	• More frequent station stops • Less walking • Less stairclimbing • Lower journey time for short trips • Easier and faster access for seniors and disabled • More pleasant waiting environment	• Slow for long trips • Less reliable
ENVIRONMENT	• Less energy for construction	• More surface disruption
ECONOMY	• Lower capital cost (10% - 20%) • Easier to add or change routes • Lower station maintenance cost	• Limited potential for automation
TRAFFIC	• Organizes street traffic	• Interferes with street traffic
SAFETY	• Eliminates accidents at stairways • Avoids accidents at high platforms	• Potential for collision with large vehicles • Less safe for car traffic, bicyclists and pedestrians
SECURITY	• Avoids walking underground • Less crime due to closer contact to driver	• Less control of fare dodgers
SOCIAL	• Contribution to urbanity • Allows riders to experience the city • Positive contribution to street scape • Increases presence of people in the streets • Positive image (panache) provides incentives to attract car and taxi users	

Chapter 3

The Case for Light Rail Transit on Manhattan’s East Side

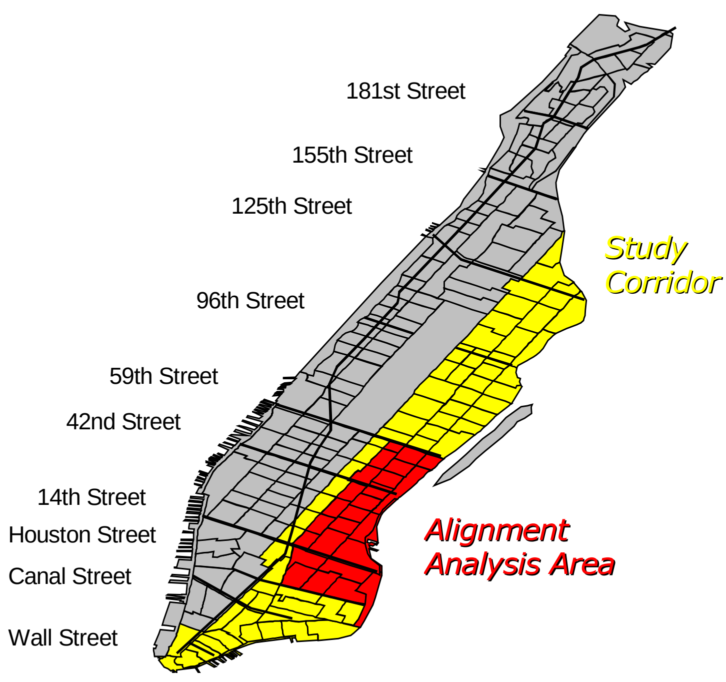
3 The Case for Light Rail Transit on Manhattan's East Side

Part 3 of this study presents the specific case for Light Rail on Manhattan's East Side. Following a description of the Study Area, existing problems and solutions are described. Finally different alignment alternatives for an ES LRT Line are described and analyzed in Chapter 3.4.

3.1 Description of Study Area

As Map 3.1-1 shows, three areas were distinguished in order to describe the Study Area. General information about demographics and transportation mode preferences is provided for all of Manhattan in order to show the characteristics of the East Side compared to the rest of Manhattan. The Study Corridor, including all areas east of 5th Avenue as well as Lower Manhattan and the Lower East Side, is the focus of a description of relevant traffic and transportation elements. And finally, the evaluation of alignment alternatives is based on the Alignment Analysis Area, including the vicinity of First and Second Avenue between Houston and 63rd Street. Because of its specific context, the description of the Alignment Analysis Area is not included in this chapter, but rather in Chapter *3.4 The East Side LRT Line*.

Map 3.1-1: Elements of the Study Area



3.1.1 Manhattan

The island of Manhattan is one of the five boroughs of New York City. It is about 13 miles (21 km) long and is generally about 2.2 miles (3.5 km) wide. The area of this island, defined by the East River in the east, the Hudson River in the west and the Harlem River in the north, is about 21 square miles (54 km²).

Manhattan's street network is primarily a grid pattern and provides easy orientation: The avenues are running north/south, being numbered from east (First Avenue) to west (12th Avenue). The crosstown running streets are numbered from Houston Street up to the northern tip of the island. A typical block length is 600 feet (180 meters) in the east/west direction and 200 feet (60 meters) in the north/south direction.

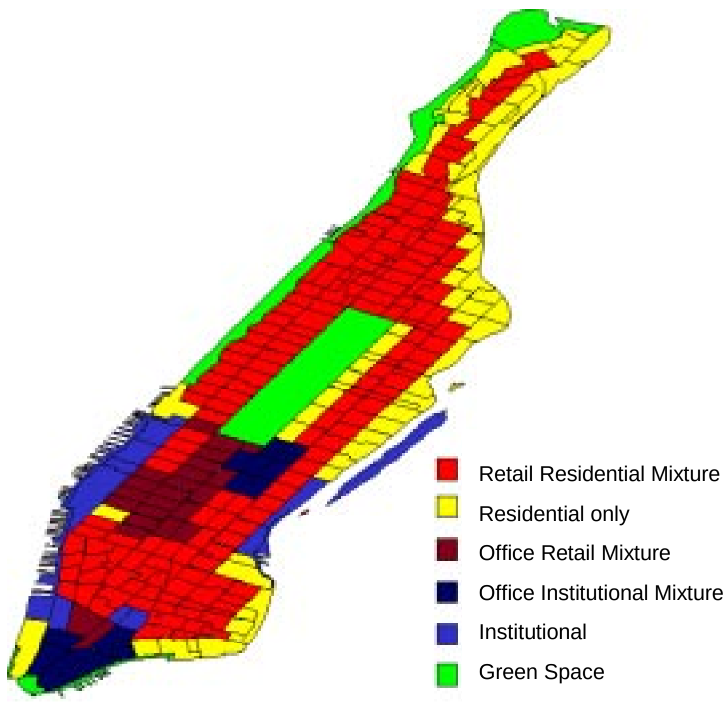
Land Use

Manhattan is almost completely built-up, with the exception of several parks. Central Park dominates the center of the island between 59th and 110th Street, stretching from 5th Avenue to Central Park West (8th Avenue), Riverside Park extents along the Hudson River north of 66th Street to the upper end of Manhattan and is the second largest green space in Manhattan. The southern tip of the island ends with Battery Park.

Manhattan contains NYC's Central Business District (CBD), usually defined as all of Manhattan south of 60th Street. Within the CBD, two areas are characterized by extraordinary numbers of high rise office buildings (Picture Appendix A, Map 3.1-2): Lower Manhattan on the southern end of Manhattan, including the Financial District, and Midtown, south of Central Park. Downtown has less retail usage, especially in the Financial District, whereas large areas of Midtown are comprised of an office/retail mixed use. The area in between these office concentrations is dominated by a residential/retail mixture that is often called "The Valley", because of its lower building heights. This varied urban land use is most common in Manhattan and covers most parts of both sides of Central Park and Harlem as well.

Residential only use is dominate along the East River in the southern half of Manhattan and parts of Harlem as a consequence of urban renewal with the implementation of "Towers in the Park" type of development. More upscale residences can be found on the Upper East Side along Central Park and the East River.

Map 3.1-2: Predominate Land Use on Census Tract level in Manhattan



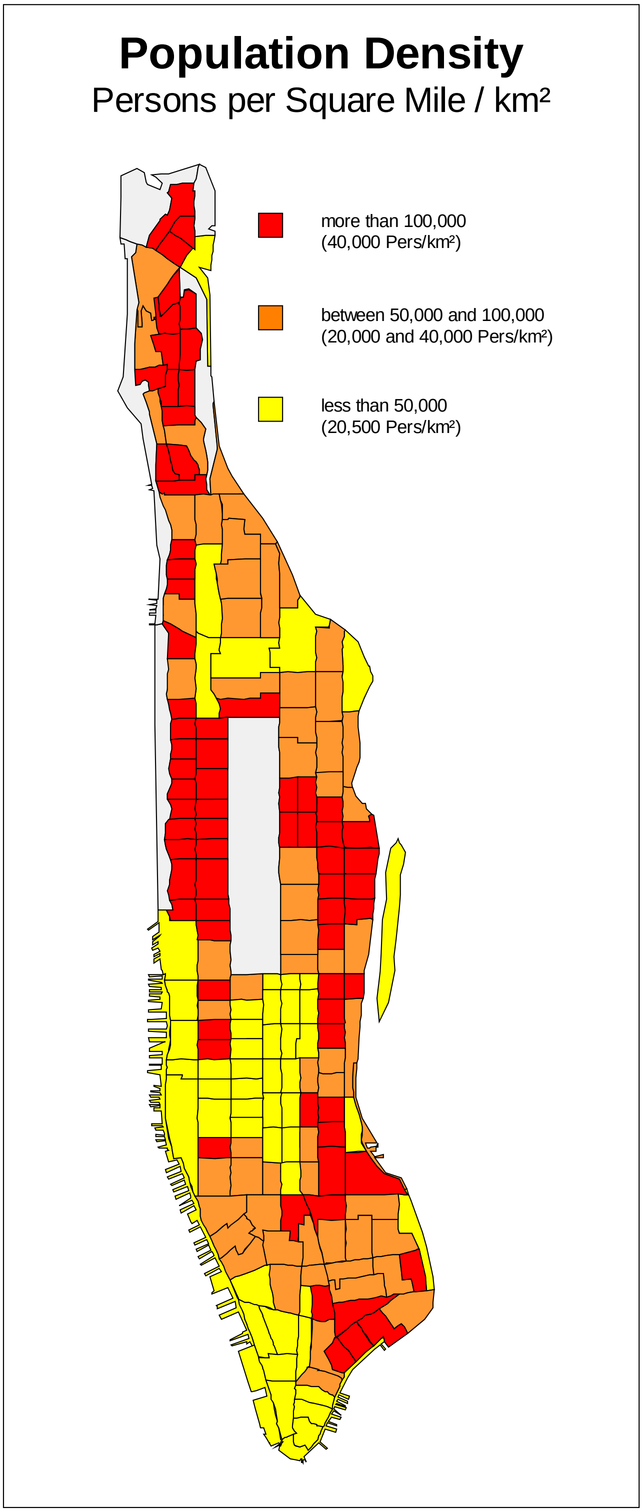
Demographics

Approximately 1.5 million people (20%) out of 7.3 New Yorkers live in Manhattan, resulting in an average density of 70,000 persons per square mile (28,000 persons per km²).[1] With 1.97 million workplaces in the CBD, Manhattan represents one of the world's densest CBDs 220,000 workplaces per square mile (85,000 workplaces per km²) compared to London's CBD with 34,000 workplaces per km² or Tokyo with 57,000 workplaces per km²).[2]

[1] USDOC, 1990, www.census.gov

[2] London Research Centre, 1998, p. I

Map 3.1-3: Population Density in Manhattan based on USDOC 1990 data

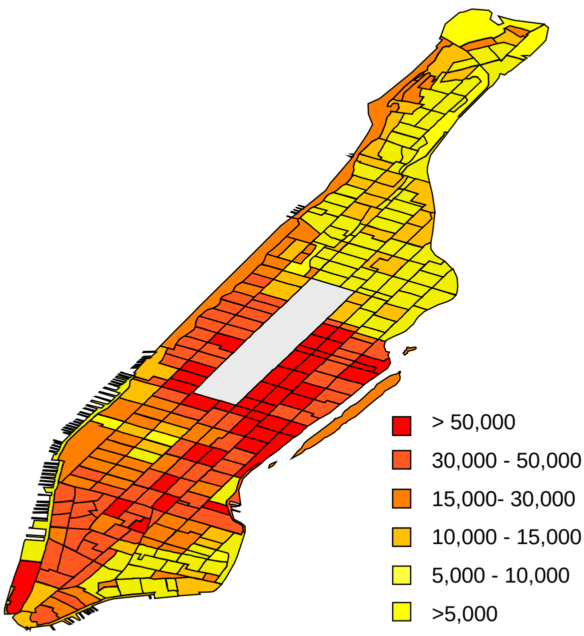


Looking at the population density on the Census Track level in Manhattan (Map 3.1-3), the following characteristics are conspicuous. The stated density of more than 100,000 persons per square mile (260,000 persons per km²), is extraordinarily dense and unusual for the US. High density areas are located east and west of Central Park, in northern Manhattan and south of 60th Street and along the East Side. In this area, the West Side has substantially less population. Understandable is the lower population density in Lower Manhattan and Midtown, where the city scape is dominated by office buildings.

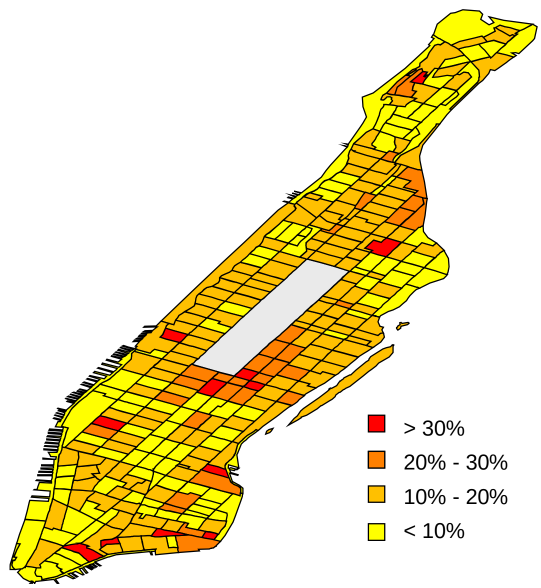
Map 3.2-4 portrays Manhattan's income per capita and shows the Upper East Side as a high income area, whereas the far East Village and Harlem communities are low income areas. Therefore, the East Side is characterized by extremely different social stratum.

Also of interest are those areas with a high percentage of senior citizens (Map 3.2-5), who are more likely to encounter mobility difficulties because of health problems. Noticeable is the high percentage of older people around the Southeast corner of Central Park. Along the East Side, Peter Cooper Village (East of First Ave, South of 23rd Street and Stuyvesant Town (East of First Ave, North of 14th Street) are also areas with concentrations of older residents.

Map 3.1-4: Income per Capita



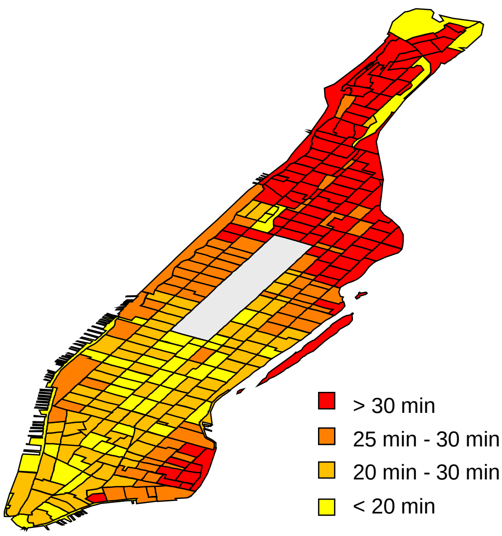
Map 3.1-5: Percentage of Persons over 65 Years



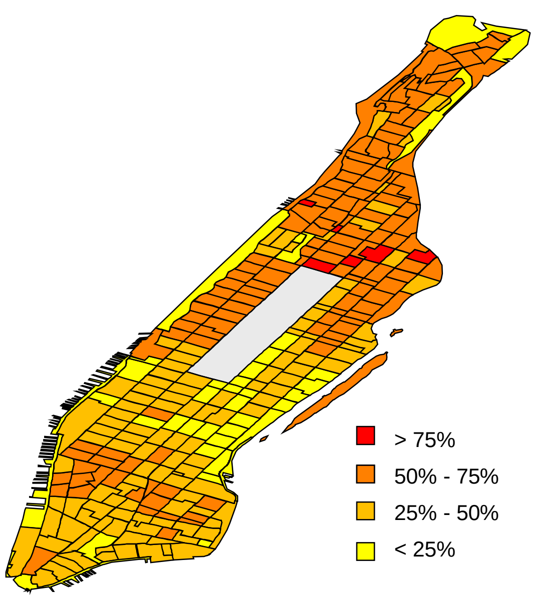
based on USDOC 1990 data

Mobility

Map 3.1-6: 1990 Average Commuting Time
based on USDOC 1990 data



Map 3.1-7: Commuted by Rapid Transit
based on USDOC 1990 data



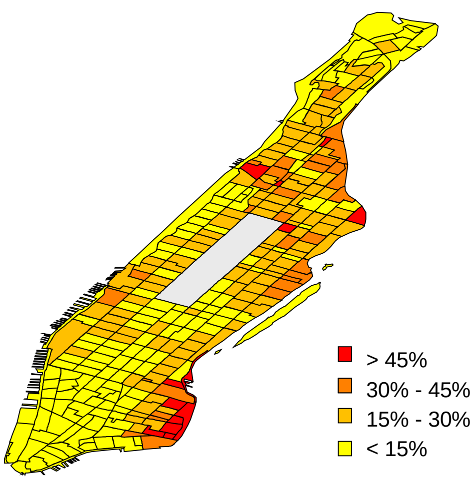
Looking at commuting times (Map 3.2-6), extended trips to work of more than 30 minutes are most common north of Central Park, explainable by the longer distance to the CBD, and in the far East Village due to the lack of rapid transit. This situation illustrates a major problem with these parts of the East Side.

Preference of Means of Transportation

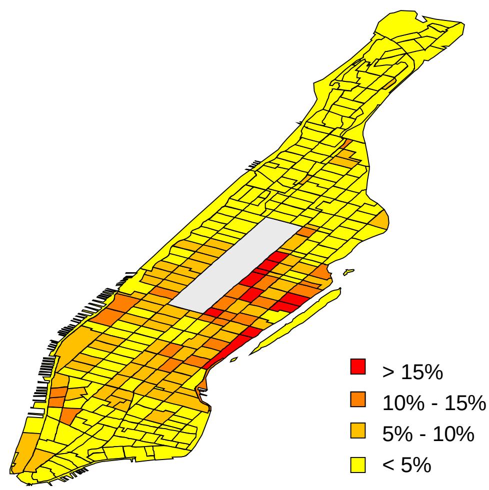
Map 3.2-7 to Map 3.2-12 show the modal split on the Census Track level for common means of transportation used for commuting. Depending on the length of the commute, available transit modes and income, most preferences shown in the data are logical. *Rapid Transit* is the dominant mode in Manhattan; it is particularly of interest for longer commutes, resulting in a greater preference in the more remote areas of Manhattan such as in the north. The *bus* is used for shorter trips and on crosstown routes, and the high bus preference along the East Side reflects the lack of suitable subway alternatives. *Taxi* use, as the most expensive mode, first of all depends on income level, explaining the higher taxi preference in high income areas, such as the upper East Side. Taxis are also competitive for "L-shape" (diagonal) trips for which going by public transit would mean a transfer at least once. Therefore taxi use is also an indicator for the insufficiency of the transit system and this would be representative of the East Side.

Not surprisingly, private *car* use for residents living in the CBD is low, due to low ownership, and expensive parking space coupled with congested streets. The higher preference for the car in Northern Manhattan might also be an indicator for reverse commutes out of Manhattan. The preference for w*alking* to work increases the closer the workplace is to the home, therefore areas with an extremely high walking percentage of more than 45% are located in Lower Manhattan and Midtown. Chinatown and the East Side between 14th Street and 60th Street also exhibit a high walking percentage.

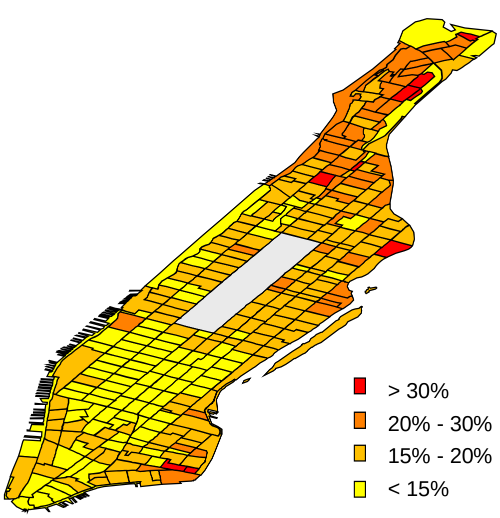
Map 3.1-8: Commuted by Bus



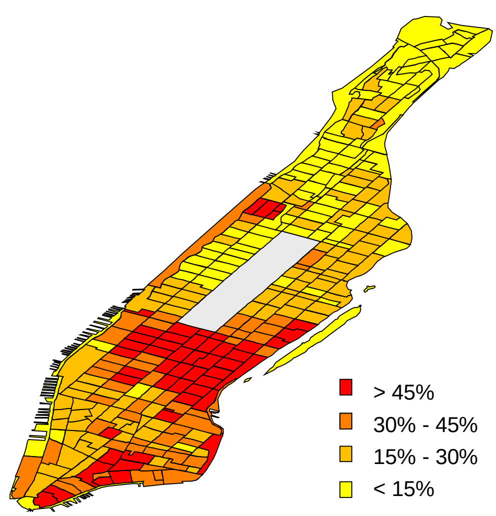
Map 3.1-9: Commuted by Taxi



Map 3.1-10: Commuted by Car



Map 3.1-11: Commuted by Walking



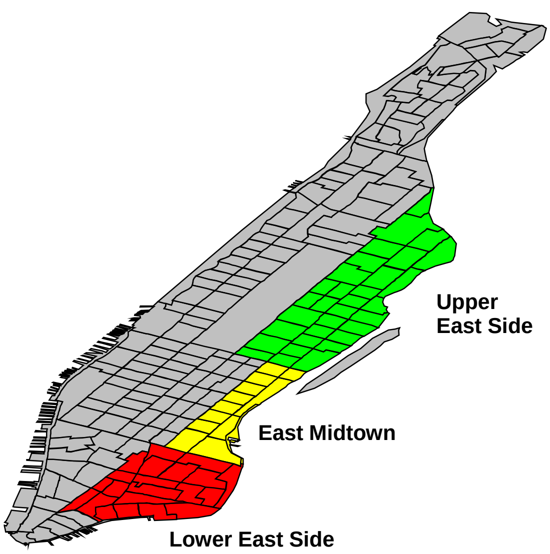
based on USDOC 1990 data

3.1.2 The Study Corridor

3.1.2.1 Origins and Destinations of Work Trips

The 1996 origin and destination data[3] employed for this study summarizes all commutes to work in the AM peak from 6:30 AM to 8:30 AM. As map 3.2-12 shows, three zones of the Study Area were selected to provide relevant information. These are: The Upper East Side Zone, east of 5th Avenue and north of 60th Street, the East Midtown Zone, east of 3rd Avenue between 14th Street and 60th Street, and the Lower East Side Zone, east of Broadway between Worth Street and 14th Street. The division of these zones is based on MTA's Journey to work zones, limiting a more exact division.

Map 3.1-12: The East Side Zones



As Figure 3.1-1 shows, only 19% of commuting trips performed by Residents of all three East Side Zones terminate within these zones. The majority of the trips (62%) ends in Manhattan but outside the East Side Zones, another 19% end outside of Manhattan.

[3] MTA, 1996, Journey to work

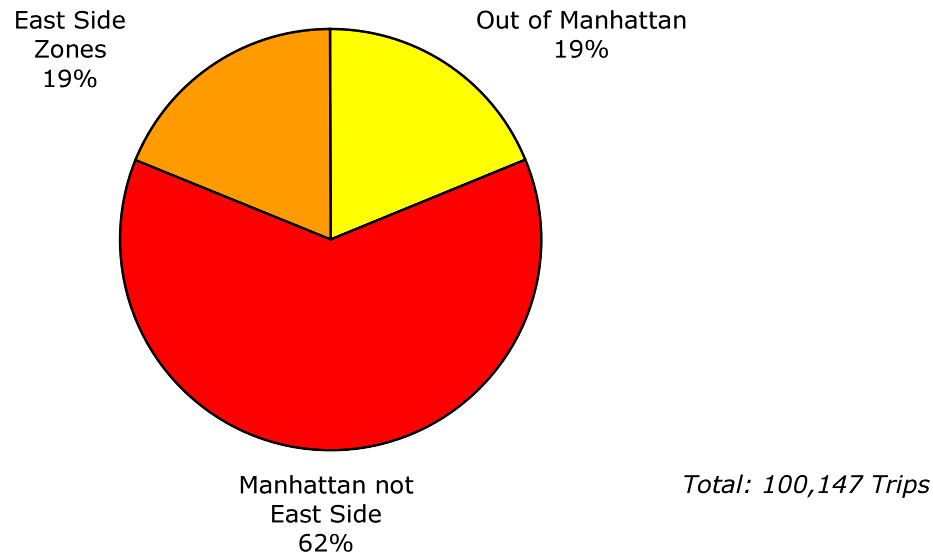


Figure 3.1-1: AM Destinations of East Side Zones Residents
Source: MTA 1996

Most commuting trips (77%) between 6:30 AM and 8:30 AM terminate in the East Side Zones start outside of Manhattan (Figure 3.1-2). Only 11% are made within these zones and 12% start in Manhattan but outside the East Side Zones.

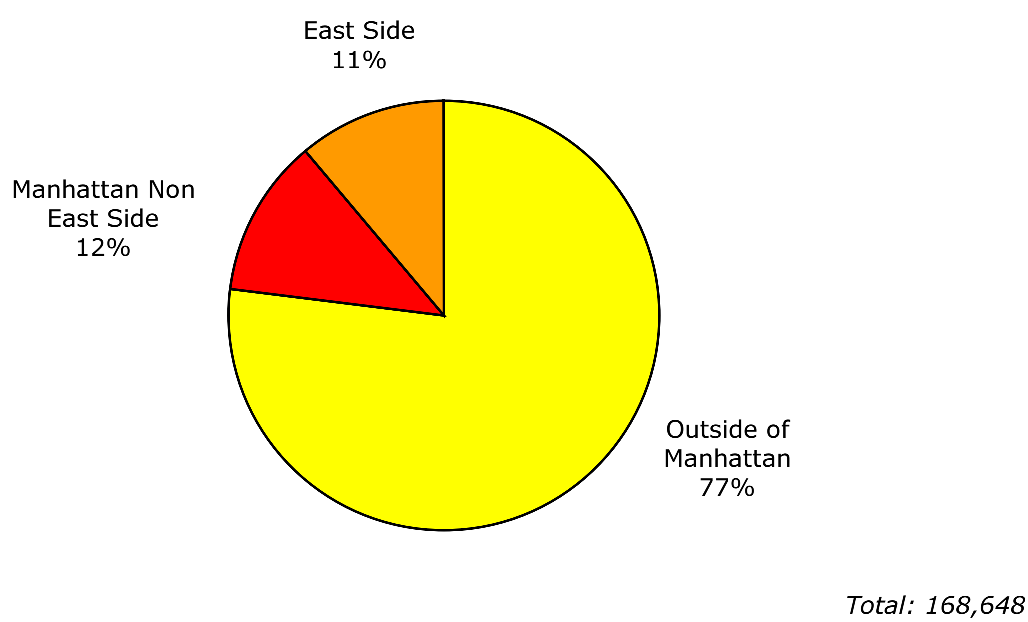
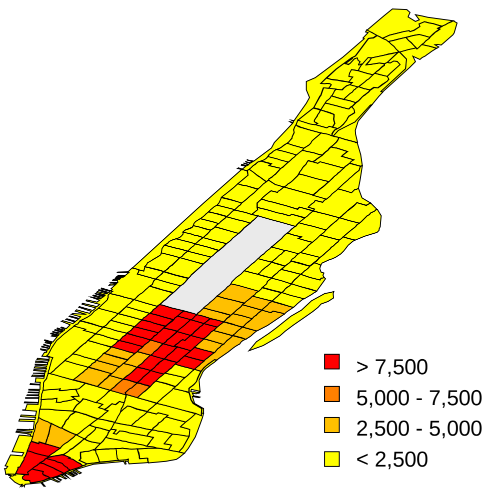


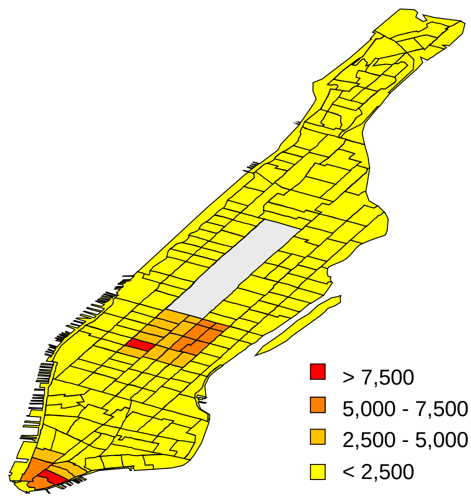
Figure 3.1-2: AM Origins of Trips to the East Side Zones
Source: MTA 1996

Examining the specific journey to work characteristics of each East Side Zone (Map 3.1-13 to 3.1-15), it is clear that all three zones have very similar destination patterns. Not surprisingly, Lower Manhattan and Midtown are dominant destination areas. Therefore many East Side Zone residents must make "L-shape" trips to get to their workplace.

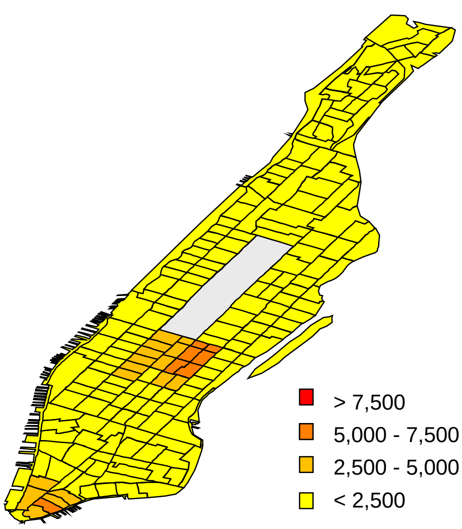
Map 3.2-13: Upper East Side Zone
Trips to Work per Square Mile



Map 3.2-14: East Midtown Zone
Trips to Work per Square Mile



Map 3.2-15: Lower East Side Zone
Trips to Work per Square Mile



based on MTA 1996 data

3.1.2.2 Transportation and Traffic

In this section, major transportation and traffic elements of the Study Corridor are described. Also included is a more detailed analysis of the M 15 Bus Service and the Lexington Avenue Subway as well as motor vehicle traffic along First and Second Avenue.

Map 3.1-16: MTA Buses in Manhattan

Bus Service

Bus service in the Study Corridor can be grouped into three general types. First, north/southbound bus lines along the avenues; second, crosstown bus service and third, a mixture of both used to serve the East Village and Lower East Side. All avenues in the Study area, and most avenues elsewhere in Manhattan, are served by at least one bus line.

The most important bus service in the study area is the M15. This bus route follows Second Avenue southbound and First Avenue northbound from Houston Street to 125th Street. Running from South Ferry at the southern end of Manhattan, the M15 bus route serves Lower Manhattan, Chinatown, the Lower East Side.

Ridership Pattern

As part of the Hub-Bound Travel Survey, which is released every year by the New York Metropolitan Transportation Council (NYMTC), hourly data about ridership and transit service entering or leaving the Hub is provided for the 60th Street Screenline.

Highest hourly volume of the M15 bus at 60th Street is registered from 9 to 10 AM, with more than 1,500 passengers per hour per direction (pphpd) for the southbound bus and between 6 and 7 PM, with about 1,000 pphpd for northbound service (Figure 3.1-3). Both, north and southbound service have a morning and evening peak hour. This indicates the existence of a substantial number of workplaces north of 60th Streets in addition to the majority which are located in the CBD south of this corridor.

As Figure 3.1-4 shows, the southbound M15 bus gets more and more crowded to 72nd Street and stays very busy to 14th Street, where many passengers leave the bus. The maximum southbound volume occurs around 54th street with around 11,000 daily riders. The northbound service (Figure 3.1-5) has a similar pattern. Although maximum ridership occurs further south, between 23rd and 34th Street and is somewhat less in volume, it is still above 10,000 riders a day at one location. The average trip length on the M15 bus is 13 stops, or about 35 blocks (1.7 miles or 2.8 km).

Figure 3.1-3: Hourly ridership volume on the M15 Bus at 60th Street
Source: Hub-Bound Travel 1996

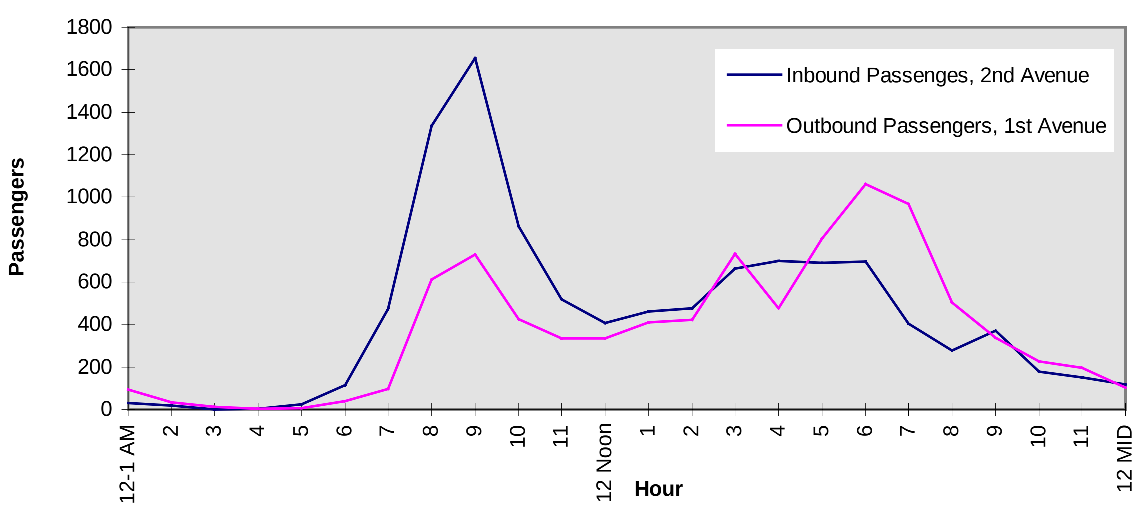


Figure 3.1-4: M15 Southbound - Weekday 24 hour Ridership 1998
Source: NYCT

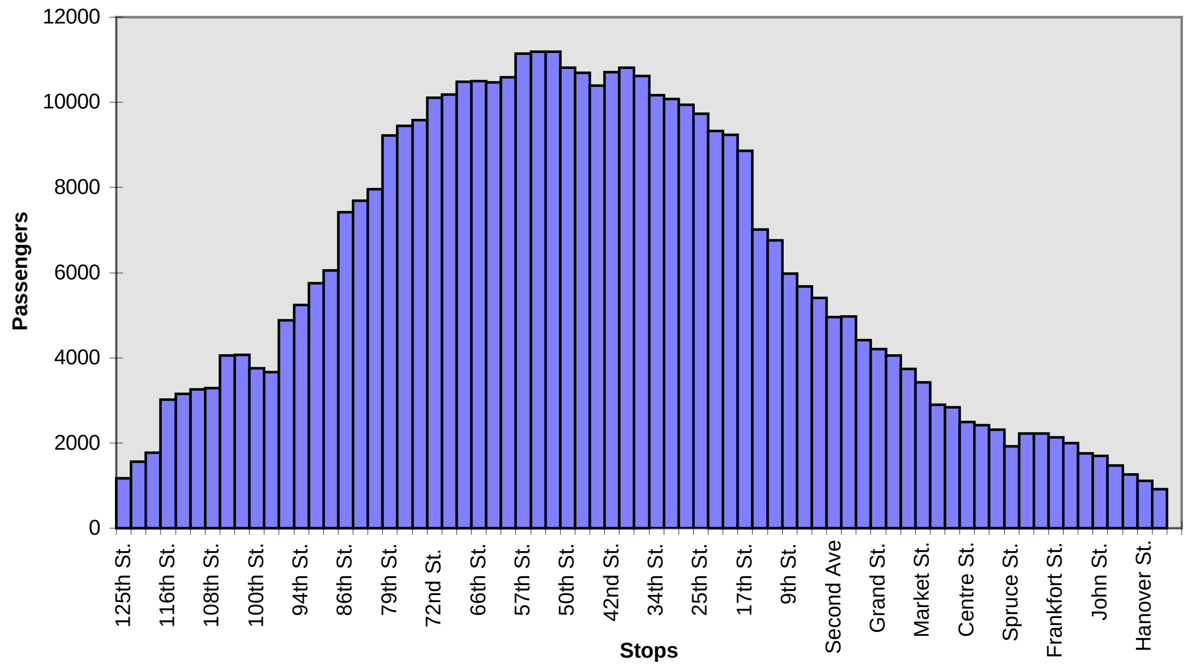
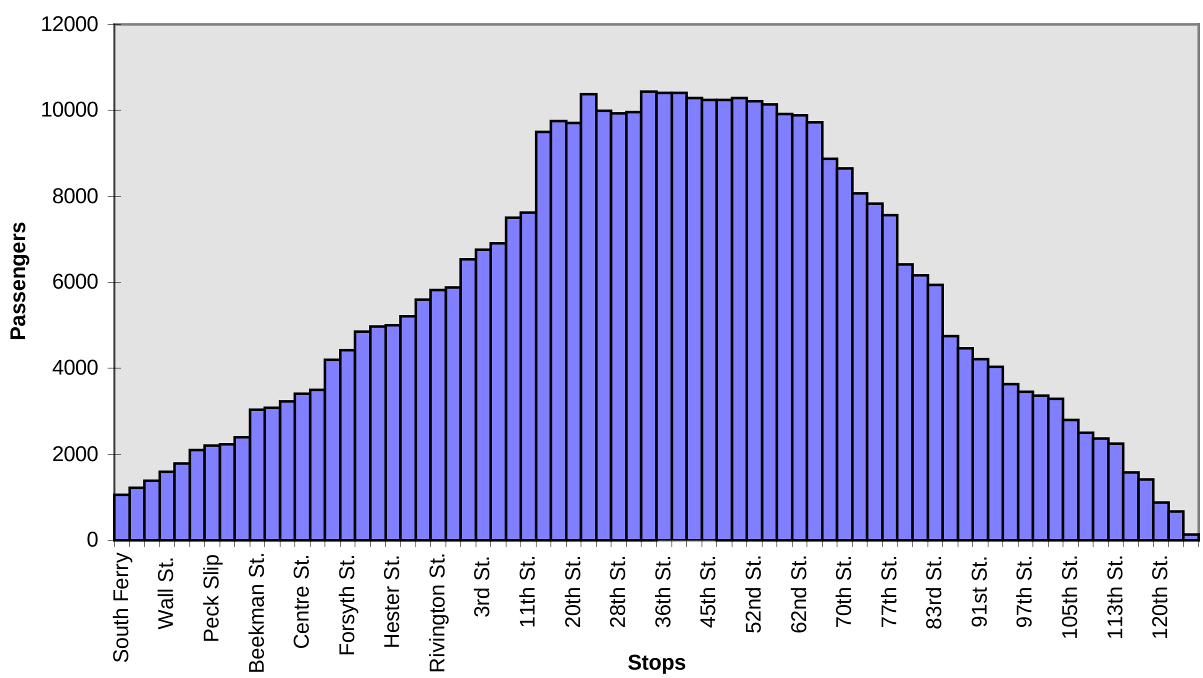


Figure 3.1-5: M15 Northbound - Weekday 24 hour Ridership 1998
Source: NYCT



The Lexington Avenue IRT

Map 3.1-17: Subway Lines in Manhattan

Although the Study Corridor is served by 21 different subway lines out of NYC's 25 lines, there is an undersupply of subway service. The most important line is the Lexington Avenue IRT; all other lines have only one or two stations in the Study Corridor. A concentration of subway stations exists between 42nd and 63rd Street as well as in Lower Manhattan. This leaves large areas in the East Village, East Midtown and the Upper East Side without any close subway station (Map 3.1-17).

The Lexington Avenue IRT (No 4, 5 and 6 train), running north/southbound along the western boundary of the study corridor, is the only subway which serves the entire East Side of Manhattan. North of Grand Central Terminal this subway line runs under Lexington Avenue; between GCT and Union Square under Park Avenue; and south of Union Square under Fourth Avenue to Astor Place where it continues south along Lafayette. Through the core of Lower Manhattan the line follows Broadway.

Sharing the same route through Manhattan, the express trains No 4 and 5 run from The Bronx via Manhattan to Brooklyn, while the No 6 Lexington Avenue train terminates at Brooklyn Bridge/City Hall station at the northern end of Lower Manhattan. Serving different areas in The Bronx all three trains come together at the lines most northern subway station in Manhattan, 125th Street Station. The No 4 and 5 trains leave Manhattan at its South End, Bowling Green Station, and serve two different areas in Brooklyn.

Altogether 10 express stops are located in Manhattan, served by all three trains. An additional 14 local stops of the No 6 train supplement this service.

Service Characteristics

During the AM peak hour period, the average observed arrival headways at Grand Central Terminal for the express trains No 4 and 5 are 2.8 minutes northbound and 2.7 minutes southbound. For the same period of time, the headway for the local train No 6 is 3.5 minutes northbound and 3.2 minutes southbound.

Ridership Characteristics

Corresponding to the bus data, hourly ridership volumes are provided for the 60th Street Screenline. Southbound service peaks between 8 and 9 AM with more than 60.000 pphpd on all three subway lines (one express one local track). About 40,000 pphpd are counted for the northbound peak between 6 and 7 PM. Comparing ridership on the Lexington Avenue Subway and the M15 Bus, Figure 3.1-6 and 3.1-7 show that the subway is clearly the dominate mode in the Study Corridor. All local buses on the East Side serve less ridership than this subway line. For southbound service, both the bus and the subway show two peaks, though the AM peak is much higher. Two peaks are also registered for northbound transit. The higher PM northbound peak is more modest then the AM peak southbound. Besides the expected commuting trips into the CBD, there is a considerable amount of travel to workplaces north of 60th Street.

Figure 3.1-8 gives an overview of turnstile activity at the Lexington Avenue subway stations in Manhattan. By far the busiest station is Grand Central Terminal with more than 115,000 passengers a day. Like most other extremely busy stations, GCT is served by several subway lines as well. Therefore not all of the registered passengers actually ride the Lexington Avenue IRT. Still, 86th Street station, with Lexington Avenue subway service only, has almost 50,000 passengers a day. This extremely busy station is an indicator of the undersupply of rapid transit on the Upper East Side.

In contrast to the M15 bus, the subway provides service between origins and destinations outside of Manhattan as well. Table 3.1-1 shows the top twenty origin and destination pairs for the Lexington Avenue subway. Origins and Destinations outside of Manhattan are summarized for the Boroughs of Brooklyn, Queens and the Bronx. Specific areas in the Study Corridor, such as Lower Manhattan, the Lower East Side, East Midtown and the Upper East Side are highlighted. Additionally, one Manhattan zone outside the Study Corridor was added, the West Midtown Zone.

Out of about 415,000 AM peak period trips (7 AM to 10 AM), more than 40,000 trips (10%) are between Brooklyn and East Midtown. More than 50% of all AM peak period trips are from outside of Manhattan to the Study Corridor, and about 15% of all trips occur within the Study Corridor.

Trips in the PM peak period are more diverse. The number one trip generator is East Midtown to the Bronx with more than 20,000 trips (6%) out of about 360,000 total PM peak period trips. About 30% of all trips are from the Study Corridor to a destination outside of Manhattan and 25% are trips inside the Corridor.

Figure 3.1-6: Southbound at 60th Street - Passengers on the Lex Ave Subway and the M15 Bus   Source: Hub-Bound Travel 1996

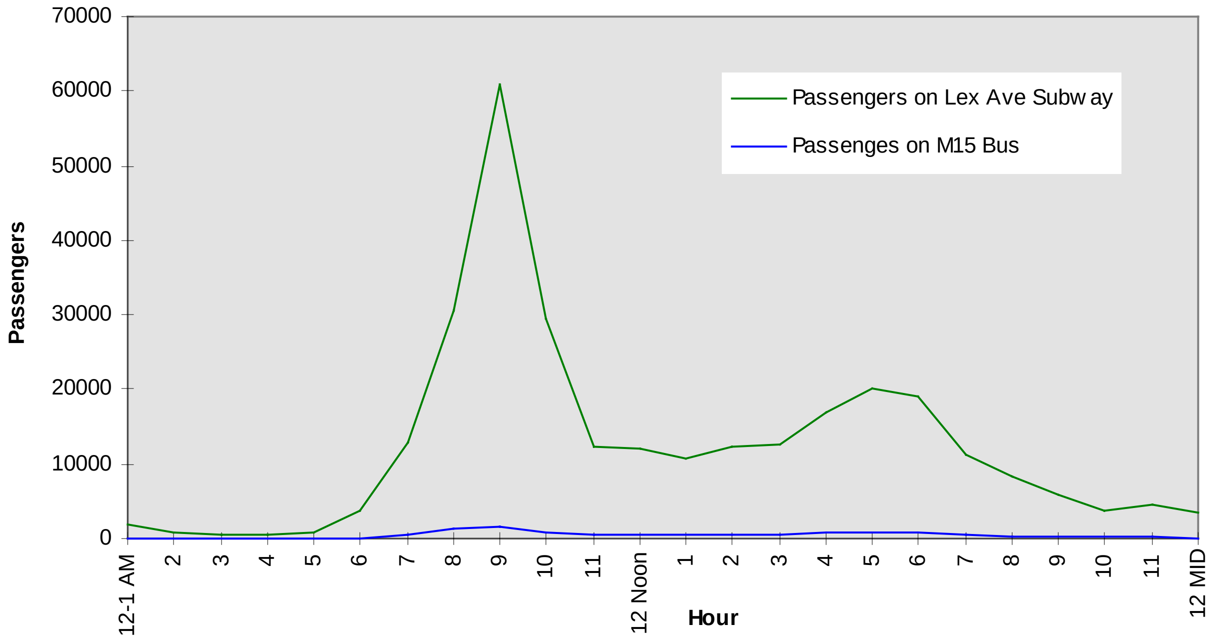


Figure 3.1-7: Northbound at 60th Street - Passengers on the Lex Ave Subway and the M15 Bus   Source: Hub-Bound Travel 1996

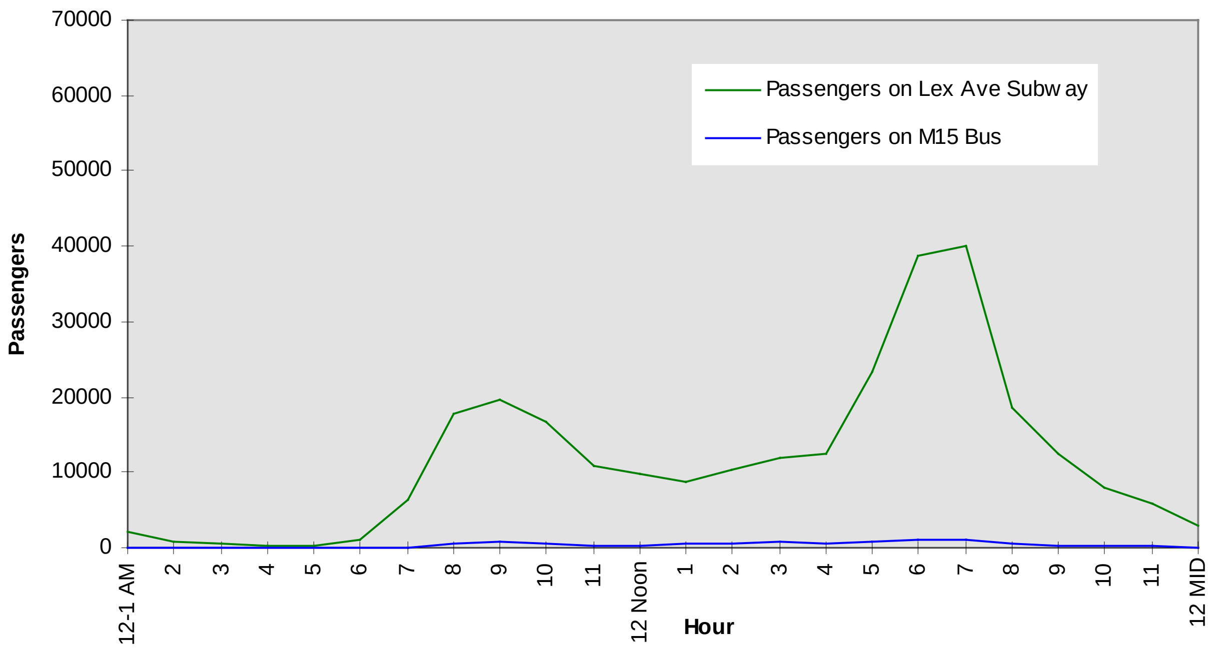


Figure 3.1-8: Southbound Lexington Avenue Subway, 24-Hours Turnstile Registration 1996

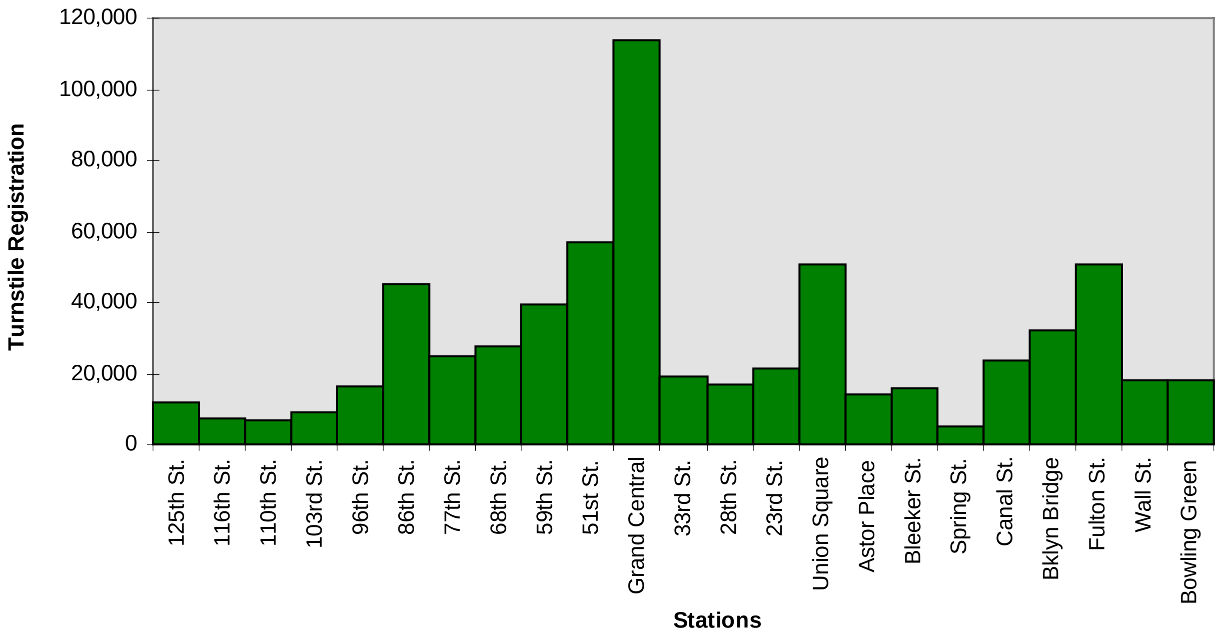


Table 3.1-1: Top Twenty Origin and Destination Pairs:
Lexington Avenue Nos. 4, 5, and 6 Trains*
Source: NYCT 1990 Subway Survey

AM PEAK PERIOD, 7AM - 10AM					PM PEAK PERIOD, 4PM - 7PM				
Rank	**Trip Origin**	**Trip Destination**	**No. of Trips**	**% of Total Trips**	**Rank**	**Trip Origin**	**Trip Destination**	**No. of Trips**	**% of Total Trips**
1	Brooklyn	East Midtown	40,792	10%	1	East Midtown	Bronx	20,274	6%
2	Bronx	East Midtown	33,298	8%	2	East Midtown	Brooklyn	17,935	5%
3	Brooklyn	Lower Manhattan	24,795	6%	3	Lower Manhattan	East Midtown	15,672	4%
4 [a]	Queens	East Midtown	24,564	6%	4 [b]	East Midtown	Upper East Side	15,612	4%
5	Bronx	Lower Manhattan	18,184	4%	5	Lower Manhattan	Brooklyn	12,787	4%
6 [b]	East Midtown	Lower Manhattan	17,531	4%	6	Lower Manhattan	Bronx	11,461	3%
7 [b]	Upper East Side	East Midtown	14,297	3%	7 [a]	East Midtown	Queens	10,898	3%
8	Queens	Lower Manhattan	12,836	3%	8 [b]	East Midtown	Lower East Side	9,259	3%
9 [a]	Queens	Upper East Side	12,599	3%	9 [b]	East Midtown	East Midtown	8,950	2%
10	Brooklyn	Upper East Side	11,689	3%	10 [b]	Lower East Side	East Midtown	8,436	2%
11	Bronx	Upper East Side	9,736	2%	11	Bronx	Bronx	8,337	2%
12	Bronx	West Midtown	8,880	2%	12	Lower Manhattan	Upper East Side	7,740	2%
13	Brooklyn	Brooklyn	8,265	2%	13	Upper East Side	Brooklyn	7,568	2%
14 [a]	Brooklyn	Lower East Side	8,100	2%	14	Brooklyn	East Midtown	7,559	2%
15	Bronx	Lower East Side	7,681	2%	15 [a]	Upper East Side	Queens	7,456	2%
16	Bronx	Bronx	7,206	2%	16 [b]	Upper East Side	East Midtown	6,836	2%
17	Upper East Side	Lower Manhattan	7,155	2%	17 [b]	East Midtown	Lower Manhattan	6,564	2%
18 [b]	Lower East Side	East Midtown	6,900	2%	18	Brooklyn	Brooklyn	6,560	2%
19 [b]	East Midtown	East Midtown	6,761	2%	19	Upper East Side	Bronx	6,405	2%
20	Lower Manhattan	East Midtown	6,123	1%	20	West Midtown	Bronx	6,336	2%
Total (Top 20 Trips)			287,392	70%	Total (Top 20 Trips)			202,645	56%
Total (All Trips)**			413,416	**	Total (All Trips)**			361,409	**

*Table includes all trips that used the Nos. 4, 5, or 6 trains for any portion of the trip. The origin location refers to the area in which the trip maker entered the subway system. The destination location refers to the area in which the trip maker exited the subway system.
** Individual percentages may not add to total because of rounding.
a and b: References from Chapter 4.5

Vehicular Traffic

A major traffic element of the Study Corridor, and of most interest for the purpose of this study, is the First and Second Avenue street pair. First Avenue is one-way northbound with seven lanes, five for moving traffic. Second Avenue has the same width between 23rd and 62nd Street. Otherwise it has only six lanes, four for moving traffic. Both Avenues start at 128th Street just off the Harlem River Drive and end on the Lower East Side at Houston Street (Map in Appendix B).

Traffic Volumes

Traffic Volumes in the Study Corridor have been fairly constant for the last 15 years (MTA 1999). Therefore it was possible to use traffic volume data in this study which was obtained from several sources, such as the Bear Stearns DEIS (1997), the 42nd Street LRT Line FEIS (1994), the New York Hospital FEIS (1993) as well as from the NYCDOT East Side Transit Study (1986).

During the AM peak period, southbound traffic volumes on Second Avenue typically first decrease from 2,500 vehicles per hour (vph) at 125th Street to about 1,700 vph at 77th Street. Then traffic increases in the Upper East Side to a maximum of just over 3,500 vph near the Queensboro Bridge, decreasing again to 1,300 vph toward 18th Street and only about 1,000 vph in the East Village. Whereas traffic volume patterns during the PM peak period are nearly identical to those in the AM peak south of 23rd Street, a decrease of 30% is registered for most of the length of Second Avenue.

First Avenue generally experiences similar traffic volumes. During the AM peak period, volumes on First Avenue south of 14th Street average less than 1,200 vph. North of 23rd Street volumes exceed 2,000 vph, reach their morning peak just above 60th Street with about 2,700 vph near the Queensboro Bridge, and then decrease to the 1,000-1,800 vph range farther north. PM volumes peak during the late afternoon as outbound flows intensify. North of 14th Street, traffic volumes range from 2,000-2,700 vph, and increase further to greater than 3,000 vph near the Queensboro Bridge. Volumes then decrease slightly on the Upper East Side to the 1,500-2,300 vph range with increasing volumes up to the Triborobridge area at 125th Street.

Traffic on both avenues comprises 40% to 60% private autos, 20% to 35% taxis, 20% trucks and about 3% buses.[1]

Figure 3.1-9: Traffic Volumes on Second Avenue

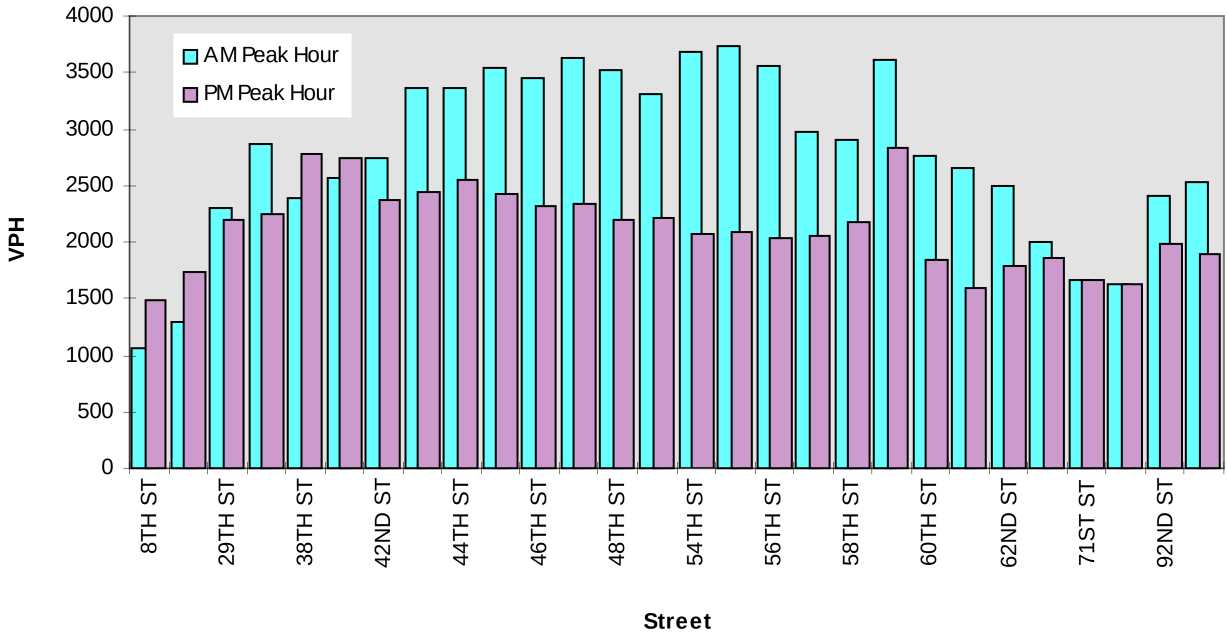
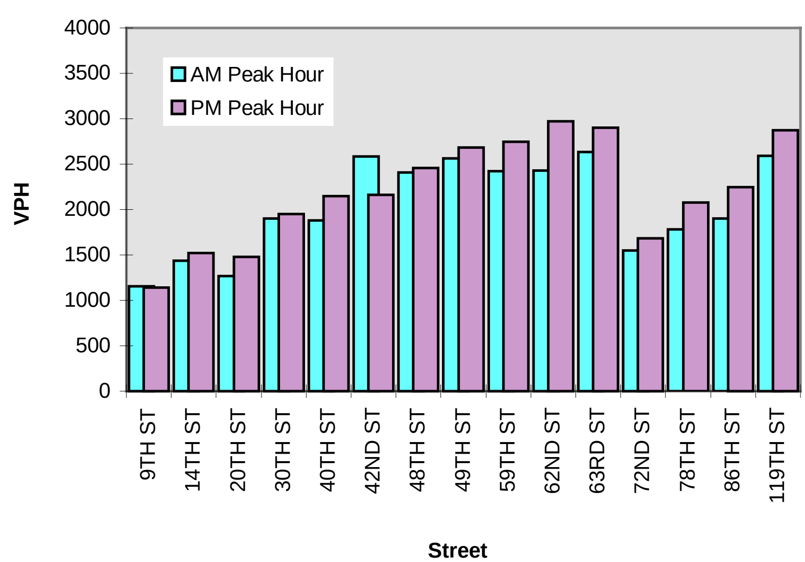


Figure 3.1-10: Traffic Volumes on First Avenue



[1] NYCDOT, 1986, p. S-4

3.2 Existing Problems

The problems and impacts of mobility facing the East Side of Manhattan can be attributed to two causes. First inadequate transit service and second, extremely high traffic volumes. These two causes and their resulting adverse effects are specified and described in this section of the study.

3.2.1 Inadequate Transit Service on Manhattan's East Side

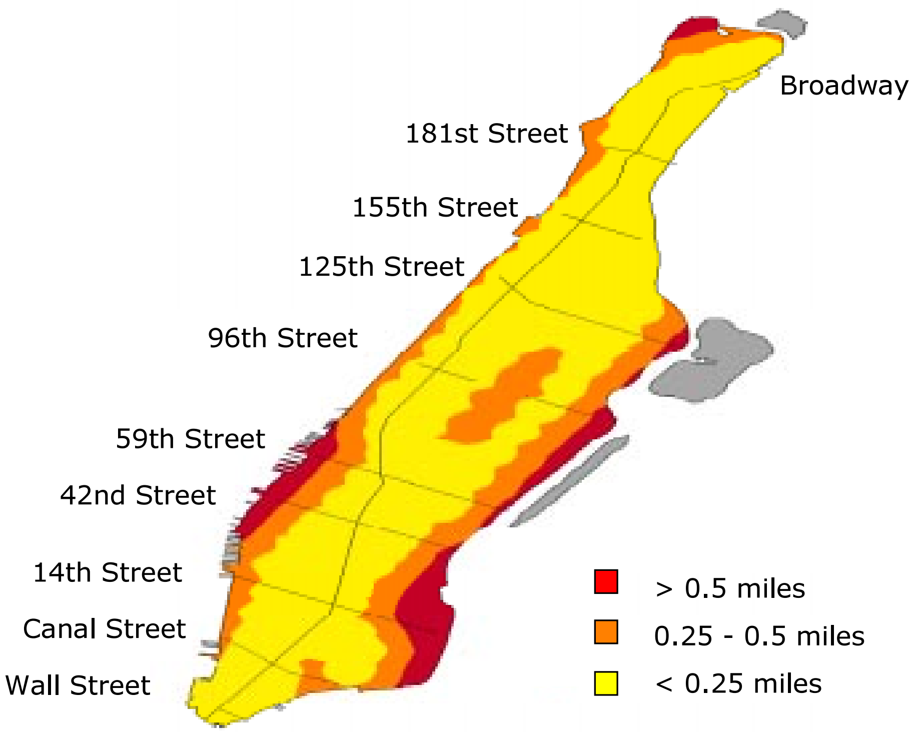
The major public transit problem of Manhattan's East Side is the lack of high-quality transit service. After the demolition of the last section of the elevated line on Second Avenue in the 1942, the often promised subway as a substitute was never built. Still anticipating the new Second Avenue subway line, much of the East Side was zoned for high-rise development. In relation to the proposed subway, the buildings were built and resulted an even greater need for a new line.

As Map 3.2-1 shows, walking distances from high density areas of the East Side of more than ½ mile to the nearest station of a north/southbound subway line are common and residents often require feeder bus service to reach the subway. Particularly, residents south of 14th Street in the East Village and Lower East Side are beyond a reasonable walk to a subway station. The ongoing revitalization and gentrification of these neighborhoods will increasingly require better connections to the rapid transit system.

Undoubtedly, in the last few years, NYC's subway system became cleaner, safer and reliable and many stations have been restored in an attractive way. But still, riding the subway is perceived as one of the more unpleasant parts of life in NYC, mainly because of the system's age: the subway is very noisy, access is provided only by small stairways, elevators and escalators were rarely added, no wheelchair access exists at most stations and stations are extremely hot in summer.

Surface transit exclusively by buses, does not provide an adequate feeder and distribution to and from subway stations. Service is extremely slow due to intensive roadway traffic and the vehicles are old fashioned high-floor, noisy, diesel powered buses.

Map 3.2-1: Distance to the nearest station of a north/southbound subway line



⇒ ***Problem No. 1 - Overcrowded Lexington Avenue Subway***

The capacity problems of New York's subway system are not surprising, if one takes into account that no new lines have been built since 1940 when the Sixth Avenue Subway was completed. In addition, the current subway system, as now configured, does not correspond in a satisfying way to the travel origins and destinations of many riders. Developments, such as Midtown becoming a major office center, a fully developed Queens and neighborhood revitalization that has resulted in the construction of hundreds of high-rise residential towers at the Upper East Side of Manhattan, have not led to changes in New York's subway system.

Additionally, since New York's subway system has become increasingly popular and therefore more used, crowded subway cars and stations became equally more prevalent. As a consequence, the Metropolitan Transportation Authority (MTA) stated that "the subway system has become the victim of it's own success."[1]

The Lexington Avenue IRT (4, 5, and 6 trains) is now the subway line with the highest ridership and with the most problems in terms of overcrowding. Compared with the BMT System (N and R trains), which serves the same general area south of Central Park, the Lexington Avenue IRT carries almost 2/3 more passengers south of 23rd Street.

This is obviously a result of the fact that the Lexington Avenue Line is the first east side transit line encountered when travelling west from the huge residential areas located principally east of Third Avenue in Manhattan.[2] Furthermore it is expected that the proposed connection of the LIRR to Grand Central Terminal will add 19,000 daily riders to the already congested Lexington Avenue subways.

Overcrowding of the Lexington IRT mostly occurs during the AM and PM peak periods. During this period, 85% of the southbound 4 and 5 express trains are filled over MTA capacity guidelines at Grand Central Terminal, while just over 15% of local 6 train cars are over capacity.[3] Overcrowded trains not only result an inconvenient ride, it also provides a higher risk of passenger/subway accidents at subway stations and cause delays with train queuing and bunching.

⇒ ***Problem No 2 - Long Walk to Subway***

Most east side residents face long walks when they want to reach the rapid transit system. The required crosstown trips to reach the Lexington Ave Subway are not sufficiently well served by buses. Often taxis substitute for transit service in many places, particularly in higher income areas of the Upper East Side.

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[1] Zupan/Weber, 1999, p. 1

[2] NYCT, 1995a, p. 9

[3] NYCT, 1995a, p. 10

⇒ Problem No 3 - Slow, Overcrowded and Unreliable Bus Service

The undersupply of transit on the East Side also results in crowded peak hour buses. North-south bus routes are especially crowded with many standees, even though service is very frequent. Because of street level congestion during peak periods, bus speeds are very slow. During the peak, average north-south bus speeds are between 5 to 7 mph. Generally, bus running times in New York increase on average by 24% in peak hours and up to 85% on some routes with specific traffic problems.[4] Additionally, bus bunching during the peak hours with a 2 minute headway results in service gaps of the M 15.[5]

⇒ Problem No 4 - Inconvenient Interfaces, Limited Mobility for the Disabled, Unpleasant Atmosphere, and lack of travel enjoyment

Subway/bus interfaces in the Study Area are badly planned. Exiting from a subway station, it is often difficult to find and reach the closest bus stop. Stops often disappear in crowded sidewalks.

Limited attention has been given to rebuilding New York's old subway stations for wheelchair accessibility in near term due to extremely high cost. Therefore, efforts to improve the use of public transit for the disabled is concentrated on bus service. Although all MTA buses have been equipped with wheelchair lifts allowing disabled persons to use public transit, this mobility support for persons in wheelchairs is still not adequate.

Next to being tied to the slowest transit system in NYC, traveling by MTA buses provides several more disadvantages for persons using wheelchairs. Boarding and alighting times are extremely high. To board a wheelchair on New York buses (virtually all of them high-floor), the driver has to go to the back door and operate the wheelchair lift (Picture Appendix A). This 70 second procedure not only extends travel time for all passengers, but makes the person in the wheelchair feel uncomfortable, realizing that everybody in the bus is waiting for his/her boarding. No wonder then that some disabled persons avoid using public transit at all, accepting the reduction of their mobility.[6]

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[4] NYCT, 1994, p. 4

[5] NYCT, 1995a, p. 10

[6] Miriam Fisher, 04/10/99

In NYC, intrinsic travel components, such as enjoying the ride, are not often considered. Though seating in buses was modified to improve window views for passengers, the seats are now closer together allowing less room for the rider. To provide fast, reliable and convenient surface transit where passengers are able to enjoy the attractiveness of Manhattan's streets, and feel as if they were outside on their way to work, is a promising first step to a more livable city.

3.2.2 High Traffic Volumes

Although most Manhattan residents do not use private cars to get around, many of their streets are congested and blocked. Besides, 10% to 20% which are trucks, the majority of private vehicles comes from other parts of the Metropolitan Area like Long Island or New Jersey. Currently more than one million vehicles enter Manhattan per day.[7]

Therefore East River crossings result in major traffic congestion in the Study Area. The following locations experience congestion throughout the day:

- The Queensboro Bridge (QBB) produces congestion on Second Avenue for up to 12 blocks. To a lesser extent, First and York Avenue are similar affected.
- The Queens-Midtown Tunnel (QMT) vicinity including Second and Third Avenue as well as 34th and 36th Streets are troublesome areas.
- The vicinity of the East River bridges in Lower Manhattan and the Lower East Side (i.e., the Brooklyn, Manhattan, and Williamsburg Bridges), particularly Chambers Street and Delancey Street are chronically congested.

Furthermore, Canal Street connecting the Manhattan Bridge with the Holland Tunnel, often experiences gridlock conditions throughout the day.

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[7] NYCT, 1999, p. 9f-2

As distinct from gridlock locations at bridges and tunnels, high traffic volume combined with high pedestrian activity contributes to the congestion along most avenues and major cross streets throughout the Study Area.

This congestion is not only caused by substantial vehicular volumes, but also because of the occurrence of double-parking and the heavy pedestrian traffic at many locations. [8] Additionally, the high volumes of taxis, frequently loading and discharging passenger on the street, contribute to this condition. However, for existing chaotic taxi behavior on these streets, Manhattanittes have only themselves to blame.

⇒ *Problem No 5 - High Pollution*

Although air quality conditions in New York City are improving, levels of carbon monoxide and particulate matter are still worrisome and ozone levels are unacceptable. Therefore, the New York Metropolitan Region is still unable to achieve National Ambient Air Quality Standards. Congested traffic on the streets and highways, as well as general high traffic volumes, contribute significantly to reduced air quality. In New York City, for example 80 to 90 percent of CO emissions are from motor vehicles.[9]

⇒ *Problem No 6 - Traffic related delays to transit service*

Vehicular congestion in the study area is a major reason for slow and unreliable bus service. Buses caught in traffic are especially frustrating to their passengers, who do not cause the traffic jams that affect them so directly. Furthermore, most existing bus lanes are not adequately enforced to insure fast service even along these stretches.

[8] NYCT, 1995a, p. 10

[9] NYCT, 1999, p. 10-1

⇒ *Problem No 7 - Delays for important traffic*

North-south vehicular travel speeds on First and Second Avenue vary from 10 to 12 mph, which is faster than those experienced on Fifth, Park and Madison Avenue which range from 6 to 8 mph.[10] But still gridlock at several locations along the East Side delay important traffic such as emergency vehicles, express deliveries and other time critical transportation.

⇒ *Problem No 8 - Reduced Safety*

Besides a general high risk of vehicle to vehicle accidents due to extensive traffic volumes in the Study Area, heavy traffic is especially dangerous for pedestrians and bicyclists. Agitated drivers are less careful, and pedestrians and bicyclists tend to respond to congestion by ignoring signals.

⇒ *Problem No 9 - Less space for walking and biking*

Finally, high traffic volumes often diminish to pedestrian and bicyclist space and amenities as vehicles block pedestrian crossings and bike lanes, and gravitate to less congested side streets.

[10] NYCT, 1995b, p. I-9

3.3 Solutions

In this chapter, the basic objectives of transit improvements for the Study Area are formulated. Subsequently, two existing proposals for improvements are briefly presented.

3.3.1 Objectives

Objectives were summarized in three categories: traffic and transportation, economy and environment.

Traffic and Transportation

Objectives for transportation are primarily efforts to decrease journey time of transit passengers. Therefore travel time, access time and reliability of transit services have to be improved. Intermodal interfaces, such as those between walking, biking and riding transit as well as compatibility to existing transit proposals for New York City have to be taken into consideration.

Furthermore, the quality of transit service has to be improved. This includes particularly strategies to eliminate overcrowding on the Lexington Avenue Subway and to provide more popular surface transit. Accessibility for disabled persons, maximum personal security and comfort as well as transit that provides riding enjoyment are other important components of a successful system.

The goal is to shift riders from private cars and taxis to transit or non-motorized modes. Drivers should be attracted by new transit service and discouraged from continuing to drive by further vehicular restrictions in the Study Area. Correspondingly, traffic congestion should be reduced and enough roadway capacity should remain for essential traffic. Finally transit and traffic safety should be maximized.

Economy

Next to a general contribution to economic development in NYC, new transit service along the east side is intended to specifically support local businesses in the Study Area.

The reduction in the overall cost of transportation, including external cost, thereby encouraging discretionary travel by transit, is another important objective.

Finally, economic feasibility and maximum operating and capital cost effectiveness should be ascertained in order to increase the likelihood of construction.

Environment

Proposed strategies should reduce both air pollution and energy consumption. Furthermore, it is intended that changes to the transit system provide a more livable city including more space for pedestrians and bicyclists as well as lessening noise impacts. The proposed transit system should create an aesthetically pleasing environment and maintain and/or improve community and neighborhood character.

Figure 3.3-1: Goals and Objectives

A. Traffic and Transportation
  - Decrease journey time of transit passengers
  - Improve quality of transit service
  - Reduce private vehicle use

B. Economy
  - Support economic development
  - Reduce cost of transportation
  - Encourage discretionary travel by transit
  - Increase possibility of construction

C. Environment
  - Reduce air pollution
  - Reduce energy consumption
  - Provide a more livable city

3.3.2 Proposed Alternatives

Most recently, two major proposals have been released: MTA's MESA Study and RPA's Metrolink.

The Manhattan East Side Alternatives Study

From 1995 to 1997, the Metropolitan Transportation Authority (MTA) and its subsidiary, New York City Transit (NYCT), carried out a study, analyzing different improvement possibilities for Manhattan's east side. With this study the MTA addressed problems stemming from 50 years of poor transit service in the area. This $4.5 million "Manhattan East Side Transit Alternatives" (MESA) Study was not only an analysis of transportation alternatives, but also a Major Investment Study (MIS) including a Draft Environmental Impact Statement (DEIS) as the end product. The DEIS will describe the Locally Preferred Alternative (LPA) as proposed in the region's Long Range Plan. [1]

MESA looked at a study area that included almost all of Lower Manhattan, the entire east side of Manhattan (east of 5th Avenue) and a small southern part of The Bronx. For this area, a selection of alternatives for transit improvement was carried out.[2] After a compilation of a multiplicity of alternatives and their public presentation, only three alternatives in addition to the "No Built" option were proposed. An initial LRT alternative along First or Second Avenue failed to be further developed due to opposition of Upper East Side residents who were concerned about traffic diversion in those thoroughfares.[3]

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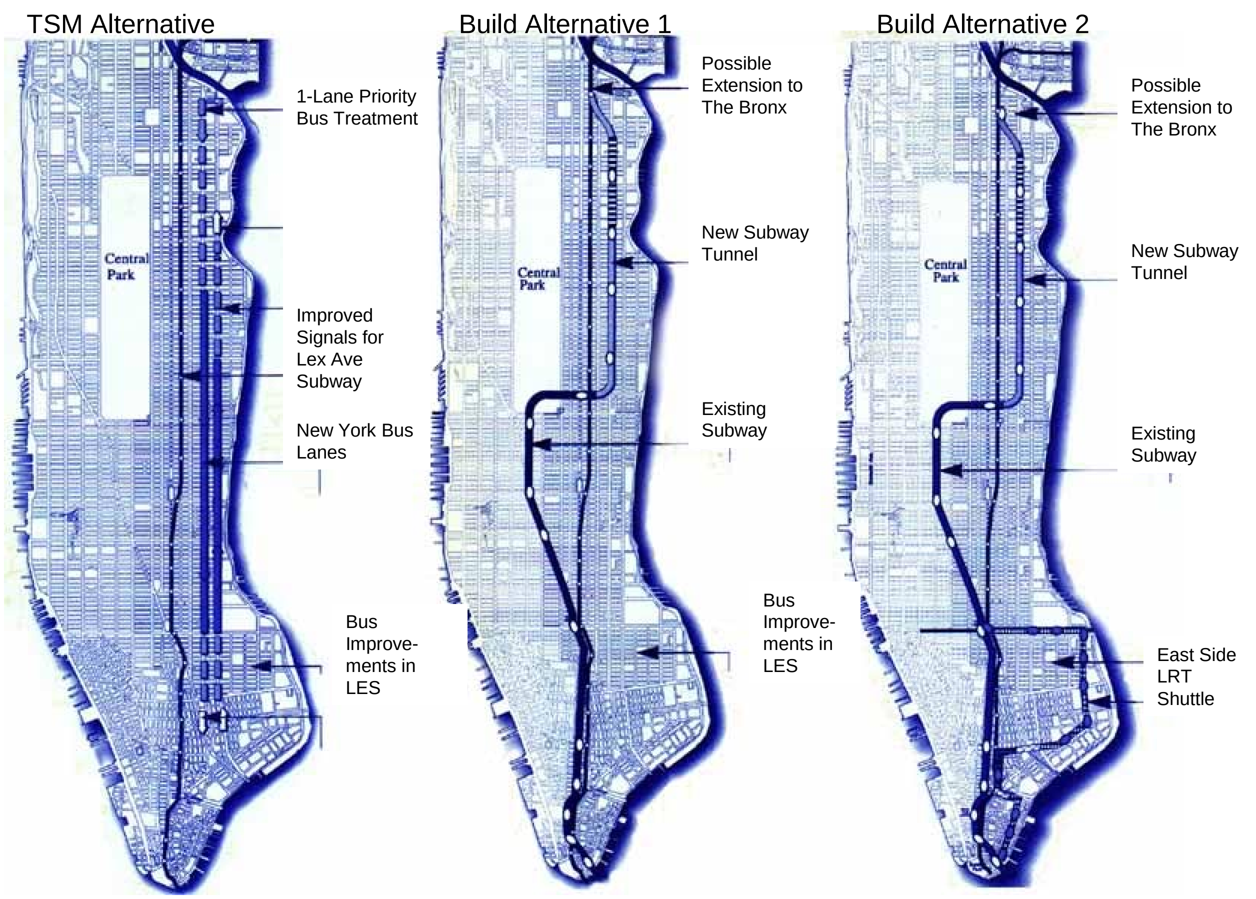
[1] NYCT, 1995a, p. 2

[2] NYCT, 1995a, p. 3

[3] Interview Cafiero, 3/24/99

Map 3.3-1: The MESA Alternatives



The TSM Alternative

The TSM Alternative contains three major transit elements: Lexington Avenue IRT subway line station "dwell time" improvements; the implementation of bus priority lanes, called "New York Bus Lanes", on First and Second Avenues between Houston and 96th Streets; and, for the Lower East Side streets which are narrow and often do not follow the traditional north-south grid—a series of new bus routes and route modifications.

Build Alternative 1

Beyond the transit improvements of the TSM Alternative, this alternative proposed a new subway beneath Second Avenue north of 63rd Street. The Line would run from 125th Street station on the Lexington Avenue via a curved tunnel to approximately 115th Street and Second Avenue. The line would then follow Second Avenue to 63rd Street and turn west in the existing tunnel of the Q (S) line. Service would continue on the BMT express tracks beneath 7th Avenue and Broadway to one of three termini (lower level of City Hall station, Whitehall Street station, or 95th Street station in Brooklyn).

Five all new local stations would serve the new subway, spaced approximately 10 blocks apart. They would be located between 69th and 72nd Streets; between 83rd and 86th Streets; between 95th and just north of 97th Street; between 106th and 109th Streets; and between 124th and 126th Streets.

Build Alternative 2

In addition to the elements contained in Build Alternative 1, LRT service for the Lower East Side and Lower Manhattan were added. The basic alignment of the proposed Lower Manhattan LRT Shuttle is described under Chapter 2.2.2 Existing Plans for New York City.

For this LRT line, a double track alignment was chosen. For most of its route, the LRT would run on non-exclusive tracks, sharing the road with other vehicular traffic. Remaining route segments include the tunnel segment of the route, the portals connecting the tunnel to the at-grade section of the route, and the portion of the alignment along Avenue D.

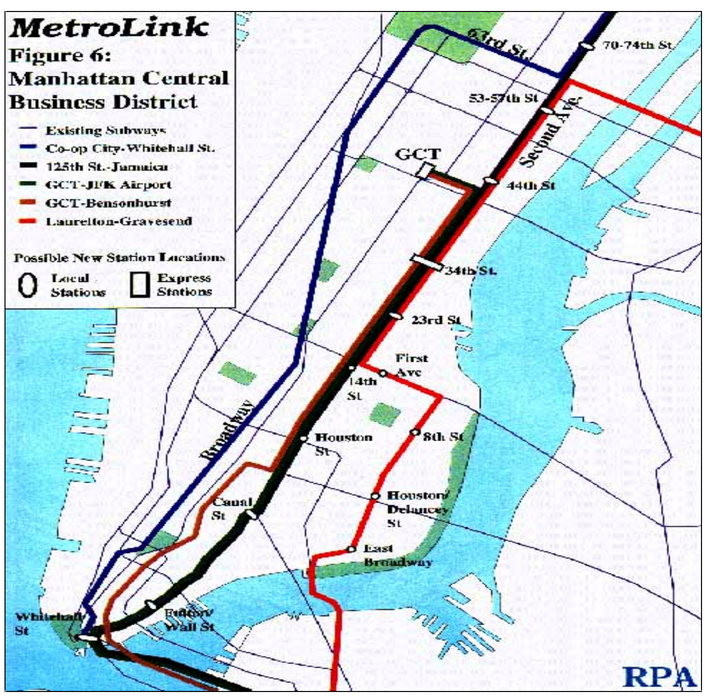
The storage and maintenance facility for the LRT vehicles would be built as an underground facility along the south side of Delancey Street, from Essex Street to just east of Clinton Street.

The Metrolink Proposal

A more comprehensive, but less detailed proposal, to solve the already described transportation problems of New York City and particularly those of Manhattan's East Side is the "Metrolink" plan prepared by the Regional Plan Association which was released in January, 1999.

For Manhattan, RPA calls for building a full length Second Avenue Subway continuing south of 63rd Street with construction of stations at 53rd, 44th, 34th, 23rd, 14th, Houston, Canal, Fulton and Whitehall Street. Another new subway under Avenue C would serve the eastern part of the East Village and the Lower East Side. This four-borough system-wide draft presents this new subway as an important part of a more integrated regional transit plan. Proposed components, were selected on the basis of "combining strategically targeted new construction with better use of under-utilized subway and rail transit facilities in a framework of citywide transportation needs."[4]

Map 3.3-2: Metro Link proposal by the Regional Plan Association



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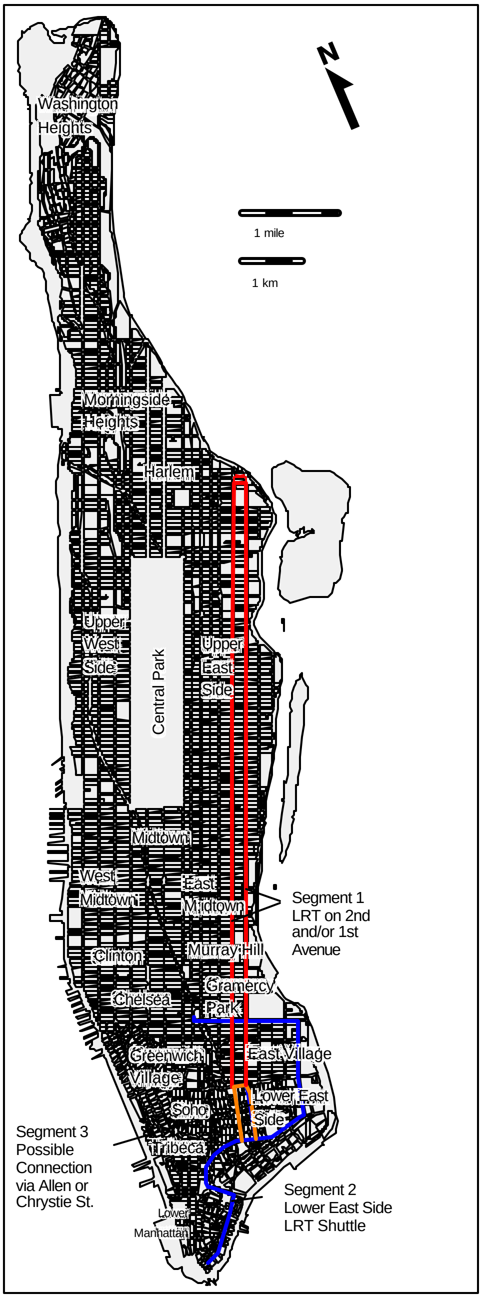
[4] Zupan/Weber, 1999, p. 7

3.4 The East Side LRT Line

Map 3.4-1: Segments of the East Side LRT Line



The key feature of the proposals for additional surface public transit on Manhattan's East Side examined in this study is the implementation of improvements in a north/south direction. Special emphasis is given to better access and transfers to and from existing rapid transit lines that serve the two principal cores of Manhattan's CBD - Midtown and Lower Manhattan. Due to the existing patterns of roadways, the range of alternatives north of 14th Street is limited for practical reasons to variations along First and Second Avenue, the only continuous Avenues through the center of the Study Area. Since Manhattan's geography extends to the east between Canal and 14th Street, and an irregular older street grid exists south of Houston Street, planners are confronted with an increased need for crosstown routings and numerous alignments are possible.

Building on MTA´s innovative proposal for a Lower East Side LRT Shuttle (see Chapter 3.3, Segment 2 in Map 3.4-1), an East Side LRT Line would represent an extension northward to 125th Street in Harlem, along the same alignment where the MTA proposal offers dedicated bus lanes (Segment 1). The obvious advantage of this LRT extension would be the implementation of a single homogeneous transit system that serves the entire East Side instead of the three different modes proposed in MTA's MESA study.

Chapter 3.4 - The East Side LRT Line

This research study concentrates on LRT concepts for Segment 1 of the East Side LRT Line on First and Second Avenue. Specific alignments for the connection to the East Side LRT Shuttle (Segment 3) and their variations along Allen or Chrystie Street are not addressed and analyzed. Furthermore, variations on MTA's Lower East Side LRT Shuttle are possible. In particular, the costly connections to the Chambers Street subway station could be avoided if an all-surface alignment serving Chinatown were selected. Consequently, the LRT running time calculations provided for the area south of Houston Street are rough estimates.

Table 3.4-1: East Side LRT Line, Length of Segments

East Side LRT Segments	Length in Miles	Length in km
Segment 1: Houston Street - 125th Street	6.2	10.0
Segment 2: Lower East Side LRT Shuttle	4.6	7.4
Segment 3: Canal to Houston Street via Allen or Chrystie St.	0.6	1.0
The East Side LRT Corridor: Southern part of Segment 2 to Canal Street, Segment 3 and Segment 1 to 125th Street	8.6	13.8

Light Rail Vehicles for Manhattan's East Side

The East Side LRT Line represents a completely new system in an urban application with speeds below 30 mph (50 km/h) which does not operate with heavy LRVs (buff strength requirements) or existing high platform stations. Therefore the opportunity to introduce state-of-the-art 100% Low Floor LRVs to North America should be considered. Without endorsing a specific product, technical specifications of Adtranz (DaimlerChrysler Rail Systems) latest vehicle, the "Incentro Type AT 8/7 L" LRT were chosen for this case study to represent a typical modern 100 % Low Floor LRV.

With a length of 166 feet (50.6 m) and a width of 8.7 feet (2.65 m), a single articulated vehicle provides 126 seats and up to 352 standees for a maximum capacity of 478 passengers. Altogether eight entrances ensure rapid discharging and boarding of passengers and help to reduce station dwell times.

Car floor height at entrances is 350 mm (13.8 inches) permitting convenient wheelchair access. To reduce vehicle costs, uni-directional vehicles can be used. With a minimal turning radius of 15 m (46 feet), these vehicles can be operated at any street in the Study Area that is selected for LRT turnback tracks. Alternatively, bi-directional vehicles can be used reducing track construction cost.

Headway and Capacity

A proposed five minute headway in peak hours results in a capacity of 5,736 pphpd (passenger per hour per direction). The maximum possible capacity with a headway of 90 seconds is theoretically as high as 19,120 pphpd. Off-peak, a five minute headway would result in a seated capacity of 1,512 pphpd.

Station design

Stations will require at least a 166 feet (50.6 m) platform to accommodate one LRV. Between Houston and 125th Street, where the uniform Manhattan street grid is in place, each station will require almost an entire block with 206 feet (63 m). This leaves enough sidewalk space (15 feet, 4.6 m) on each side of a block (35.5 feet, 10.8 m) for pedestrians to cross the Avenues in front or behind an LRV stopping at a station or a red traffic signal. Besides high capacities, long LRVs provide faster discharging and boarding times (reducing running times) as well as less walking for passengers.

Platform heights for 100% Low-Floor LRVs of 350 mm are a little higher than a typical curb. While boarding from street level is theoretically possible, this would only be needed for emergencies.

Stop Frequency

Independent from the actual alignment, an optimal stop frequency of the East Side LRT Line is discussed in this subchapter. This information can be used for further refinement of travel time estimates for each alignment alternative.

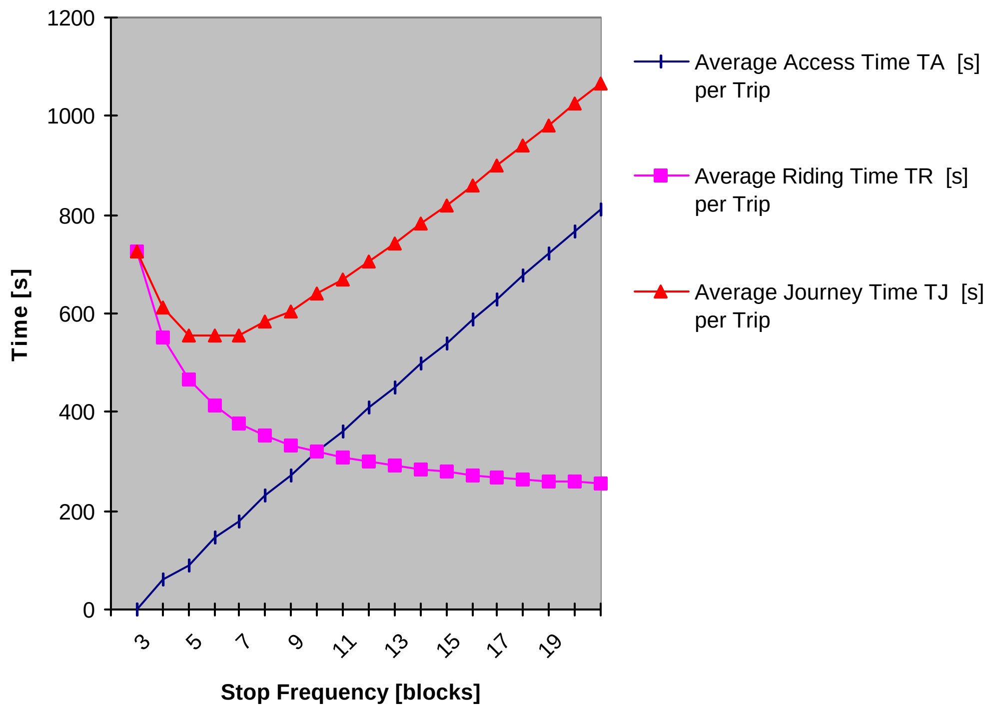
Top priority in establishing a stop frequency for a transit system is the reduction of the average passenger journey time. Journey time composed of three elements: access time to and from the transit system, waiting time at the station and riding time. The waiting time is independent from the stop frequency; it depends only on the service frequency. Therefore, with regard to access time, one has to balance two contradicting objectives: To decrease the access time, additional stops are desired, but this results in a longer riding time.

The regular street grid of Manhattan north of Houston Street allows the description of this contradiction in a simplified model (Appendix C) which offers a theoretical optimization for the journey time. Furthermore, it is important to take into account the subjective (i.e. perceived) journey time, which is generally higher for access time (walking) than for more convenient riding time.

The average trip length of M15 bus riders is 13 stops or about 35 blocks based on ridership surveys. This number is confirmed by a logical explanation of transit trips along the East Side: The two business concentrations, Lower Manhattan and Midtown, are about 70 blocks apart. It is another 70 blocks from Midtown to the north-east end of Manhattan. Neglecting the Upper East Side residents commuting to Lower Manhattan, who use the faster subway, the number of 30 to 40 blocks is about the average commuting distance of all East Side residents.

Figure 4.3-1 shows the average subjective journey time for a 35 block length trip with a factor of 1.5 for the subjectively longer access (walking) time and a relatively high station dwell time of 20 seconds. The minimum journey time is registered with a stop frequency of 4 blocks. A frequency of 5 or 6 blocks takes only slightly longer, though the advantage of a 4 block frequency increases with lower station dwell times. Lower dwell times occur because a lesser amount of riders board or leave an LRV at each station with more stops given a fixed number of projected passengers. As average station dwell times are likely to be lower with the proposed multiple entrance LRVs, the theoretical 4 block frequency was chosen. With a 10 second dwell time, this frequency would be favorable even for a subjectivity factor of one.

Figure 3.4-1: Journey Time and Stop Frequency

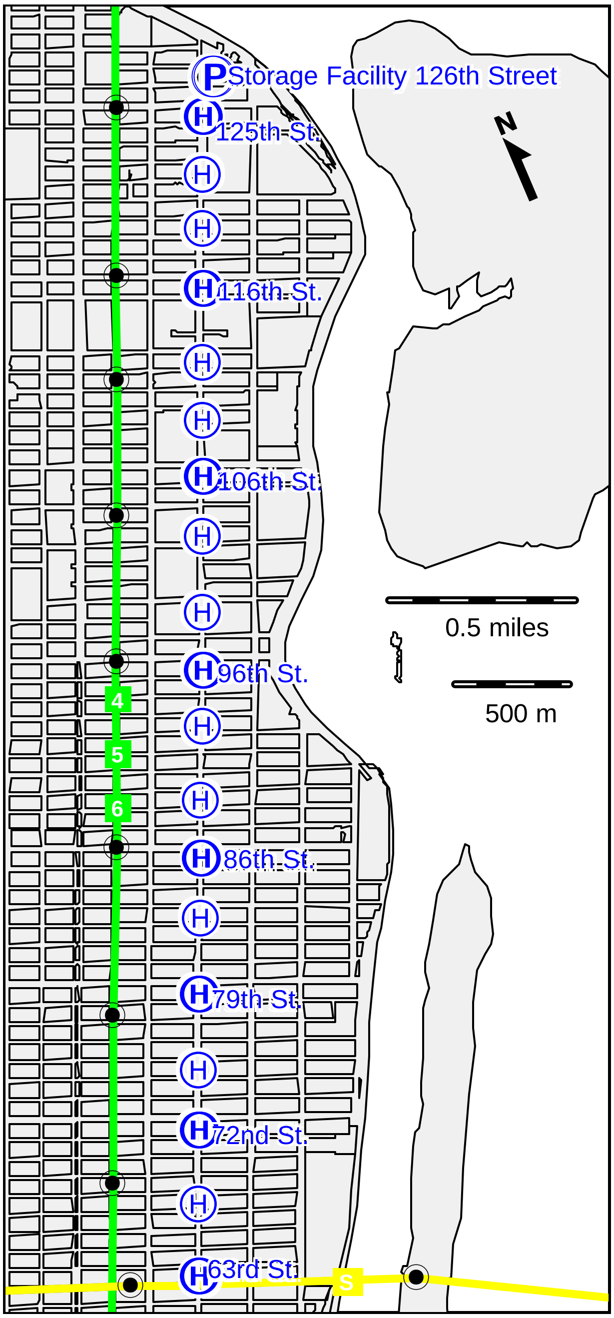


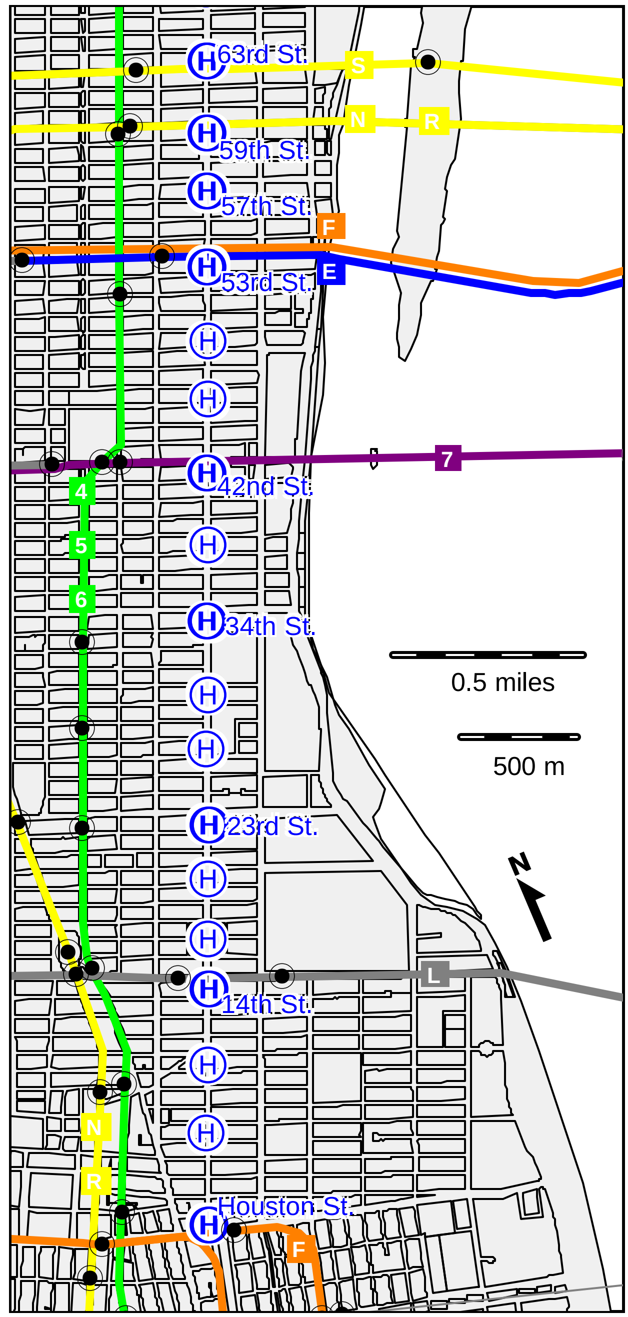
As shown In Map 3.4-2 and 3.4-3, minor stops (stations in blue without a name) on the basis of this theoretical number were added to necessary stops (e.g. at major crosstown streets and subway interfaces). In this way, 36 stops were designated along the 6.2 miles (10 km) stretch between 125th Street and Houston Street: 17 between Houston and 63rd Street and 19 between 63rd and 125th Street. This represents an average stop frequency of 3.5 blocks or 920 feet (280 meters). This relatively high LRT stop frequency takes into consideration an urban application of LRT through high density areas. Latest LRT developments in Europe also tend to have higher stop frequencies responding to the importance of subjective journey time.[1]

Without preference for a specific alignment on First or Second Avenue, stations in Map 3.4-2 and 3.4-3 have been placed along Second Avenue.

[1] VDV, 1997, p. 224

Map 3.4-2 and 3.4-3: Proposed LRT Stations between Houston and 125th Street with existing subway lines and stations





Ideal LRT Running Times

Under ideal circumstances, with a station dwell time between 10 to 20 seconds, a service acceleration and deceleration of 3 mph/s (1.3 m/s^2) and a maximum speed of 30 mph (50km/h), the running time along this 6.2 miles (10km) stretch from 125^{th} to Houston Street is about 25 to 30 minutes.

Assuming the same average speed of 12 to 15 mph (20 to 24 km/h) for the 2 miles (3,3 km) southern stretch from Houston Street to the southern tip of Manhattan, for which the ideal running time is between 8 to 10 minutes, the LRT Line would require 33 to 40 minutes to cross Manhattan on the East Side from north end to the southern tip.

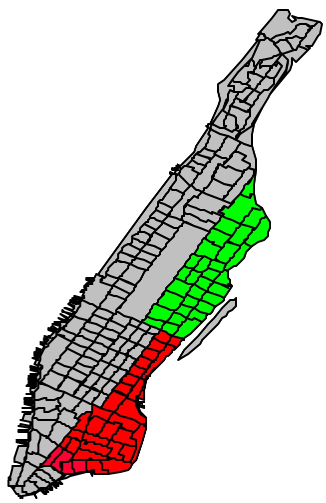
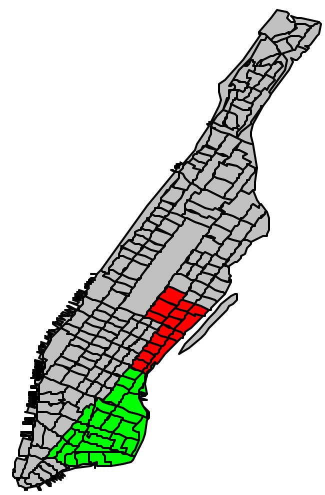
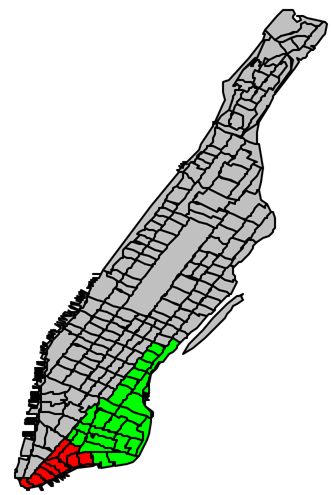
In reality, significantly higher running times are expected in particular because of the high density of crosstown streets, each with signaled intersection only 260 feet (80 m) apart from each other.

Ridership Potential

For establishing the potential number of passengers using the East Side LRT Line, MTA's Distribution/Mode Choice Model for the AM peak period has been used. Manhattan residents' most reasonable origin and destination zones for potential East Side LRT trips were chosen on the basis of the available data cells (Table 3.4-2). Additionally, out of the top twenty origin-destination AM peak pairs for the Lexington Avenue Subway, ridership numbers for those pairs for which riding the East Side LRT line would be the better alternative to the subway, have been added (Table 3.4-3).

The busiest location for intra-Manhattan trips (those with origin and destination in Manhattan) that might use the East Side LRT is the North Midtown Screenline at 60^{th} street. At this location almost 3,800 pphpd might want to use the LRT line for a southbound commute. This is more than twice the number of the current M15 AM peak hour volume at 60^{th} Street.

Table 3.4-2: Ridership Estimates for East Side LRT Line

Screenline	North Midtown 60th Street	South Midtown 23rd Street	Lower Manhattan Canal Street
Origin Zones Destination Zones			
Description	Southbound trips starting in Upper East Side north of 60th Street going to East Midtown south of 60th Street, the East Village or the Lower East Side.	Northbound trips starting in the Lower East Side, East Village and East Midtown south of 23rd Street going to East Midtown north of 23rd Street.	Southbound trips starting in East Midtown south of 42nd Street, the East Village and the Lower East Side going to Lower Manhattan.
Peak Hour[1] Person Trip by Auto	856	277	521
Peak Hour[1] Person Trip by Transit	2939	1401	2027
Peak Hour[1] Person Trip Total	3795	1679	2547

[1] Calculated from 2 hour peak period data. Peak hour data of 60th Street Screenline showed that about 70% of peak period volumes took place during the peak hour.

Table 3.4-3: Potential LRT Trips with Non-Manhattan Origins

Trip Origin	Trip Destination	AM Peak Hour Trips* on Lexington Avenue Subway	Estimated Percentage of trips changing to ES LRT	LRT Ridership Potential
Queens	East Midtown	9,826	30%	2,947
Queens	Upper East Side	5,040	30%	1,512
Brooklyn	Lower East Side	3,240	80%	2,592

* 40% of Peak Period Volumes (3 hours)

Additionally, a potential ridership of 3,000 pph, deduced from Lexington Avenue subway trips, is concentrated in the same general area. This number results from trips starting in Queens and having destinations in East Midtown. These travelers use the Lexington Avenue subway north/south travel on Manhattan's East Side after crossing the East River westbound with another subway line, either the No.7, E, F, N, R, or S train. It is estimated that about 30% of these transferees, the LRT Line would be preferred if an adequate interface is provided. Unfortunately this data sources does not permit making estimates of expected ridership volumes at specific locations and about the distribution in each direction.

Together with the information about other volumes in Table 3.4-2 and 3.4-3, ridership estimates make a strong case for the East Side LRT Line and highlight the importance of flexibility to provide even higher transit capacity. As previously shown, this LRT Line could have a capacity of up to 19,120 pphpd.

Storage and Maintenance Facility

The existing MTA bus facility at 126th Street between First and Second Avenue would be a possible location for East Side LRT storage and maintenance facility. By expending along the entire block between 126th and 127th Street, a parcel of land of 100,000 feet^2 (9,150 m^2) is created, big enough to store up to 30 LRVs adjacent to a maintenance building.

3.4.1 The Alignment Analysis Area

In order to keep within the time limits of this student based research study, an Alignment Analysis Area was defined to describe and evaluate the alternatives. Including only the part of the Study Area between Houston and 63^{rd} Street, this area represents the major alignment factors for First and Second Avenue, therefore research results have a certain validity for the stretch on First and Second Avenue north of 63^{rd} Street.

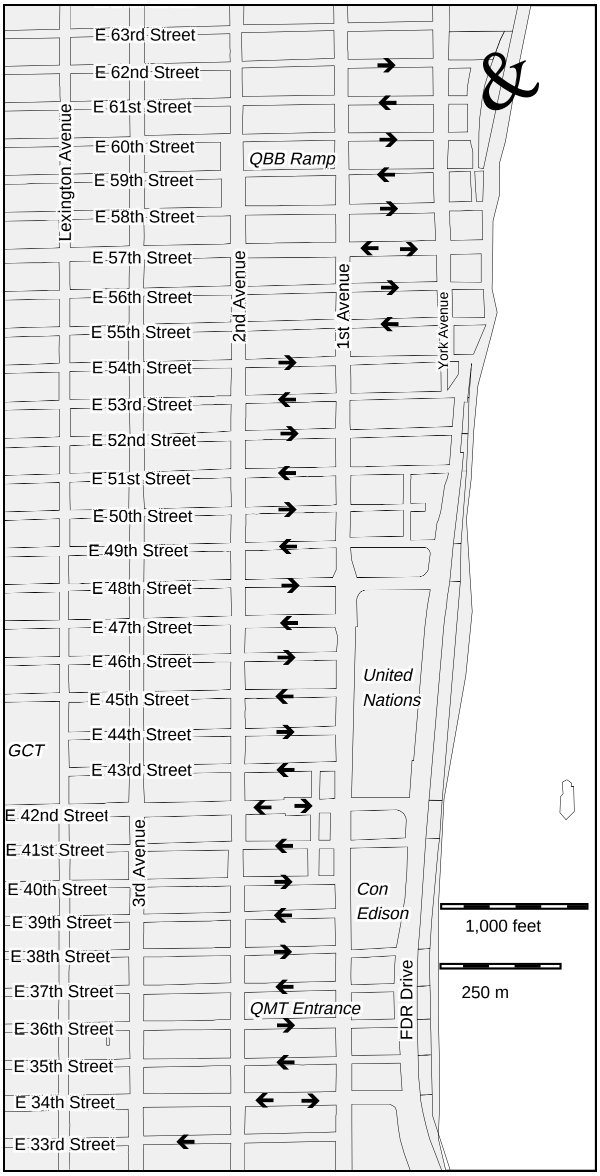
The additional data provided for the Alignment Analysis Area includes more specific information about the local street network, in particularly First and Second Avenue with its layout, turning volumes, goods movement and parking as well as detailed land use.

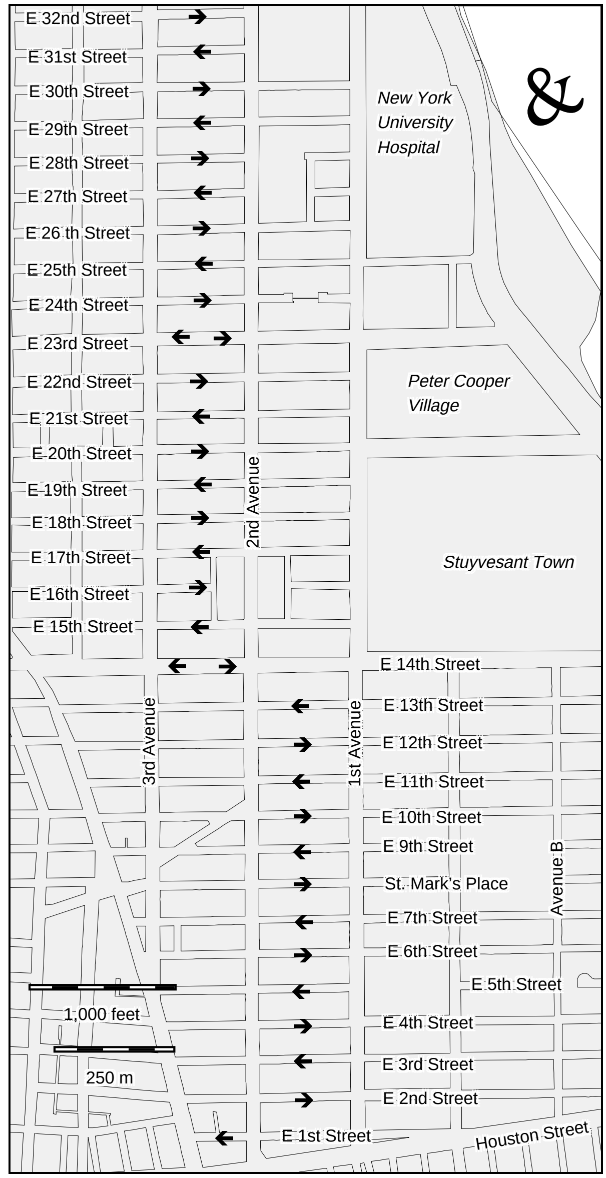
The Street Network with Problematic Traffic Locations

Maps 3.4-4 and 3.4-5 show an overview of the surrounding crosstown streets of First and Second Avenue in the Alignment Analysis Area. Five major two-way crosstown streets are located between Houston and 63^{rd} Street. These are 14^{th} Street, 23^{rd} Street, 34^{th} Street, 42^{nd} Street and 57^{th} Street. These streets normally consists of six lanes, two moving lanes in each direction with a parking lane on each side. The narrower crosstown streets normally provide parking on both sides, leaving a single lane for moving traffic in the middle.

The entrance to the Queensboro Bridge (QBB - Picture Appendix A) on Second Avenue, between 59^{th} and 60^{th} Street, provides one of the most complex traffic flows along this avenue. Second Avenue comprises seven traffic lanes at this location: the most western one an exclusive bus lane, four lanes in the middle for through traffic, the second lane from the east for through traffic and left turns on the bridge and a left turn only lane on the very east side. The QBB entrance provides two lanes for Queensbound traffic, which is the continuation of eastbound 59^{th} Street. All together five Manhattan bound traffic lanes lead onto Second Avenue, providing for traffic turning into Second Avenue southbound and for crossing of Second Avenue for further westbound travel along 60^{th} Street.

Map 3.4-4 and Map 3.4-5: Street Network of the Alignment Analysis Area





Further south, the entrance from Second Avenue to the Queens Midtown Tunnel (QMT) at 36th Street is another considerable traffic generator though less critical than the Queensboro Bridge area. This is due to the fact that there is no exit on Second Avenue. The two eastern traffic lanes are used for traffic turning east to the tunnel, the remaining five lanes contain the southbound through traffic. Eastbound traffic on 36th Street crosses Second Avenue and either continues on 36th Street or enters the tunnel.

Turning Volumes

In addition to already provided data on traffic volumes on First and Second Avenue (Chapter 3.1), information about turning volumes along these avenues was obtained by several Environmental Impact Statements (EIS) such as the 1997 Bear Stearns DEIS, the 1994 42nd Street LRT FEIS and the 1993 New York Hospital FEIS (Table 3.4-4 and 3.4-5). The combined data of all three statements were defined as the Representative Turning Movement (RTM) for the entire Alignment Analysis Area.

Table 3.4-4: Volumes (North) and Turning Volumes (East and West) on 1st Avenue

1994		**AM Peak Hour**				**PM Peak Hour**			
42nd Street LRT Line FEIS		**North**	**West**	**East**	**Total**	**North**	**West**	**East**	**Total**
1ST AVE at	E 40TH ST	1880	0	0	1880	2150	0	0	2150
1ST AVE at	E 42ND ST	525	220	10	755	485	155	30	670
1ST AVE at	E 43RD ST	1370	0	40	1410	1395	0	45	1440
1997		**AM Peak Hour**				**PM Peak Hour**			
Bear Stearns DEIS		**North**	**West**	**East**	**Total**	**North**	**West**	**East**	**Total PM**
1ST AVE at	E 42ND ST	2350	230	5	2585	2000	155	5	2160
1ST AVE at	E 48TH ST	2255	0	155	2410	2400	0	55	2455
1ST AVE at	E 49TH ST	2345	205	15	2565	2460	185	35	2680
1993		**AM Peak Hour**				**PM Peak Hour**			
The New York Hospital FEIS		**North**	**West**	**East**	**Total**	**North**	**West**	**East**	**Total**
1ST AVE at	E 59TH ST	1913	484	25	2422	2216	485	42	2743
1ST AVE at	E 62ND ST	2230	0	203	2433	2752	0	222	2974
1ST AVE at	E 63RD ST	2502	130	0	2632	2336	563		2899
Representative Turning Movement (RTM)			**1269**	**453**			**1543**	**434**	

On both Avenues turning volumes to the west are generally higher than to the east. For obvious reasons, traffic on these most eastern Avenues is more orientated to the west. However this applies even more for First Avenue with less destinations on its easterly side. High turning volumes to the east on Second Avenue, especially in the PM peak hour, are connected with Queensbound traffic over the QBB and through the QMT.

Table 3.4.-5: Volumes (South) and Turning Volumes (East and West) on 2nd Avenue

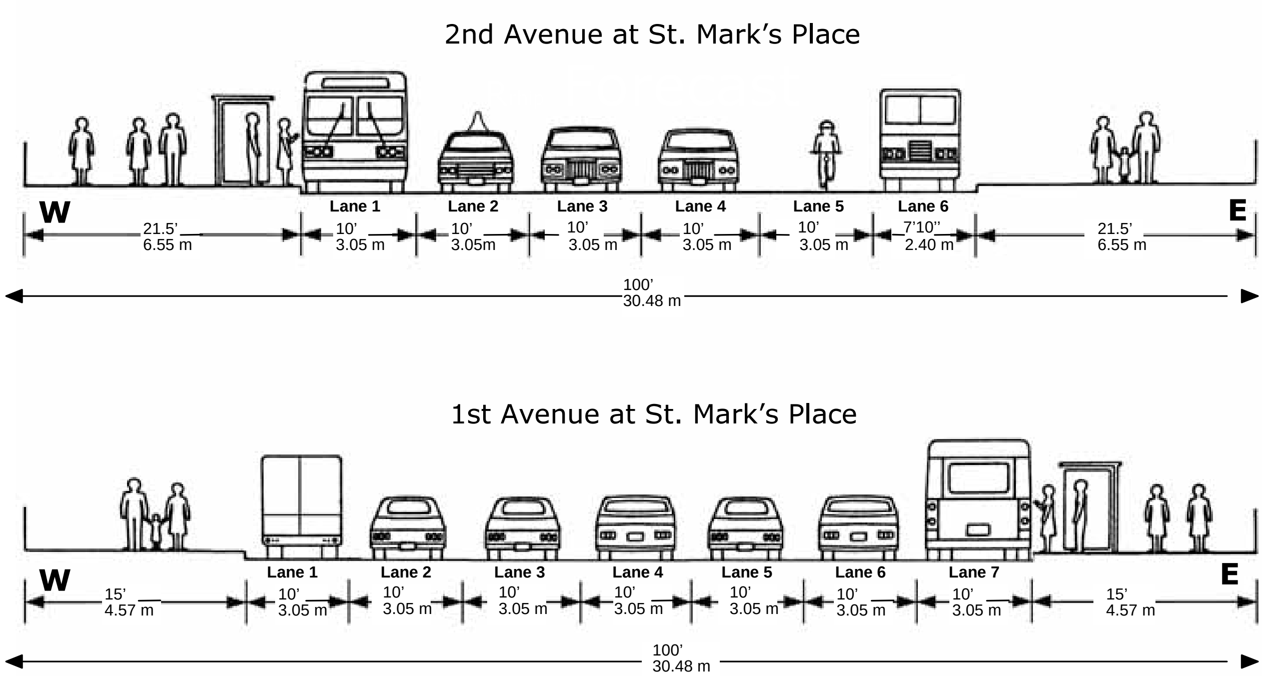
1994		AM Peak Hour				PM Peak Hour			
42nd Street LRT Line FEIS		**South**	**West**	**East**	**Total**	**South**	**West**	**East**	**Total**
2ND AVE at	E 38TH ST	2290	0	95	2385	2660	0	115	2775
2ND AVE at	E 40TH ST	2405	0	160	2565	2625	0	115	2740
2ND AVE at	E 42ND ST	2150	225	295	2670	2340	150	310	2800
2ND AVE at	E 48TH ST	2732	0	100	2832	2688	0	150	2838
					0				
1997		**AM Peak Hour**				**PM Peak Hour**			
Bear Stearns DEIS		**South**	**West**	**East**	**Total**	**South**	**West**	**East**	**Total**
2ND AVE at	E 42ND ST	2265	260	215	2740	2025	190	150	2365
2ND AVE at	E 43RD ST	3050	305	0	3355	2350	95	0	2445
2ND AVE at	E 44TH ST	3215	0	155	3370	2355	0	190	2545
2ND AVE at	E 45TH ST	3220	325	0	3545	2220	200	0	2420
2ND AVE at	E 46TH ST	3320	0	135	3455	2170	0	155	2325
2ND AVE at	E 47TH ST	3340	295	0	3635	2050	280	0	2330
2ND AVE at	E 48TH ST	3360	0	165	3525	2040	0	150	2190
2ND AVE at	E 49TH ST	3098	215	0	3313	1980	230	0	2210
1993		**AM Peak Hour**				**PM Peak Hour**			
The New York Hospital FEIS		**South**	**West**	**East**	**Total**	**South**	**West**	**East**	**Total**
2ND AVE at	E 54TH ST	3554	0	121	3675	1970	0	98	2068
2ND AVE at	E 55TH ST	3395	346	0	3741	1889	201	0	2090
2ND AVE at	E 56TH ST	3448	0	105	3553	1894	0	133	2027
2ND AVE at	E 57TH ST	2668	298	15	2981	1841	213	0	2054
2ND AVE at	E 58TH ST	2879	0	28	2907	1962	0	221	2183
2ND AVE at	E 59TH ST	2866	0	738	3604	2055	0	776	2831
2ND AVE at	E 60TH ST	2643	98	16	2757	1710	114	19	1843
2ND AVE at	E 61ST ST	2530	130	0	2660	1518	82	0	1600
2ND AVE at	E 62ND ST	2433	0	69	2502	1453	0	338	1791
2ND AVE at	E 63RD ST	1855	146	0	2001	1711	152	0	1863
Representative Turning Movement (RTM)			**2643**	**2412**			**1907**	**2920**	

Street Layout of First and Second Avenue

Along the entire length of the Alignment Analysis Area, First and Second Avenue each have a total width of 100 feet (30.5 m). Except for the four lane, eight block long underpass in front of the UN Headquarter between 42nd and 47th Street, First Avenue is a continuous seven lane street. Five lanes are reserved for moving traffic, the western curb lane for on-street parking and the eastern curb lane either for bus lanes or parking. Sidewalks on both sides are 15 feet (4.5 m) in width.

Between 23rd and 61st Street, Second Avenue has the same street layout with 7 lanes. South of 23rd Street, wider sidewalks of 21.5 feet (6.5 m) reduce the number of lanes by 1 to 6. The lane on the eastern curb provides on-street parking, whereas the one on the western curb is reserved for bus lanes or parking. Additionally, a bike lane has been implemented between 14th and Houston Street, leaving 3 lanes for moving traffic (Figure 3.4-2)

Figure 3.4-2: Existing Street Configuration on 2nd and 1st Avenue



Parking

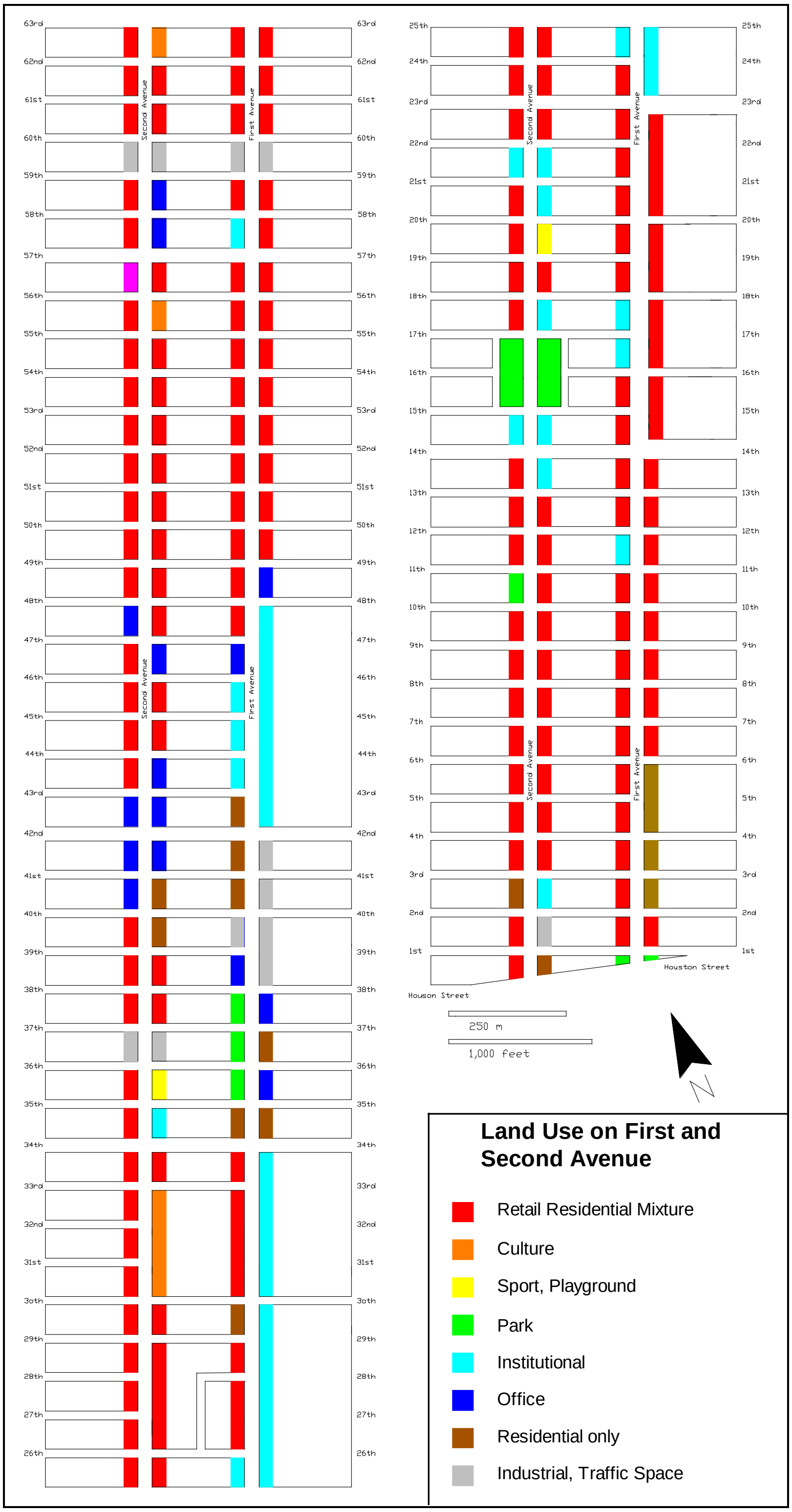
The number of legal on-street parking spaces and curbcuts was obtained by field surveys. The red zone bus lane in the Alignment Analysis Area along First and Second Avenue runs from 63rd to 34th Street. An additional curbside bus lane on Second Avenue runs from 34th Street to 14th Street. Per average block, eight parking meters are installed; blocks with bus stops provide 6 parking spaces. On-street parking along Second Avenue from Houston to 63rd Street provides approximately 600 parking spaces during peak hours and 950 during periods when the bus lane is not active. First Avenue has 750 spaces during peak periods, otherwise 950.

Besides on-street parking, First and Second Avenues include a number of private and public parking garages. Most garage entrances are on cross streets but a few are located on First and Second Avenue. These are accessible by crossing the sidewalk coming from the Avenue, therefore curbcuts were built. Map 3.4-6 gives an overview of all curbcuts on First and Second Avenue in the Alignment Analysis Area. The location of curbcuts is an important factor because they represent additional track crossings by vehicles. Appropriate solutions, and if possible avoidance of these crossings, are important elements for successful operation of LRT.

Map 3.4-6: Curbcuts on 1st and 2nd Avenue

Curbcut	Description
1E1	Parking
1E2	Entrance for Hospital
1E3	Entrance
1E4	Entrance NYU Medical Center
1E5	Parking
1E6	Ramp for Hospital
1W1	Big Parking Garage
1W2	Parking
1W3	Rapid Park Garage
2E1	Parking Garage
2E2	Parking
2E3	Business Garage
2E4	Mobil Gas Station
2W1	Entrance Marlboro House
2W2	Private Garage
2W3	One Car Parking Lot
2W4	Business Parking

Map 3.4-7: Land-Use along First and Second Avenue



Land-Use Pattern

In general both Avenues have a very diverse land-use pattern. About 70 % of the blocks fronting 2nd Avenue are used for a mixture of retail businesses and residences. A further 15 % are categorized as office or institutional use. Most of the remaining 15 % are cultural, sport and recreational facilities.

For First Avenue a lower percentage, (57%) for retail/ residence blocks, was noted. More blocks are used for offices and by institutions (23 %) as well as for residential-only (8%) compared to 2nd Avenue.

Field surveys showed that the retail/residential use is more likely to be delivery intense (more goods movement) than others.

Finally, the number of street-cafés was counted. 2nd Avenue has 24 and 1st Avenue only 5. This confirms 2nd Avenue as the more pedestrian friendly.

3.4.2 Description and Impacts of Alignment Alternatives

Due to the necessary limitation of both time and resources available for this study, a large number of possible LRT alignments along First and/or Second Avenue was narrowed down based on the following criteria:

1. The East Side LRT alignments alternatives should range between being either semi-exclusive, when sharing the street with other vehicles, or non-exclusive in a pedestrian mall. In the case of a parallel roadway, the street right-of-way is separated by a mountable curb.

2. Semi-Exclusive Alignments should be designed in such a fashion so as to minimize the loss of roadway capacity to guarantee free flowing traffic and thereby provide a higher potential speed for the LRT Line.

3. The East Side LRT Line should have direct access from at least one sidewalk. Curb transitways cause fewer traffic impacts and pedestrian/vehicular safety impacts than do facilities placed in the median of a roadway. Furthermore, accessibility for passengers is more convenient and the cost of constructing curb facilities is less than the cost for median facilities.[1]

4. A high priority is placed on the avoidance of traffic crossing the right of way (Vehicles and Pedestrians).

5. Contra-flow lanes were not included for the one-way-pair alignment due to pedestrian safety concerns.

[1] NYCDOT, 1986, p. 4-17

3.4.2.1 Alignment 1 - One Way Pair Alignment

First Avenue: Positioning along the eastern curb of First Avenue appears more practical regarding the Representative Turning Movements (RTM), which are three times higher to the west than to the east (Table 3.4-5). The larger number of curbcuts, including some important vehicles entrances to hospitals, on the east side (six) compared to the Avenue's west side (three) is more than offset by the occurrence of fewer crosstown streets on the eastern side (41) than on the western side (59).

Second Avenue: In addition to a somewhat higher (20%) Representative Turning Movement (RTM) to the east on Second Avenue, critical locations such as the Queensboro Bridge ramp and the entrance to the Queens Midtown Tunnel, with extremely high eastern turns, dictate an alignment along the western curb. The amount of curbcuts on each side is equal with four.

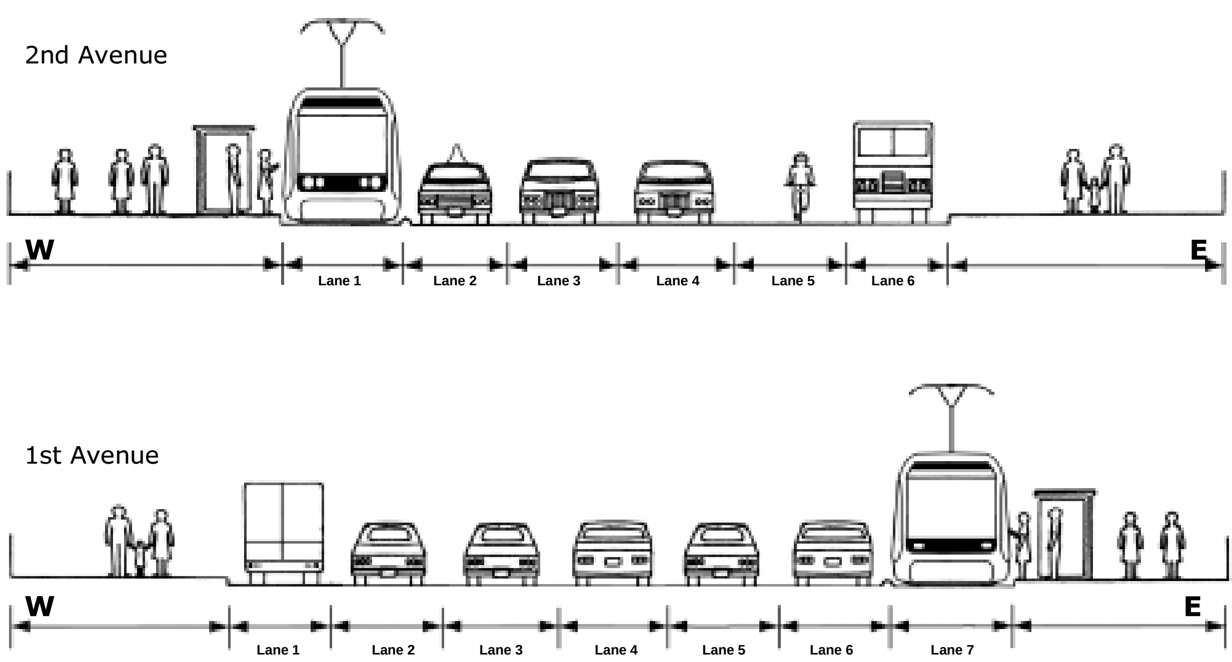
Variations like an LRT Alignment similar to the proposed New York Bus Lanes are reasonable. However they were excluded because of a higher loss of roadway capacity. This variation would reserve a second lane on Second Avenue for the transit right-of-way. The additional space between the sidewalk and the tracks would be used for station platforms and allowing parking along blocks without stations, which would require track crossings for parking. The decrease of through traffic capacity results from the need for a right turning lane on one of the through traffic lanes.

Summarized, the One Way Pair Alignment would provide LRT service in a similar way which the M15 bus does today. Southbound tracks would run along the western curb of Second Avenue while northbound tracks run along the eastern curb of First Avenue. Existing bus lanes on both Avenues would be converted to an LRT transit way. Stations would be located on the existing sidewalks the same way today's M15 bus stations are arranged.

Alignment 1 - Street Configuration

On Second Avenue, Lane 1 is continuously used for the LRT right of way. Lanes 2 to 5 will generally be used for through traffic. To ensure safe and efficient LRT service, a separate signal for right (west) turning traffic has to be installed, therefore Lane 2 is reserved for right turns for half the length along blocks followed by westbound cross-streets. The remaining segments of Lane 2 are reserved for on-street parking. Left (east) turning traffic on Second Avenue will not be affected by the one way pair LRT alignment. The additional 7th lane on Second Avenue between 62nd and 23rd Street opens lane 6 for moving traffic. Further, on-street parking is possible on the far east lane, either lane 6 or 7. It is intended to implement bike lanes and/or widening of sidewalks along blocks which require less traffic capacity. Bike lanes if desired are best added on the opposite side of the avenue from the LRT Line because of the potential risk of the mountable curb.[2]

Figure 3.4-3: The One-Way-Pair Alignment on 2nd and 1st Avenue



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[2] McNamara, 06/14/99

On First Avenue, Lane 7 will be used for the LRT right of way. Lanes 1 to 6 are generally used the same way there are as they are today, mainly for through traffic. Along blocks followed by an eastbound crosstown street, Lane 6 is reserved for (east) right turning traffic with separate signals. The remaining sections of Lane 6 are dedicated to parking.

Alignment 1 - LRT Performance

To guarantee an efficient transit service along Manhattan Avenues, the high density of signaled intersections has to be taken into consideration. To provide faster traffic flows, current New York City signals along one-way avenues have been designed to be progressive. These "green waves" with speeds set at 30 mph (50 km/h) along both First and Second Avenue, permit vehicles to drive a much longer distance without stopping than would random or simultaneous signal configurations. A simple adjustment of the green wave to the average speed of the LRVs of 12 mph (20 km/h) would not be acceptable for vehicular traffic.

In Figure 3.4-4, the green and the red lines show signal switching either green or red depending on time and location. For modeling the LRT performance, a stop frequency of 300 m (985 feet) or every 4th block and a signal reliance independent from the location (due to extremely high signal density) was assumed.

For a 40 block distance of 2 miles (3.2 km), including 10 stops, the running time increases by 2.2 minutes from 10 minutes (lilac performance line) to 12.2 minutes if the LRT line would operate with the existing signal configuration (blue performance line). Therefore, the running time from 125th to Houston Street would be approximately 37 minutes, 7 minutes longer than the optimal running time of 30 minutes assuming a 20 second dwell time.

A possible modification of the existing signal configuration in favor for the LRT system, could be an increase of the green wave speed up to a hypothetical 30 m/s (67 mph) combined with a longer green phase of 60 s. The signal time cycle would remain 90 seconds. As shown in Figure 3.4-5 this configuration would provide optimal LRT performance assuming ideal circumstances. The decrease of the green phase for crosstown traffic and pedestrians could be compensated with flexible configurations, providing additional green time when no LRV is expected to cross these streets.

Flexibility of these configurations is also important for LRT signal preemption, allowing the LRV driver to extend the green or reduce the red phase for a couple of seconds if he is falling behind the green wave due to longer station dwell times or service interruptions.

Figure 3.4-4: LRT and the existing "Green Wave" on 1st and 2nd Avenue

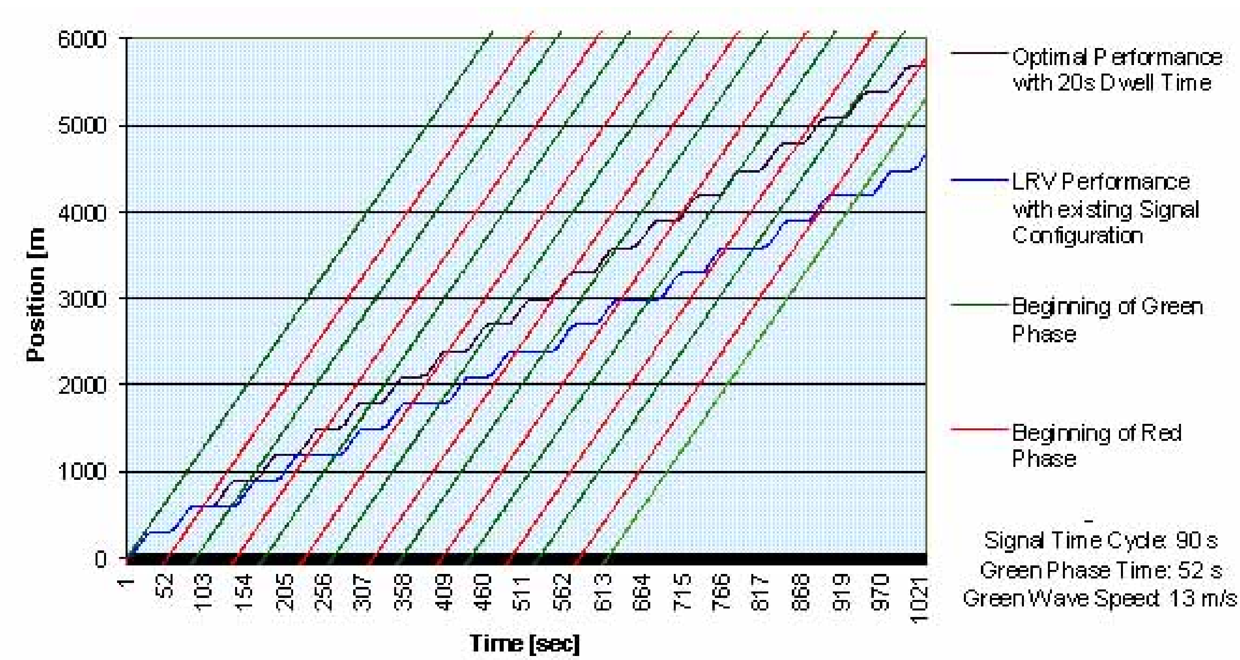
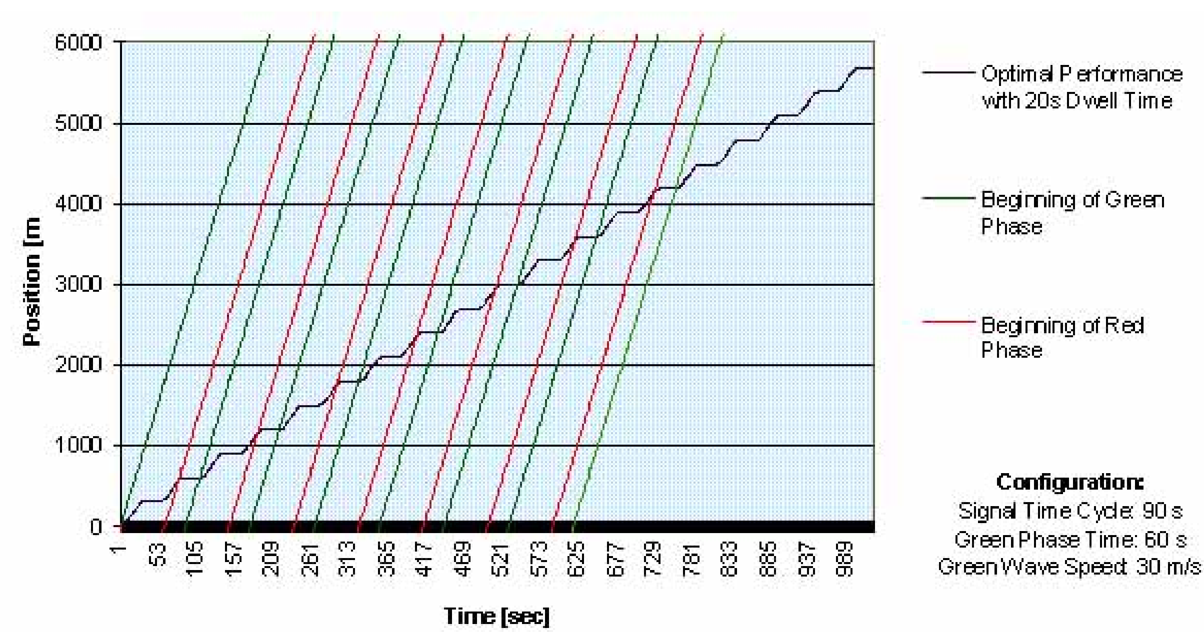


Figure 3.4-5: LRT and possible "Green Wave" configuration on 1st and 2nd Avenue



Alignment 1 - Vehicular Traffic

Vehicular traffic on both avenues will be effected; however, reduction in capacity for through traffic is insignificant and results from a loss of capacity for right turning traffic on both avenues. Assuming a conservative capacity of 750 vehicles per hour (vph) per lane for through traffic and an average of 500 vph for the far right and left lane with combined through and turning traffic on Manhattan's one-way avenues, capacity for through traffic on Second Avenue will remain 3250 vph between 23rd and 63rd Street and 2500 vph south of 23rd Street. First Avenue's through traffic capacity will be 3250 vph for the entire length.

In the Alignment Analysis Area, 34 right turns on Second Avenue and 24 right turns on First Avenue would be effected by separate signaling, reducing the green phase by 20% in favor for the LRT line during the peak period assuming 5 minute headway.

Alignment 1 - On-Street Parking

About 55% of lane 2 on Second Avenue and 45% of lane 6 on First Avenue is either reserved for LRT stations or right turning lanes. The remaining 45% on Second and 55% on First Avenue is used for on-street parking.

The loss of on-street parking spaces is about 450 on each avenue compared to today when the dedicated bus lane is not in effect. During the peak period, assuming today's bus lanes are enforced, the loss of parking on Second Avenue is approximately 100, and on First Avenue about 250 spaces. Altogether there will be 550 to 700 less parking spaces.

Alignment 1 - Goods Movement

51 blocks (80%) on the west side of Second Avenue and 22 blocks (35%) on the east side of First Avenue are identified as delivery intensive. Assuming the ability to load and unload goods in Lane 2, hand carting distance would double for deliveries to consignees along the west side of Second Avenue and the east side of First Avenue. Delivery distances to crosstown streets are insignificantly higher.

An inherent problem for these deliveries is the need to move goods along the moving traffic lanes which might block moving vehicles and decrease capacity. If lane 2 is reserved for moving traffic only, the hand carting distance would increase by an average of 150% assuming that trucks park on Lane 6 on the opposite side of Second Avenue and Lane 1 on First Avenue respectively.

Alignment 1 - Curbcuts

At 10 locations along both Avenues, vehicles accessing entrances to parking garages or driveways would have to cross a single LRT track. Affected curbcuts include important entrances to Hospitals and parking garages.

Alignment 1 - Subway Connection

The F train station at Houston Street is accessible from First and Second Avenue, therefore it would have a full connection to the East Side LRT Line. At 14th Street the L train station would be directly accessible from northbound LRT stations on First Avenue; southbound LRT service is one block away.

Building new eastern entrances of the E and F train at the Lexington Avenue station could provide a convenient subway connection for southbound LRT service on Second Avenue. However for all other connections, a walking distance of one or two blocks is necessary without major subway station reconstruction.

Alignment 1 - Future Second Avenue Subway Interface

An interface with a future Second Avenue Subway is possible in southbound direction only. For changes between the Second Avenue Subway and the northbound LRT Line on First Avenue, passengers are confronted with a minimum walking distance of 600 feet (180 m).

Alignment 1 - Cost

Construction Cost for the entire segment on Second and First Avenue between Houston and 125th Street is somewhat higher than a traditional two-way-pair alignment because two separate efforts are required. A detailed list of construction costs is included in Chapter 3.5.1. In order to realize a 5 minute headway, assuming signal preemption for the LRT Line, 16 LRVs will need to be purchased at an estimated cost of $ 3 million per vehicle.

Alignment 1 - Safety

A potential for collision between LRVs and other vehicles exists primarily at right turn locations. However, the separate signal for the right turning traffic should minimize this conflict and guarantee a free flowing LRT service.

Sidewalks bordering the LRT tracks are a danger spot for pedestrians especially along blocks were the LRV runs with 30 mph (50km/h) speeds. For these locations appropriate fencing harmonizing with the affected neighborhoods is an effective protection. Additional safety installations at pedestrian crossings are essential considering that many NYC pedestrians ignore signals and are not accustomed to any kind of surface railway.

Bike lanes positioned on the opposite side of the LRT line avoid any conflicts with its tracks or mountable curb. Crossing tracks at crosstown streets normally occurs at angle of 90° which is relatively safe.

Alignment 1 - Pedestrian Space

Because of the stations being located on the existing sidewalks there will be some loss of pedestrian space. As compared to existing bus stops, waiting passengers will spread along the sidewalk for the entire block in order to board the 160 feet (50 m) long LRVs instead of bunching at a small bus stop.

Alignment 1 - Land Use

The southbound LRT service on Second Avenue fits well with the existing land use mix of retail and residential. This pleasant walking environment would be accomplished by surface transit. Running northbound, the LRT line serves less pedestrian friendly First Avenue, though it provides access to and from major residential concentrations like Stuyvesant Town and large institutions such as the United Nations Headquarters and several major hospitals.

Alignment 1 - Station Accessibility

Accessibility to LRT stations is about the same as the current accessibility to bus stops. Longer distances between LRT stops are compensated to some extent by longer LRT stations, compared to concentrated bus stops.

Alignment 1 - East Side Livability

Besides the benefits of a quiet and efficient zero emission transit service coupled with the reduction of major negative impacts of the existing bus service, livability on the East Side will increase as residents and visitors alike are able to avail themselves of the attractive LRT mode. Synergistic effects of efficient surface transit, pedestrian amenities and local attractions will help the East Side toward becoming a healthy revitalized urban environment. Unfortunately, though vehicular traffic volumes will remain at the same level with their attendant negative impacts. But perceived benefits and improvements for the East Side as a function of the LRT construction will be significant and will outweigh negative aspects that arise.

3.4.2.2 Alignment 2 - Two Way Transit Way Alignment on First Avenue

Since northbound traffic on First Avenue is one way, a right hand running LRT Line would have to run along the western curb. Though turning movements to the east are less than to the west (as shown under 3.4.2.1), this "with-flow" alignment was chosen considering hospital entrances on the east side of First Avenue to which 2 tracks would have to be crossed.

Alignment 2 - Street Configuration

As shown in Figure 3.4-6 and 3.4-7, Lanes 1 and 2 are continuously employed for the LRT right-of-way, and Lane 3 is taken for northbound stations. Along those blocks without stations, half the length of this lane is used for left (west) turns which are controlled by separate signals; the other half remains for on-street parking as well as the entire Lane 3 along those blocks followed by eastbound crosstown streets. Lanes 4 to 6 are mainly designated for through traffic, Lane 6 also for right (east) turns. Lane 7 provides on-street parking spaces.

Figure 3.4-6: Two-Way-Transit-Way Alignment on 1st Avenue with Station

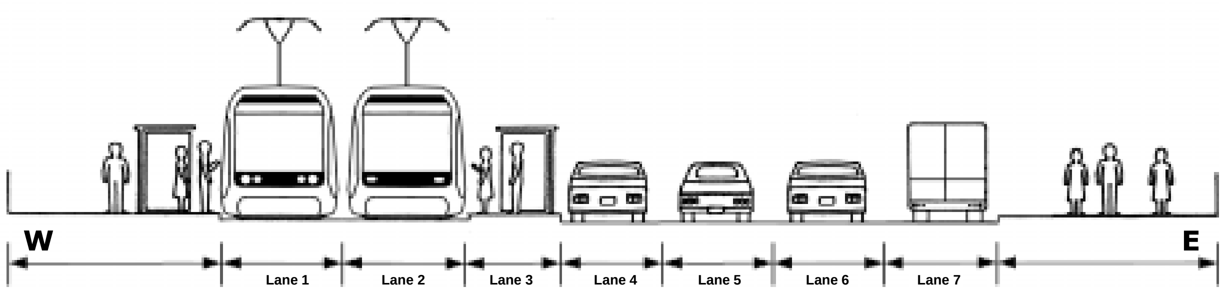
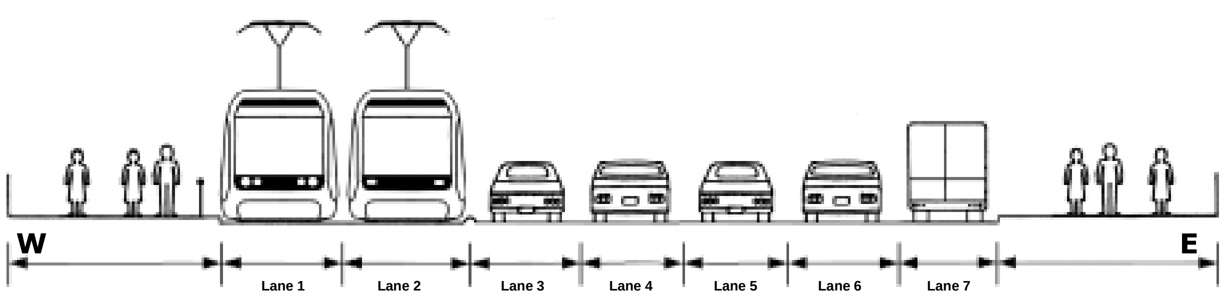


Figure 3.4-7: Two-Way-Transit-Way Alignment on 1st Avenue without Station

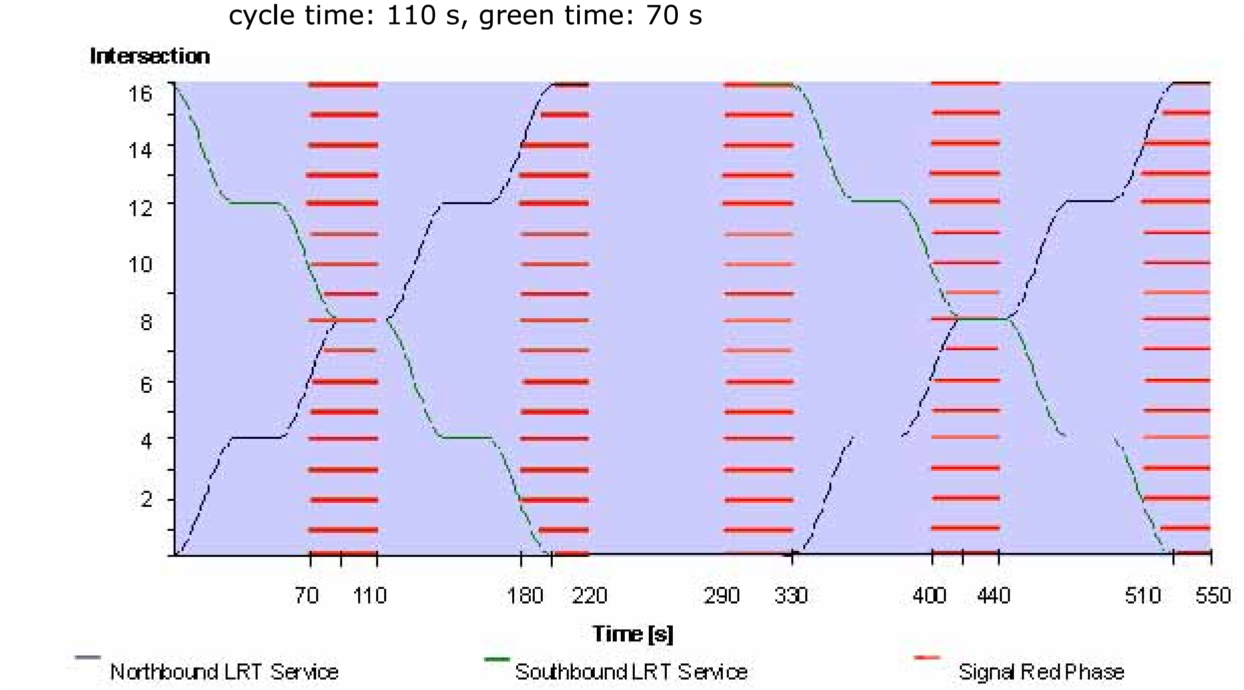


Alignment 2 - LRT Performance

Unlike the previous alignment, Alignment Alternative 2 has to deal with an additional southbound contra-flow lane along the western curb of First Avenue. Therefore the existing northbound progressive signal configuration along First Avenue contradicts the performance of southbound LRT service and it will be necessary to change the signal configuration to a simultaneous bi-directional one which is more favorable for the LRT Line but yet still acceptable for northbound vehicular traffic.

Figure 3.4-8 shows a possible signal configuration with which optimal LRT service could be provided. Assuming a station frequency of 4 blocks, for example from 29th to 46th Street, the signal time cycle would be adjusted to the LRT performance and would be 110 seconds instead of 90 seconds.

Figure 3.4-8: Possible simultaneous signal configuration, cycle time: 110 s, green time: 70 s



In this case, LRT headways within this cycle would result in a theoretical 5.5 min headway with LRVs approaching intersections every 3rd signal cycle. The red phase generally would be 40 seconds, guaranteeing almost the same green time per hour for crosstown street and pedestrian traffic .

Additionally, at 6 out of the 16 intersections (almost 40%), flexible signal configurations would have to be installed. At these locations, every 3rd red phase has to be shortened and could be compensated during the remaining two signal cycles at which time no LRVs would be present.

Irregular stop frequency, varying from three to five block intervals, along most of the alignment requires further modifications. Intelligent Transportation System (ITS) technology could provide optimal LRT service for this alignment with a running time from 125th to Houston Street of 30 minutes.

Alignment 2 - Vehicular Traffic

Capacity of First Avenue is decreased by 1,250 vph from today's capacity (3,250 vph) to 2,000 vph. In the Alignment Analysis Area, 33 left (west) turns on First Avenue would be effected by separate signaling, reducing the green phase by 30 % in favor the LRT Line during the peak period (5 min headway).

Alignment 2 - On-Street Parking

About 50% of Lane 3 is either reserved for LRT stations or left (west) turning lanes. The remaining 50% are used for on-street parking, with 250 spaces.

In the peak period as well as off peak, 750 on-street parking spaces would be located on First Avenue. This equates to a loss of 200 spaces in off peak hours.

Alignment 2 - Goods Movement

41 blocks (65%) on the west side of First Avenue are identified as delivery intensive. Assuming the possibility to load and unload delivery vans and trucks on Lane 3, hand carting distance would still increase by an average of 100% for affected deliveries. An unfortunate likelihood for these deliveries is the need to move goods across the moving traffic lanes which might block moving vehicles and decrease roadway capacity.

If Lane 3 is reserved for moving traffic only, the hand carting distance would increase by an average of 150% assuming that trucks park on the opposite side on Lane 7.

Alignment 2 - Curbcuts

At only 3 locations, vehicles accessing entrances to parking garages would have to cross two LRT tracks. Affected curbcuts are exclusively entrances to parking garages.

Alignment 2 - Subway Connection

Direct access is provided to and from the F train at Houston Street as well as to the L train at 14th Street. Other transfer subway stations are mostly two blocks away.

Alignment 2 - Future Second Avenue Subway Interface

For transfers between a future Second Avenue Subway and an LRT Line on First Avenue, passengers are confronted with a minimum walking distance of 600 feet (180 m).

Alignment 2 - Cost

Construction cost for the entire segment on First Avenue between Houston and 125th Street are slightly lower compared to Alignment Alternative 1 attributed to savings related to building one double track instead of two single ones. Due to an optimal LRT performance, the same number of light rail vehicles, 16, would have to be acquired.

Alignment 2 - Safety

A potential for collision between LRVs and other vehicles exists primarily at each of the 33 left hand turn locations. Here, drivers of turning vehicles are confronted with LRT traffic in both directions. However the separate signal for these left (west) turns should minimize this conflict and guarantee free flowing LRT service.

Similar to the previous alignment, sidewalks neighboring the LRT tracks are a danger spot for pedestrians especially along those blocks where the LRV runs with 30 mph (50km/h). For these locations appropriate fencing is an effective protection. This is only the case, though, for southbound LRT traffic.

Additional safety installations at pedestrian crossings are essential considering that many NYC pedestrians ignore signals, are not used to any kind of surface railway and will not expect southbound trains on one-way northbound First Avenue.

Alignment 2 - Pedestrian Space

Southbound stations which will be located on the existing sidewalks therefore some loss of pedestrian space on the western sidewalk of First Avenue will occur. As sidewalks on First Avenue are only 15 feet (4.5m) wide, crowded stations might block pedestrian traffic.

Alignment 2 - Land Use

This LRT line serves less pedestrian friendly First Avenue, though it provides access to and from major residential concentrations like Stuyvesant Town and large institutions such as the United Nations Headquarters and several hospitals. It might also help to reinforce current commercial outlets and promote First Avenue as a shopping street by providing additional accessibility for Manhattan's residents.

Alignment 2 - Station Accessibility

Compared to the existing accessibility to bus stops, positioning of the LRT stations will be an improvement for residents east of First Avenue as well as for employees/visitors of major institutions along First Avenue. Though stations are more remote to Midtown jobs and for residents west of Second Avenue.

Alignment 2 - East Side Livability

For similar reasons to those of the previous alternative, livability increases. First Avenue does profit more from this alternative since the LRT line runs in both a north and south direction, whereas Second Avenue remains the same in terms of traffic and its negative impacts.

3.4.2.3 Alignment 3 - Two Way Transit Way Alignment on Second Avenue

If it was desired for a southbound LRT to travel with traffic on Second Avenue this would position both tracks along the eastern curb. However, as shown before with the One-Way-Pair Alignment, the western side of Second Avenue is more favorable due to critical eastbound vehicular turning volumes at the QBB ramp and the QMT entrance. Therefore a compromise has to be adopted in order to run the LRT Line along the western side. Keeping the LRT vehicles right hand running would result in a contraflow northbound LRT service neighboring a southbound traffic lane. The other option would be to change the LRT transit way to a left hand running alignment. Due to safety reasons whereby pedestrians are accustomed to right hand running, the contraflow alignment was chosen.

Alignment 3 - Street Configuration

Similar to the Two-Way-Transit Way Alignment on First Avenue, Lanes 1 and 2 on Second Avenue are continuously used for the LRT right of way. Additionally, Lane 3 has to be used for northbound stations. Along blocks without stations, half of the block length of this lane is used as a right (west) turning lane with separate signal, the other half remains on-street parking as well as the entire Lane 3 along blocks followed by eastbound crosstown streets. Lanes 4 and 5 are mainly designated for through traffic, Lane 4 also for right turns. Lane 6 provides also on-street parking spaces. The additional 7th lane for parking on Second Avenue between 62nd and 23rd Street opens Lane 6 for moving traffic.

Figure 3.4-9: Two-Way-Transit-Way Alignment on 2nd Avenue with Station

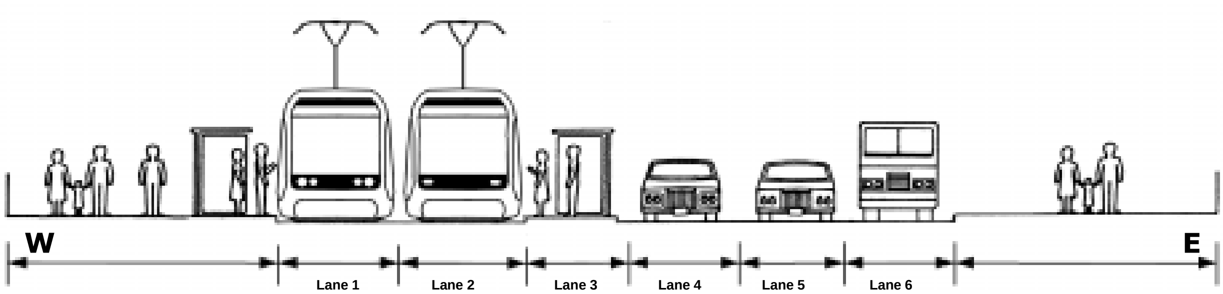
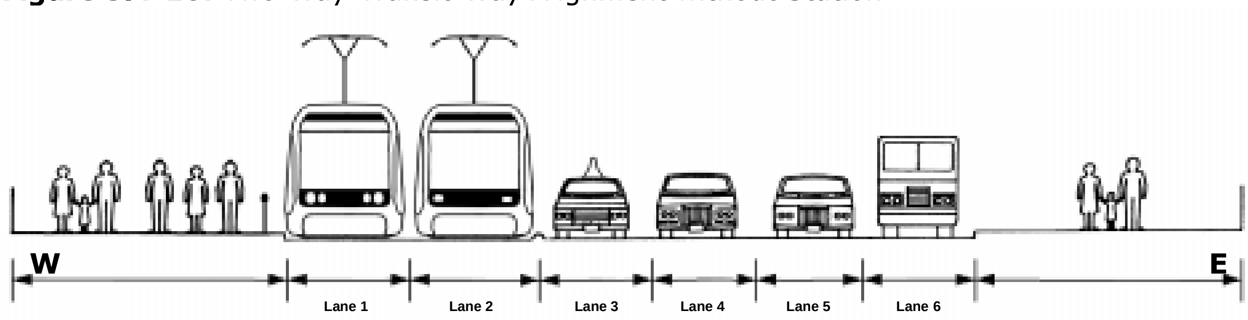


Figure 3.4-10: Two-Way-Transit-Way Alignment without Station



Alignment 3 - LRT Performance

Basic performance factors for this alignment are the same as for Alignment Alternative 2. Therefore corresponding data was extracted from the previous chapter. Running time from 125^{th} to Houston Street is approximately 30 minutes.

Alignment 3 - Vehicular Traffic

Capacity of Second Avenue decreases by 1,250 vph from today's capacity of 3,250 vph to 2,000 vph between 23^{rd} and 63^{rd} Street. Capacity south of 23^{rd} Street decreases from 2,500 to 1,250 vph.

In the Alignment Analysis Area, 34 right turns on Second Avenue would be accomplished by separate signaling, reducing the green phase by 30% in favor of the LRT Line during the peak period (5 minute headway).

Critical traffic locations such as the QBB ramp and QMT entrance are affected by this alignment. At the QBB ramp, vehicular traffic coming from Queens and turning south into Second Avenue will continue along the 3 southbound lanes. Queensbound, neither left turning traffic on Second Avenue nor traffic along 60^{th} and 59^{th} street is not affected by the LRT alignment. But the decreased capacity of Second Avenue between 61^{st} and 57^{th} Street by 750 vph from 3,750 to 3,000 is critical and results in lower level of service (LOS). Impacts at the QMT are minor since Queensbound left turns do not conflict with the LRT.

Alignment 3 - On-Street Parking

About 50% of southbound Lane 3 is either reserved for LRT stations or right turning lanes. The remaining 50% is used for on-street parking. In the peak period as well as off peak, 750 on-street parking spaces would be located on Second Avenue. This means a gain of 150 spaces in peak hours.

Alignment 3 - Goods Movement

50 blocks (80%) on the west side of Second Avenue are identified as delivery intensive. Assuming the possibility of loading and unloading commercial shipments on Lane 3, hand carting distance would still increase by an average of 100% for specific deliveries.

If lane 3 is reserved for moving traffic only, the hand carting distance would increase by an average of 150% assuming that trucks park on the opposite side on lane 6 or 7.

Alignment 3 - Curbcuts

Vehicles accessing entrances to parking garages and driveways would have to cross two LRT tracks at only 4 locations. One parking lot could be accessed from the crosstown street, another is not an issue since it provides parking space for only one vehicle.

Alignment 3 - Subway Connection

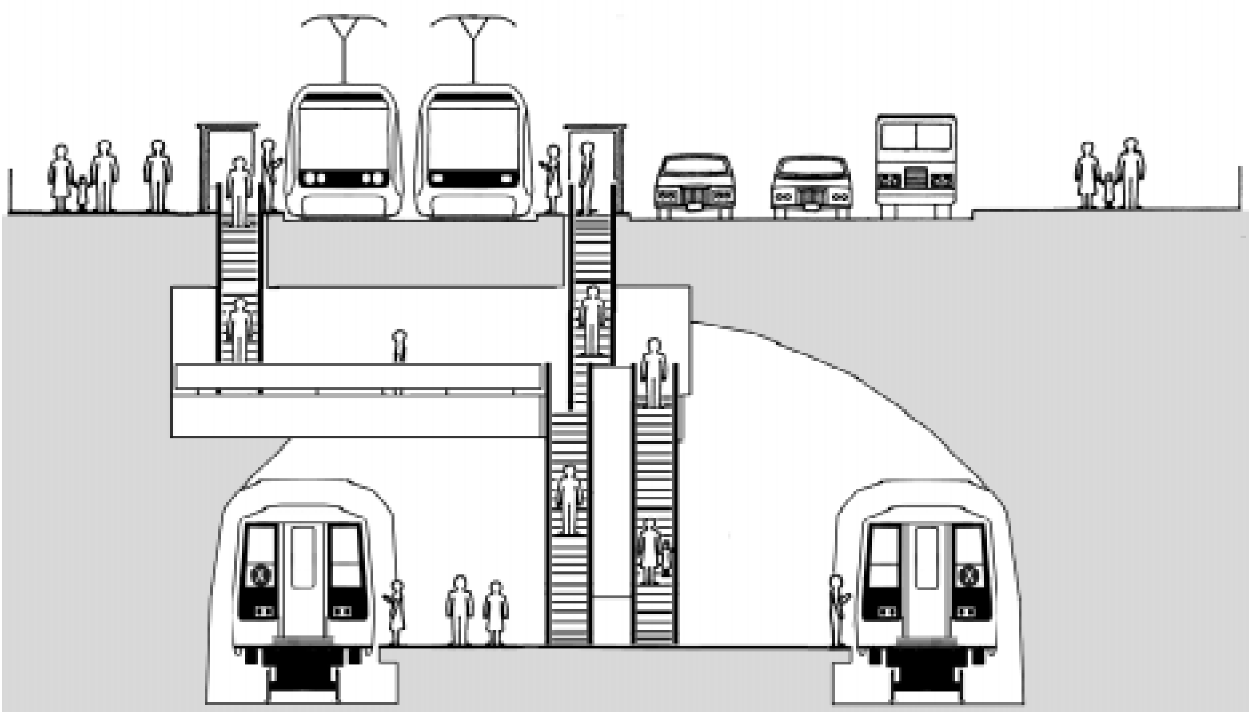
The F train station at Houston Street is accessible from Second Avenue, therefore it would have a full connection to the East Side LRT Line.

Building new eastern entrances of the E and F train at Lexington Avenue Station could provide convenient subway connections for both north and southbound LRT service on Second Avenue. However, for all other connections a walking distance of one or two blocks is necessary without major subway station reconstruction.

Alignment 3 - Future Second Avenue Subway Interface

An interface with a future Second Avenue Subway is possible along the entire length of this alignment. Therefore the Second Avenue Subway and an East Side LRT line could operate symbiotically as an express and local transit service, similar to NYC's current express and local subway concept.[1]

Figure 3.4-11: Two-Way-Transit-Way Alignment on Second Avenue with a 2nd Avenue Subway Interface



Alignment 3 - Cost

Construction cost and operating cost are about the same as for a Two-Way-Transit-Way on First Avenue.

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[1] Haikalis, 03/20/99

Alignment 3 - Safety

A potential for collision between LRVs and other vehicles exists primarily at one of the 34 right hand turn locations. Drivers on Second Avenue would have to become accustomed to contraflow LRVs running northbound immediately next to southbound traffic lanes. This unusual situation may provide significantly higher safety risks. All other potential conflicts are similar to those of the previous alignment.

Alignment 3 - Pedestrian Space

Southbound stations, which will be located on the existing sidewalks, will cause some loss of pedestrian space on the western sidewalk of Second Avenue. Wide 21.5 feet (6.5 m) sidewalks south of 23rd Street guarantee enough pedestrian space. Narrower sidewalks north of 23rd Street, 15 feet (4.5 m) in width, are less problematic due to lower pedestrian volumes.

Alignment 3 - Land Use

LRT service on Second Avenue integrates well into the existing land use mix of retail and residential. This pleasant walking environment would be accentuated by surface transit.

Alignment 3 - Station Accessibility

Compared to the existing accessibility to bus stops, distances to LRT stations improves for residents west of Second Avenue as well as for Midtown employees. Longer walks to stations would result for residents east of First Avenue and employees/visitors of major institutions on First Avenue. This assumes no bus service is continued on First Avenue.

Alignment 3 - East Side Livability

Similar to previous alternatives, East Side livability increases. Second Avenue would profit especially from this alternative, with less vehicular traffic and excellent transit accessibility. On the other hand First Avenue remains the same in terms of traffic and its negative impacts. Altogether traffic volumes are expected to decrease more than with the previous alignments and therefore some reduction of negative impacts is anticipated.

3.4.2.4 Alignment 4 - Pedestrian Mall Alignment on Second Avenue

In contrast to existing patterns along First and Second Avenue with vehicular roadways and sidewalks, a Pedestrian Mall Alignment is considered for Second Avenue. Second Avenue provides more pedestrian amenities such as a more pleasant walking environment with street cafés, retail and public spaces and is more suitable for conversion to a pedestrian LRT mall than First Avenue.

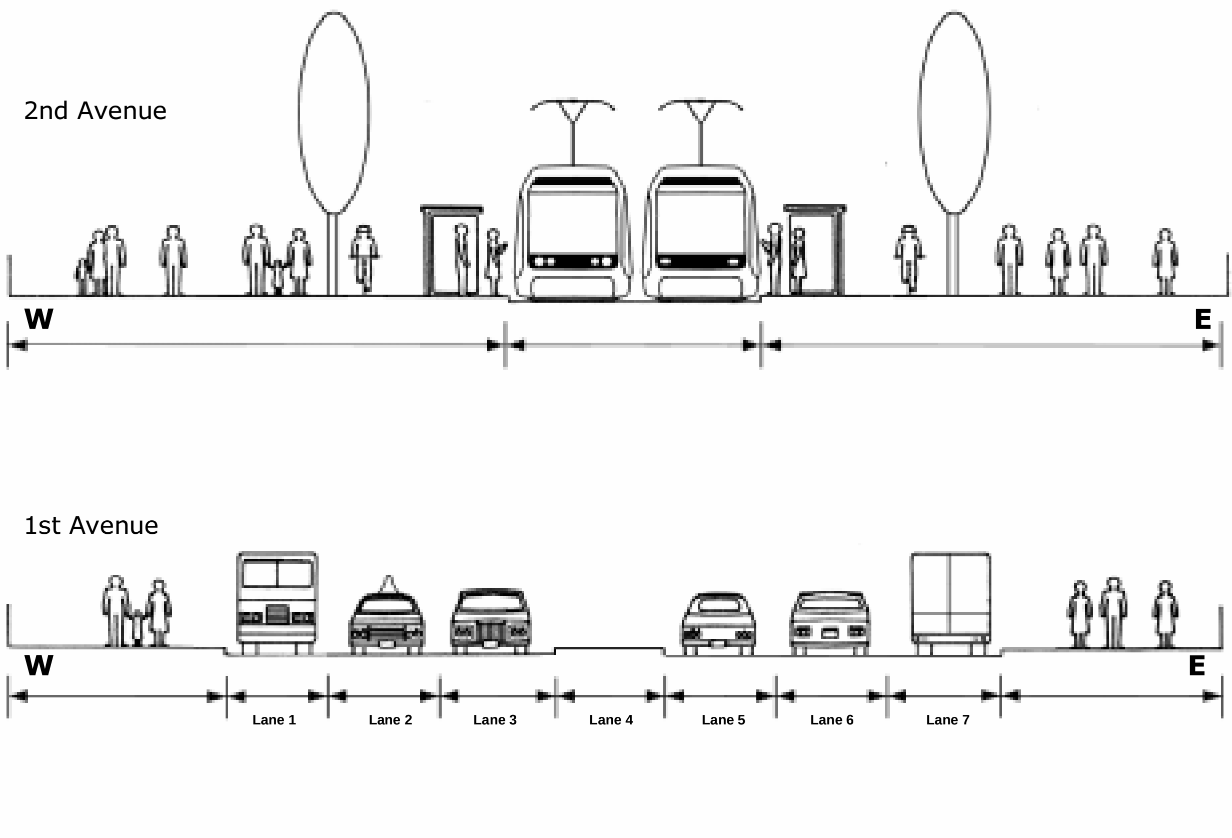
In this situation, the LRT Line would run in the middle of Second Avenue, Stations are located on both sides of the tracks. This Alignment could also be realized in parts, in combination with Alignment 3, so that the pedestrian LRT mall could extend for either a short stretch of a few blocks up to the entire length of Second Avenue.

Alignment 4 - Street Configuration

The Pedestrian Mall Alignment requires a dramatic layout change for Second Avenue. Figure 3.4-12 shows an example of how this could be done. No vehicular traffic would be allowed. The remaining space is reserved for pedestrians and urban amenities. Additionally, trees could be planted and cafés could offer outside service. Furthermore, the public space freed up could be filled by benches, decorative plantings, art work and playgrounds. Next to the LRT line running in the middle of the mall, bike lanes in both directions could be implemented, if desired.

To compensate for at least some of the loss of traffic capacity, First Avenue would be converted to a two-way street with a median to ease crossing for pedestrians. This two-way alignment fits well to existing infrastructure, such as the underpass at the UN which was originally designed for a traffic in both directions, and at Allen Street where First Avenue already continues south of Houston Street in a two-way street with a wide median.

Figure 3.4-12: Pedestrian Mall Alignment on 2nd Avenue, two-way 1st Avenue



Alignment 4 - LRT Performance

As with the performance envelope of previous alignments, maximum speed is limited to 18 mph (30 km/h) in pedestrian zones. Therefore an increase of running time of 12 seconds per 4 block pedestrianized intervals was calculated compared to a two way transit way alignment. Converting the 14 East Village blocks between Houston and 14th Street to a pedestrian mall would increase the running time by 42 seconds and pedestrianizing the entire length of Second Avenue would result in an increase from 6 minutes to 36 minutes in total running time.

Alignment 4 - Vehicular Traffic

Second Avenue's capacity of 3,250 vph between 23rd and 63rd Street and 2,500 vph south of 23rd Street would be decreased to 0 vph. In the Alignment Analysis Area, 34 right turns on Second Avenue and 32 left turns would be eliminated. An additional southbound capacity of 1,250 vph is provided by a two-way First Avenue. The current northbound capacity of First Avenue would decrease by 2,000 vph from 3,250 vph to 1,250 vph.

At certain critical locations such as the QBB ramp and the entrance to the QMT, closing Second Avenue to traffic may not be possible without major reconstruction. Keeping several short segments of Second Avenue open to vehicular traffic may be necessary.

Alignment 4 - On-Street Parking

On street parking on Second Avenue would be reduced by an average of 12 spaces per pedestrianized block compared to Alignment 3. A pedestrian Alignment along the entire length of Second Avenue reduces parking spaces by 600 to 750 spaces compared to today's amount.

Alignment 4 - Goods Movement

50 blocks (80%) on the west side and 35 blocks (55%) on the east side of Second Avenue are stated as delivery intensive. Assuming the possibility to load and unload commerce shipments in the pedestrian mall at specific times, hand carting distance would decrease and delivery would be much easier without surrounding traffic. If deliveries have to be done from crosstown streets, distances increase by at least by 300%.

Alignment 4 - Curbcuts

Eight existing curbcuts would be removed, and access from Second Avenue will not be permitted. For 4 of these entrances, access from crosstown streets is possible. For the remaining 4 locations, individual solutions can be devised.

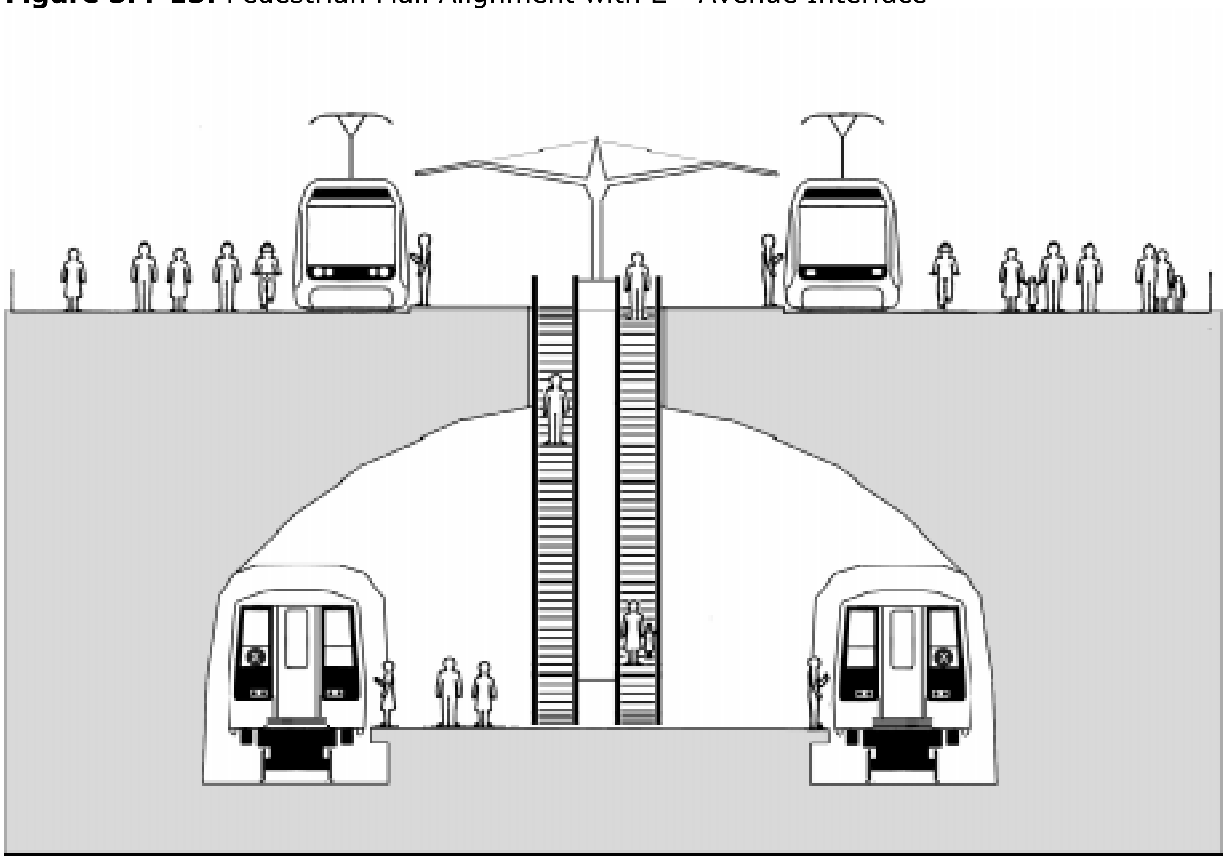
Alignment 4 - Subway Connection

Connection to existing subways is the same as with the Alignment Alternative 3.

Alignment 4 - Future Second Avenue Subway Interface

An interface with a future Second Avenue Subway is possible along the entire length of this alignment. Therefore the Second Avenue Subway and the East Side LRT line could operate as a symbiotic express and local transit service, similar to today's NYC express and local subway concept.

Figure 3.4-13: Pedestrian Mall Alignment with 2nd Avenue Interface



Alignment 4 - Cost

Obviously construction cost for this alignment are significantly higher due to major reconstruction of Second Avenue including pedestrian amenities and the required changes on First Avenue to accommodate two-way traffic. Though construction for the LRT line is more efficient because of adjacent tracks, the entire segment between Houston and 125th Street will be more expensive than any other alternative.

In order to realize a 5 min headway, two additional LRVs have to be purchased due to higher running times compared with previous alignments. Operating costs would be somewhat higher than with other alignments, as more vehicles have to be operated.

Alignment 4 - Safety

This alignment avoids car turning conflicts and a potential for collisions exists only for vehicles on crosstown streets ignoring a red light. Pedestrians on Second Avenue will have to become acclimated to sharing the mall with LRVs and perhaps with bicyclists. Therefore some pedestrian protection is needed. The median on First Avenue will make crossings for pedestrians safer.

Alignment 4 - Pedestrian Space

Besides the major gain of pedestrian space, opportunities for pedestrian amenities are provided. Together with these amenities, the Second Avenue Mall would not only be a place with enough space for walking but also an urban public space where people like to spend their time, perhaps to frequent the numerous stores and commercial outlets that line that thoroughfare.

Alignment 4 - Land Use

The pedestrian mall with LRT service on Second Avenue fits well to the existing land use mix of retail and residential, particularly in the East Village. Though the East Village flair diminishes further north, a mall could revitalize these areas and therefore be quite practical.

Alignment 4 - Station Accessibility

A major advantage of this alternative is an easier and more pleasant walk to and from LRT stations. Otherwise accessibility is equal with the one described in Alignment Alternative 3.

Alignment 4 - East Side Livability

The Pedestrian Mall Alignment provides a dramatic gain in livability on Manhattan's East Side. The Second Avenue Mall will be a mixture of park, shopping mall and transitway with zero emissions. People in the street will guarantee a friendly and safe walking environment. The Second Avenue Transit Mall would represent all the advantages of public space in the middle of a high density working and living area.

A temporarily decrease in livability is expected for a transitional phase were traffic diversion to adjacent streets might occur until an expected new travel behavior pattern with less taxi and private auto use takes place.

3.4.3 Alignment Evaluation

To assist in the alignment evaluation, a scoring model was chosen. After defining a matrix with categories, elements and indicators, a percentage weight for each group was assigned (Table 3.4-6). While obviously somewhat subjective, the "weighting" system permitted a variety of factors to be compared in a rational manner. For the three categories, the following weighting was chosen:

Providing optimal service for transit riders:	40%
Economic efficiency, Cost:	20%
Impacts on traffic in general:	20%
Amenities leading towards a more livable city:	20%

In order to gain information about the sensitivity of the scoring model, different weights are used for a sensitivity table (Table 3.4-8) and those results are compared with the previous ones. The following weights were chosen for the second calculation:

Providing optimal service for transit riders:	20%
Economic efficiency, Cost:	20%
Impacts on traffic in general:	20%
Amenities leading towards a more livable city:	40%

As Table 3.4.7 shows, the four alternative alignments were scored for each of 37 indicators and given from one (1) to four (4) points with four being the highest. Alignment Alternative 3 with a Two-Way-Transit-Way on Second Avenue scored highest with 2.946, followed by Alignment Alternative 4 with 2.888, the Pedestrian Mall Alignment on Second Avenue. Less attractive were the Two-Way-Pair Alignment on First Avenue (Alignment Alternative 2 with 2.706 points and the One-Way-Pair Alignment (Alignment Alternative 1) with 2.436 points.

The sensitivity check where greater weight was given to "livable city" indicators resulted in Alignment 4 (3.092) having the highest score, followed by Two-Way-Transit-Way Alignment 3 (2.758) and Alignment 2 (2.586) and the lowest score was for Alignment 1 with 2.136. Higher weight in interest for more livability generally results in favoring the Pedestrian Mall alignments due to the dramatic gain of open and public space as well as an overall decrease in negative traffic impacts.

However, taking into account the political acceptance, which is not represented in the scoring model, the One-Way-Pair Alignment (Alternative 1) probably becomes the most attractive alternative due to its marginal traffic impacts and its similarity to the existing M15 bus service.

Concluding, a final selection of alternatives on the basis of the scoring model alone is not possible. As shown with the sensitivity check, preferences depend for a great extent on society's current assessment of contradicting factors such as maximizing mobility, access to private property or a more livable environment.

Based on the initial results of the scoring model, a combination of the Two-Way Pair Alignment on Second Avenue (including Alignment Alternative 3 and 4) was chosen for further comparison and verification. This hybrid alignment permits pedestrianizing selected blocks while providing space for traffic next to a Two-Way-Transit-Way where that technique is more feasible.

Time did not permit detailed development of the hybrid alternative on a block by block basis, but the segment south of 14^{th} Street is certainly a candidate for the Pedestrian Mall LRT Alignment. Other segments could be considered as well.

Table 3.4-6: Scoring Model with weights (First Calculation)

Category	a	Elements	a	b	Indicator	a	b
Transit Rider	40%	Running Times	30%	12%	Overall Running Time	70%	8.4%
					Reliability	30%	3.6%
		Station Accessibility	30%	12%	Access for Residents east of 1st Ave	40%	4.8%
					Access for Residents west of 2nd Ave	20%	2.4%
					General Access to Jobs	30%	3.6%
					No. of major institutions directly served	10%	1.2%
		2nd Avenue Subway Interface	20%	8%	No. of Directions with Interface	70%	5.6%
					Convenience of change	30%	2.4%
		Other Subway Connection	20%	8%	Number of direct connections	60%	4.8%
					Distance to intersecting Subways	40%	3.2%
Operator	20%	Capital Costs	40%	8%	Infrastructure	70%	5.6%
					Vehicles	15%	1.2%
					Stations	15%	1.2%
		Operating Costs	60%	12%	Operators	60%	7.2%
					Maintenance of Vehicles	25%	3.0%
					Maintenance of Tracks	10%	1.2%
					Maintenance of Stations	5%	0.6%
General Traffic	20%	Vehicular Traffic	40%	8%	Through Capacity	50%	4.0%
					Affected critical traffic locations	30%	2.4%
					Turning Capacity	20%	1.6%
		On-Street Parking	10%	2%	Number of Spaces	100%%	2.0%
		Goods Movement	20%	4%	Delivery intensity of affected side	50%	2.0%
					Increase in hand carting distances	30%	1.2%
					Convenience of loading	20%	0.8%
		Curbcuts	10%	2%	Number of affected Curbcuts	30%	0.6%
					Curb activity	70%	1.4%
		Safety	20%	4%	No. of potential Traffic/LRT conflicts	30%	1.2%
					Pedestrian Safety	50%	2.0%
					Biking Safety	10%	0.4%
					Goods Movement Safety	10%	0.4%
Amenities	20%	Pedestrian Space	10%	2%	Number of Stations on Sidewalk	40%	0.8%
					Additional Pedestrian Space	60%	1.2%
		Land Use	10%	2%	Harmony	100%	2.0%
		East Side Livability	80%	16%	Less Vehicular Traffic	40%	6.4%
					Less Emissions	20%	3.2%
					More public and open space	20%	3.2%
					General Accessibility	20%	3.2%
		Total		*100%*			*100%*

a - relative assessment
b - absolute assessment

Table 3.4-7: Assessment and Scoring of Alignments (First Calculation)

Indicator	Weight	Assessment of Alignments				Scoring of Alignments			
		1	2	3	4	1	2	3	4
Overall Running Time	8.4%	4	4	4	3	0.336	0.336	0.336	0.252
Reliability	3.6%	4	3	3	4	0.144	0.108	0.108	0.144
Access for Residents east of 1st Ave	4.8%	2	3	1	1	0.096	0.144	0.048	0.048
Access for Residents west of 2nd Avenue	2.4%	2	1	4	4	0.048	0.024	0.096	0.096
General Access to Jobs	3.6%	2	1	4	4	0.072	0.036	0.144	0.144
No. of major institutions directly served	1.2%	2	4	1	1	0.024	0.048	0.012	0.012
Number of Directions with Interface	5.6%	2	1	4	4	0.112	0.056	0.224	0.224
Convenience of change	2.4%	2	1	3	4	0.048	0.024	0.072	0.096
Number of direct connections	4.8%	2	4	1	1	0.096	0.192	0.048	0.048
Distance to intersecting Subways	3.2%	2	1	4	4	0.064	0.032	0.128	0.128
Infrastructure	5.6%	1	4	4	2	0.056	0.224	0.224	0.112
Vehicles	1.2%	4	4	4	3	0.048	0.048	0.048	0.036
Stations	1.2%	4	2	2	1	0.048	0.024	0.024	0.012
Operators	7.2%	4	4	4	3	0.288	0.288	0.288	0.216
Maintenance of Vehicles	3.0%	4	4	4	3	0.12	0.12	0.12	0.09
Maintenance of Tracks	1.2%	2	4	4	4	0.024	0.048	0.048	0.048
Maintenance of Stations	0.6%	4	2	2	1	0.024	0.012	0.012	0.006
Through Capacity	4.0%	4	3	3	1	0.16	0.12	0.12	0.04
Affected critical traffic locations	2.4%	4	3	2	1	0.096	0.072	0.048	0.024
Turning Capacity	1.6%	3	4	4	2	0.048	0.064	0.064	0.032
Number of Spaces	2.0%	2	3	3	1	0.04	0.06	0.06	0.02
Delivery intensity of affected side	2.0%	2	4	4	1	0.04	0.08	0.08	0.02
Increase in hand carting distances	1.2%	2	2	2	1	0.024	0.024	0.024	0.012
Convenience of loading	0.8%	2	1	1	4	0.016	0.008	0.008	0.032
Number of affected Curbcuts	0.6%	1	4	3	2	0.006	0.024	0.018	0.012
Curb activity	1.4%	1	3	4	2	0.014	0.042	0.056	0.028
No. of potential Traffic/LRT conflicts	1.2%	2	1	1	4	0.024	0.012	0.012	0.048
Pedestrian Safety	2.0%	4	2	2	4	0.08	0.04	0.04	0.08
Biking Safety	0.4%	4	2	2	3	0.016	0.008	0.008	0.012
Goods Movement Safety	0.4%	1	2	2	4	0.004	0.008	0.008	0.016
Number of Stations on Sidewalk	0.8%	1	2	2	4	0.008	0.016	0.016	0.032
Additional Pedestrian Space	1.2%	1	2	2	4	0.012	0.024	0.024	0.048
Harmony	2.0%	2	1	3	4	0.04	0.02	0.06	0.08
Less Vehicular Traffic	6.4%	1	2	2	4	0.064	0.128	0.128	0.256
Less Emissions	3.2%	1	2	2	4	0.032	0.064	0.064	0.128
More public and open space	3.2%	1	1	1	4	0.032	0.032	0.032	0.128
General Accessibility	3.2%	1	3	3	4	0.032	0.096	0.096	0.128
Total Score						2.436	2.706	2.946	2.888

Table 3.4-8: Scoring Model with weights (Sensitivity)

Category	a	Elements	a	b	Indicator	a	b
Transit Rider	20%	Running Times	30%	6%	Overall Running Time	70.0%	4.2%
					Reliability	30.0%	1.8%
		Station Accessibility	30%	6%	Access for Residents east of 1st Ave	40.0%	2.4%
				6%	Access for Residents west of 2nd Ave	20.0%	1.2%
					General Access to Jobs	30.0%	1.8%
					No. of major institutions directly served	10.0%	0.6%
		2nd Avenue Subway Interface	20%	4%	No. of Directions with Interface	70.0%	2.8%
					Convenience of change	30.0%	1.2%
		Other Subway Connection	20%	4%	Number of direct connections	60.0%	2.4%
					Distance to intersecting Subways	40.0%	1.6%
Operator	20%	Capital Costs	40%	8%	Infrastructure	70%	5.6%
					Vehicles	15%	1.2%
					Stations	15%	1.2%
		Operating Costs	60%	12%	Operators	60%	7.2%
					Maintenance of Vehicles	25%	3.0%
					Maintenance of Tracks	10%	1.2%
					Maintenance of Stations	5%	0.6%
General Traffic	20%	Vehicular Traffic	40%	8%	Through Capacity	50%	4.0%
					Affected critical traffic locations	30%	2.4%
					Turning Capacity	20%	1.6%
		On-Street Parking	10%	2%	Number of Spaces	100%	2.0%
		Goods Movement	20%	4%	Delivery intensity of affected side	50%	2.0%
					Increase in hand carting distances	30%	1.2%
					Convenience of loading	20%	0.8%
		Curbcuts	10%	2%	Number of affected Curbcuts	30%	0.6%
					Curb activity	70%	1.4%
		Safety	20%	4%	No. of potential Traffic/LRT conflicts	30%	1.2%
					Pedestrian Safety	50%	2.0%
					Biking Safety	10%	0.4%
					Goods Movement Safety	10%	0.4%
Amenities	40%	Pedestrian Space	10%	4%	Number of Stations on Sidewalk	40%	1.6%
					Additional Pedestrian Space	60%	2.4%
		Land Use	10%	4%	Harmony	100%	4.0%
		East Side Livability	80%	32%	Less Vehicular Traffic	40%	12.8
					Less Emissions	20%	6.4%
					More public and open space	20%	6.4%
					General Accessibility	20%	6.4%
		Total		*100%*			*100%*

a - relative assessment
b - absolute assessment

Table 3.4-9: Assessment and Scoring of Alignments (Sensitivity)

Indicator	Weight	Assessment of Alignments				Scoring of Alignments			
		1	2	3	4	1	2	3	4
Overall Running Time	4.2%	4	4	4	3	0.168	0.168	0.168	0.126
Reliability	1.8%	4	3	3	4	0.072	0.054	0.054	0.072
Access for Residents east of 1st Ave	2.4%	2	3	1	1	0.048	0.072	0.024	0.024
Access for Residents west of 2nd Avenue	1.2%	2	1	4	4	0.024	0.012	0.048	0.048
General Access to Jobs	1.8%	2	1	4	4	0.036	0.018	0.072	0.072
No. of major institutions directly served	0.6%	2	4	1	1	0.012	0.024	0.006	0.006
Number of Directions with Interface	2.8%	2	1	4	4	0.056	0.028	0.112	0.112
Convenience of change	1.2%	2	1	3	4	0.024	0.012	0.036	0.048
Number of direct connections	2.4%	2	4	1	1	0.048	0.096	0.024	0.024
Distance to intersecting Subways	1.6%	2	1	4	4	0.032	0.016	0.064	0.064
Infrastructure	5.6%	1	4	4	2	0.056	0.224	0.224	0.112
Vehicles	1.2%	4	4	4	3	0.048	0.048	0.048	0.036
Stations	1.2%	4	2	2	1	0.048	0.024	0.024	0.012
Operators	7.2%	4	4	4	3	0.288	0.288	0.288	0.216
Maintenance of Vehicles	3.0%	4	4	4	3	0.12	0.12	0.12	0.09
Maintenance of Tracks	1.2%	2	4	4	4	0.024	0.048	0.048	0.048
Maintenance of Stations	0.6%	4	2	2	1	0.024	0.012	0.012	0.006
Through Capacity	4.0%	4	3	3	1	0.16	0.12	0.12	0.04
Affected critical traffic locations	2.4%	4	3	2	1	0.096	0.072	0.048	0.024
Turning Capacity	1.6%	3	4	4	2	0.048	0.064	0.064	0.032
Number of Spaces	2.0%	2	3	3	1	0.04	0.06	0.06	0.02
Delivery intensity of affected side	2.0%	2	4	4	1	0.04	0.08	0.08	0.02
Increase in hand carting distances	1.2%	2	2	2	1	0.024	0.024	0.024	0.012
Convenience of loading	0.8%	2	1	1	4	0.016	0.008	0.008	0.032
Number of affected Curbcuts	0.6%	1	4	3	2	0.006	0.024	0.018	0.012
Curb activity	1.4%	1	3	4	2	0.014	0.042	0.056	0.028
No of potential Traffic/LRT conflicts	1.2%	2	1	1	4	0.024	0.012	0.012	0.048
Pedestrian Safety	2.0%	4	2	2	4	0.08	0.04	0.04	0.08
Biking Safety	0.4%	4	2	2	3	0.016	0.008	0.008	0.012
Goods Movement Safety	0.4%	1	2	2	4	0.004	0.008	0.008	0.016
Number of Stations on Sidewalk	1.6%	1	2	2	4	0.016	0.032	0.032	0.064
Additional Pedestrian Space	2.4%	1	2	2	4	0.024	0.048	0.048	0.096
Harmony	4.0%	2	1	3	4	0.08	0.04	0.12	0.16
Less Vehicular Traffic	12.8%	1	2	2	4	0.128	0.256	0.256	0.512
Less Emissions	6.4%	1	2	2	4	0.064	0.128	0.128	0.256
More public and open space	6.4%	1	1	1	4	0.064	0.064	0.064	0.256
General Accessibility	6.4%	1	3	3	4	0.064	0.192	0.192	0.256
Total Score	100.0%					2.136	2.586	2.758	3.092

3.5 The Role of the East Side LRT Line

In order to better explain the relative role of an East Side LRT Line, the following chapter provides specific data about the Two-Way-Pair Alignment on Second Avenue as well as comparisons to existing plans for a Second Avenue Subway and the New York Bus Lanes. General advantages and disadvantages of LRT service were discussed in chapter 2.3.4 and therefore are not included. Also, the need for comprehensive planning is identified and suggestions for an integrated East Side LRT Line are made.

3.5.1 Traffic and Transportation

Decreased journey time

Both the East Side LRT Line and the Second Avenue Subway would significantly decrease journey times for East Side residents and improve accessibility to many destinations in Manhattan and the other boroughs. Compared to the existing M15 Bus service (scheduled times), the East Side LRT Line would be twice as fast during peak hours and still 20% quicker during late night service, running between 125th Street and South Ferry (Table 3.5-1). The faster LRT peak hour service is due to the faster boarding times of low-floor, multiple entrance LRVs and to the exclusive 100% right-of-way whereas bus service is impeded by high traffic volumes. This accounts for the M15 Limited bus being 75% longer in trip times during peak periods.

Lower LRT station frequency is partly compensated for by enhanced accessibility to rail stations compared to bus stops. Whereas bus stops provide only specific spot or corner access to buses, LRT stations would extend over a length of 166 feet (50.6 m) and LRVs would be accessible over the entire length.

As expected, estimates for a Second Avenue subway show even greater decreases in running times such as between 125th Street and South Ferry, journey times would be another 25% faster than LRT service.

Though the subway is the superior system for long Manhattan trips and trips between different boroughs, the East Side LRT Line provides faster service for most intra Manhattan trips. These trips, as previously shown, typically are not longer than 35 blocks or about 2 miles (3.2 km). These are distances where LRT's advantage of higher stop frequency and easier station accessibility results in significantly lower journey times.

Map 3.5-1 and 3.5-2 show a comparison of areas that are accessible within 5, 10 and 15 minutes by either taking the LRT line or the subway. The journey starts at 42nd Street on the surface and continues southbound. Waiting times are not taken into consideration, they depend on service frequency only. A prime disadvantage of the subway starts from the beginning of this trip: the longer walking time to the platform.

The comparison shows that the 5 min area is almost twice as large using the LRT and the 10 min area is still 30% greater than corresponding areas when using the subway.

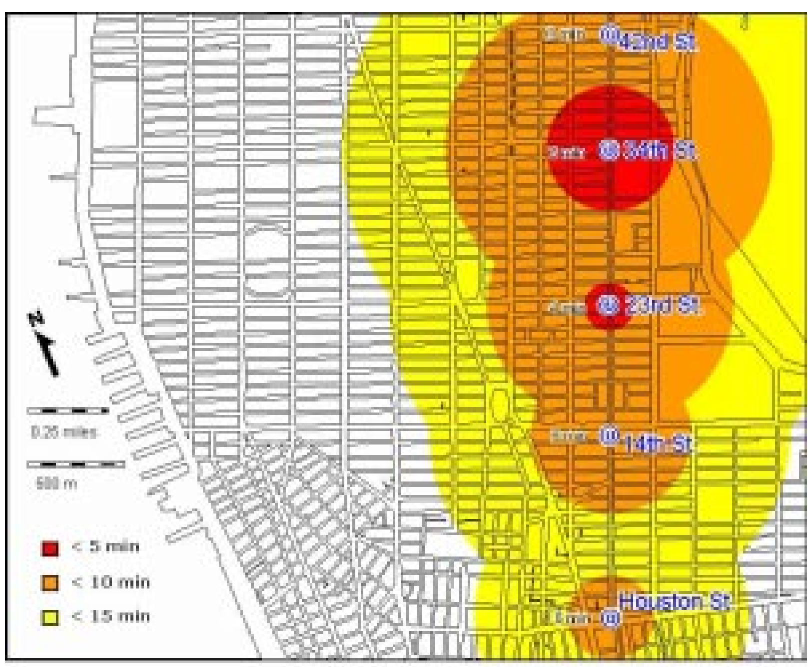
Table 3.5-1: Stops and Running Time Comparison

	ES LRT Estimate	**2nd Ave Subway Estimate**	**M15 Bus Schedule**	**M15 Ltd. Bus Schedule**	**Lex Ave Local Schedule**	**Lex Ave Express Schedule**
Number of Stops between 125th Street and South Ferry	53	15	71	39	20	10
Nite (12AM-4AM) Running Times in min 125th St. to South Ferry	40 (b)	*29*	49	48 (a)	31	23
Peak Hour (5PM-6PM) Running Times in min 125th St. to South Ferry	49 (c)	*35*	100	88	38 (d)	26

a - Early Morning Run
b - Optimal Performance with 20s Dwell Time
c - Estimate on the basis of a 20% running time increase for peak hour periods
d - South of Brooklyn Bridge No. 4 and 5 Train

Map 3.5-1: East Side LRT Line Accessibility up to 2 miles
Journey times from 42nd Street traveling south

Map 3.5-2: Second Avenue Subway Accessibility up to 2 miles
Journey times from 42nd Street traveling south



Intermodal interfaces

As previously shown, Alignment Alternatives 3 and 4 would have one direct subway connection, the F train, at Houston Street. Studies have shown that building new subway stations at 42nd or 63rd Street is exceedingly expensive.[1] However, better access from Second Avenue to the Lexington Avenue station of the E and F train, which extends almost to the middle of the block on 53rd Street between Second and Third Avenue, could be feasible.

As LRT allows bikes to be taken on board or stored next to the platform, a convenient interface with bicycle traffic would be available. In contrast to the subway no carrying and stair climbing would be necessary.

Finally, when either entering or leaving an LRV convenient transfer between a bus or taxi, which stops almost at the same location or right around the corner, may occur.

Network Implications

With the existing proposal for LRT on 14th Street as part of the Lower East Side LRT Shuttle and the 42nd Street LRT line, the possibility for direct "L-shape" LRT routes is another important advantage of LRT: At grade crossings and turns are easy to add in order to provide a more extensive LRT network.

This flexibility also allows the storage facility at 126th Street to serve other LRT segments of a possible Manhattan LRT network.

Stop overcrowding on the Lex Ave Subway

Whereas overcrowding on the Lexington Avenue Subway would be eased with a Second Avenue Subway, the East Side LRT Line would attract a smaller percentage of peak period subway riders.

Among the top twenty origin and destination pairs of the Lexington Avenue Subway (Table 3.1-1), three pairs of non-Manhattan to Manhattan trips (a in Table 3.1-1) and four pairs of Manhattan to Manhattan trips (b in Table 3.1-1) in the AM peak period are potentially

[1] NYCT, 1999, p. E-9

diverted to the East Side LRT Line. These pairs account for about 22% of the total peak period Lexington Avenue subway volume of 413,416 trips. Assuming a 20% diversion ratio (correspondingly to the average catchment area of the East Side LRT Line), Lexington Avenue subway volume could be decreased by 18,000 trips during the AM peak period.

The lower Lexington Avenue subway PM peak period volume of 361,409 trips is reduced by 14,456 trips assuming the same diversion ratio. Two pairs of Manhattan to non-Manhattan trips and six pairs of Manhattan to Manhattan trips are affected in the PM peak period.

In general, the potential for shifting trips from the other boroughs to the East Side LRT line depends to a high degree on the convenience of the transfer to the subway, whereas the Second Avenue Subway could provide a one-seat-ride for many of these trips.

Popular surface transit

Experience with LRT in other cities has shown that this mode is extremely popular with transit riders. While the proposed New York Bus lanes would provide more efficient bus service, the basic incentives besides journey time for riding the bus would remain the same. Besides the obvious advantages of LRT in general, New Yorkers will have the opportunity to take surface transit without riding the "old-fashioned, low-image" bus assuming the implementation of an East Side LRT Line. In particular for cosmopolitan New York City, with an overall emphasis on style and panache, a new age of world class surface transit which is up-to-date, efficient and, above all, user friendly and readily accessible, would be an attractive alternative to car and taxi travel, LRT will be easier to promote and more likely to succeed.

Accessibility for disabled persons

As previously discussed, the East Side LRT Line would provide improved mobility for disabled persons in wheelchairs. On the other hand, wheelchair accessibility to a new subway line is less convenient and would still require difficult transfers to other lines. Improving surface transit that is compatible with ADA requirements is an appropriate solution.

Riding enjoyment

In providing more inducements for the public to ride transit, the East Side LRT Line is unbeatable. Whether for tourists, commuters or shoppers, the riding experience with high-tech trains on the surface including a fabulous view of Manhattan's East Side, provides important advantages. Traditional bus service or trips through dark, noisy and unattractive subway tunnels are less pleasant travel options.

Shifting travelers from private cars and taxis to transit or non-motorized modes

To shift people from private cars and taxis to alternative modes, two methods can be used: push effects and pull effects.

On the push side, it is important to decrease the strong attraction of the private auto mode. Two ways are evident. First, the most accepted method is pricing. This is only modestly done in NYC, by bridge tolls (road pricing) and high parking fees. The second important push factor is a reduction in space provided for vehicular traffic, through fewer vehicle lanes and less parking space.

Pull factors are incentives for the transit and non-motorized alternatives. Among the most important for transit are lower journey times and increased riding enjoyment, and for non-motorized modes, improved walking and biking conditions and a more pleasant environment.

The highest mode shift rates can be expected to occur by using a combination of both strategies. However, push factors are not directly connected with a new subway line, but they are when building the East Side LRT Line because they reduce vehicular capacity in favor of the street-right of way. As previously shown, the capacity of Second Avenue decreases by 1,250 vph from today's capacity of 3,250 vph to 2,000 vph between 23rd and 63rd Street. Capacity south of 23rd Street decreases from 2,500 to 1,250 vph. The decrease of capacity would be far more along fully pedestrianized blocks with reduction of about 1,500 vph southbound and about 2,000 vph northbound, assuming a two-way First Avenue. Reducing the same amount of capacity when building the subway especially when above ground vehicles lanes will still be available for autos, is politically more difficult.

Pull factors related to journey times are higher with a new subway, taking into consideration that most private auto traffic is interboro traffic, where the subway is significantly faster. This advantage is compensated to a certain degree by the reduction of taxis inside the Study Area. Taxi riders are more likely to change to LRT, and its relatively enhanced surface service. Furthermore, as auto and taxi riders perceive "their" environment is on the surface rather than underground, their attention will be more easily attracted to LRT, than to the subway, as a possible transit alternative. Therefore the message of LRT to car and taxi users is much clearer: "We reduced your space to provide you this service alternative." Finally, the necessary street reconfiguration for the East Side LRT line could easily include increases in pedestrian and bicyclist space.

Most important for a successful mode shift is the implementation of a package of incentive and disincentive strategies, using as many synergistic effects as possible. To be successful, the East Side LRT Line should include such a package.

Special Treatment of the Queensboro Bridge

As shown before, the Queensboro Bridge entrance on Second Avenue is the most troublesome "hotspot" on Second Avenue. Therefore, a special treatment to solve existing and future problems is necessary. A possibility to minimize traffic impacts would be building an LRT tunnel under the bridge approach between 58th and 62nd Streets. Some portion of the existing old underground trolley station between 59th and 60th Street could be used and restored.

A more extensive plan including reconfiguration on the Queensboro Bridge was included in a proposal submitted for an urban design competition sponsored by the Van Alen Institute.

The proposal envisioned restoration of LRT service over the bridge into Queens on its outer lanes, today's pedestrian walkway, and closing the upper deck to traffic and creating pedestrian and bicycle space.[2] The lower deck would remain for vehicular traffic only.

This proposal would greatly reduce potential traffic/LRT conflicts on Second Avenue between 59th and 60th Streets.

Reduce traffic congestion

The degree of shifting from vehicular traffic to alternative modes, is dependent on the degree to which the "push" and "pull" strategies are applied.

Initially, today's peak traffic volumes on Second Avenue with about 3,500 vph could not be handled with the LRT plan where the remaining capacity - 2,000 vph - would guarantee congested conditions. The question of whether long-term conditions would lead to a corresponding mode shift which would result in a better situation than today can not be answered at this point. In conclusion additional studies about traffic shrinkage and diversion and the response to "push" and "pull" strategies need to be performed.

Traffic and Transit Safety

Safety should be maximized for vehicles, pedestrians, bicyclists and transit riders. On those segments where the Two-Way-Transit-Way operates adjacent to traffic lanes, separate signals for right turning vehicular traffic, fenced curb lanes on the west side of Second Avenue along blocks without LRT station, bike lanes on the opposite side of the street, and a clear arrangement of tracks are needed. Still, a Second Avenue subway would be safer because it does not interfere with surface traffic. Buses on the proposed New York Bus Lanes are deemed equally as safe as the LRT. Where the Two-Way-Transit-Way operates in a pedestrian mall, LRV speeds will be lower, and track areas will be paved in a manner that discourages pedestrians from walking on the trackway.

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[2] Gordon/Haikalis, 03/23/99

Creating Auto-Free Space

Most preferable blocks for the Pedestrian Zone Alignment are between Houston and 14th Street. This East Village part of Second Avenue is characterized by relatively low traffic volumes of about 1,000 vph and a pleasant walking environment with many shops, restaurants and cafés. Additionally Midtown and the Upper East Side provide several attractive segments of Second Avenue well suited for a pedestrian zone.

The transportation element of auto-free space is a major aspect. Providing excellent transit access along streets that are closed for vehicular traffic is one of the most important factors for success by guaranteeing enough potential retail costumers.[3]

However, creating more open and public space in cities goes far beyond a transportation issue and it has to be recognized as a generic urban element of living quality. Pedestrianizing the entire length of Second Avenue from Houston to 125th Street would create additional 54 acres (135,000 m²) of public open space on the East Side of Manhattan, a very dense area with few parks.

[3] Holguin-Veras, 01/29/99

3.5.2 Economy

Contribution to local economic development

Whereas the subway provides certain economic advantages of higher long distance accessibility (more than 3 miles), including a larger potential customer market for retail services on Manhattan's East Side, the East Side LRT line brings shoppers directly in front of these establishments' entrances. Additionally, transit passengers become aware of opportunities along the East Side when riding along Second Avenue which will not happen when traveling on the subway. Finally, LRT links retail establishments along the East Side with each other providing a larger supply of potential choices for customers and increasing the attraction of all businesses.

Capital Cost

To augment the capital cost estimates prepared by the NYCT for the Lower East Side LRT Shuttle (Segment 2 of the East Side LRT line), additional estimates were done for Segment 1 along Second Avenue and Segment 3 along Allen or Chrystie Street (Map 3.4-1). Construction cost for this 6.8 mile (10.9 km) long segment from Canal Street to 125th Street are about $ 680 million. These estimates, based on NYCT cost calculation of $ 90 million per mile for LRT are extremely high compared to other cities in the US. For example, San Francisco builds its new Light Rail Line extension with costs of $ 65 million per mile.[4] Assuming these guidelines, this stretch of the East Side LRT line would cost only about $ 440 million. For the same length, a Second Avenue Subway would cost at least about $ 5 billion. Therefore, construction cost for the LRT line, even with conservative estimates, would be less than 14% of those for the subway. Construction costs for New York Bus Lanes are lowest at only $ 40 million total.[5] Total capital cost for the LRT line, including the rolling stock, is estimated with $ 728 million.

[4] Moscovich, 09/01/99

[5] NYCT, 1999, Appendix

Table 3.5-2: Capital Cost for the East Side LRT Line, Segment 1 and 3 from Canal Street to 125th Street

Capital Investment Component	Miles or Units	Cost per Mile or Cost per Unit[1]	Costs from Canal to 125th Street (6.8 miles)
Structures, Tracks, Stations, Shops and Yards			
Right of Way Preparation and Construction	6.8	35,000,000	238,000,000
Concrete Roadway/Track	6.8	50,000,000	340,000,000
Line & Station Structure	6.8	200,000	1,360,000
Stations	38	700,000	26,600,000
Shops	1	27,000,000	27,000,000
Yard Tracks	1	5,000,000	5,000,000
Signal Communications, Power & Line Equipment			
Signals	6.8	300,000	2,040,000
Communications	6.8	2,000,000	13,600,000
Traffic Signal Configuration	6.8	650,000	4,420,000
Electric Power / Overhead Wire	6.8	3,000,000	20,400,000
Line Equipment	6.8	200,000	1,360,000
Total Construction Cost			679,780,000
Rolling Stock			
Low Floor Light Rail Vehicles	16	3,000,000	48,000,000
Total Capital Cost			727,780,000

[1] NYCT, Mesa Study

Construction Schedules

A total of three to four years would be required to construct the East Side LRT Line. This would take somewhat longer than implementing the New York Bus Lanes, which could be done in about two years. Building a Second Avenue Subway is estimated to take up to 10 years.[6]

[6] NYCT, 1999, S-3 f.

3.5.3 Environment

Aesthetically pleasing environment

Depending on individual taste, questions of aesthetics are extremely difficult to evaluate. Many people are concerned LRT might not be visually pleasing due to its use of overhead wires. However, this could be minimized by attractive pole design and reducing the number of supporting wires. Furthermore, implementing well designed LRVs, together with a more pleasant street configuration, reduces adverse effects and results in an overall aesthetical plus. For those segments in a transit mall, positive visual impacts would outnumber the negatives.

Community and neighborhood character

Implementing a new attractive and well suited transit system improves community ambience and adds to neighborhood character. Compared to the anonymous subway out of sight somewhere in the ground, the LRT Line will represent Manhattan's East Side and residents will identify themselves with it.

3.6 Possible Implementation of the East Side LRT Line as part of an Integrated Transportation Plan

In this section of the study, NYCT's MESA proposal for a Build Alternative 2 is assumed as a starting point. Again, this alternative proposes a subway north of 63rd Street beneath Second Avenue to 125th Street connecting with the Lexington Avenue subway. The most southerly subway station would be located between 69th and 72nd Street. Additionally the Lower East Side LRT Shuttle and New York Bus Lanes would be implemented.

In this study as a first implementation step, the East Side LRT Line would be built as a extension of the LES LRT Shuttle, running north on Allen or Chrystie Street from the Canal Street intersection, than along Second Avenue to a terminus at 70th Street. There it would connect with the 69th-72nd Street Station. In a second step, an extension north to 125th Street is possible. Furthermore, the LRT would connect with the proposed 42nd Street crosstown LRT Line, running from the UN Plaza to the Hudson River.

The frequently discussed extension of a Second Avenue subway south of 63rd Street to Lower Manhattan would accomplish efforts to provide a full transit corridor along Second Avenue. Synergistic effects between the East Side LRT Line and the Second Avenue Subway, such as using the LRT as a feeder or local service to an express subway, help to reduce capital costs for subway stations and provides an even faster and therefore more efficient subway service.

In this way, a Second Avenue Subway serving the entire East Side of Manhattan could have the following eight stations: 125th Street, 86th Street, 72nd Street, 53rd Street, 44th Street, 14th Street, Fulton Street and Whitehall Street. The additional six stations necessary for typical subway service would not have to be built, reducing the total construction cost of $ 4,920 million by $ 500 million. Put differently, with the costs saved for the subway stations, fully 70% of the East Side LRT Line between Canal and 125th Street could be funded.

In order to avoid further traffic congestion on Manhattan's East Side, especially along a Second Avenue with LRT service as well as all over the island, so called "gatekeeping" concepts supported by Intelligent Transportation Systems (ITS) should be installed on all bridges and tunnels. With this plan, only the hourly amount of vehicles identified as not causing congestion are allowed to enter Manhattan. Additional bridge and tunnel tolls are highly recommended to perform this "gatekeeping" function and avoid long queues forming at the bridge approaches in Brooklyn and Queens. Tolls would provide the needed incentives to switch motorists to public transit and to finance costly transit improvements.

Chapter 4

Conclusion

4 Conclusion

Implementation of LRT along Manhattan's East Side is recommended, based on the conclusion of this research study, on the condition that it is part of an integrated transportation plan for New York City. In comparison to other Second Avenue transit remedies, the LRT solution is a cost effective solution that New York City can afford while providing the benefits of quicker journey times, an enhanced quality of life as well as the basis for a strengthened and expanded economic outlook for retail and commercial establishments in an area of NYC that has waited far too long for additional mobility options.

Important next steps to advance LRT include an extensive study about vehicular traffic shrinkage and diversion for the East Side Study Area. Further, possibilities of ITS to optimize traffic signal times and goods movement as well as to implement "gatekeeping" concepts, have to be analyzed. Finally, origin and destination data on the microscale level has to be included to make a final decision about alignment alternatives and station placements.

During the preparation of this study, many public hearings and presentations concerning transit improvements in Manhattan were attended and dialogs with residents, local transportation planners and elected officials were held. Most reactions to LRT proposals were ones of reservation. Residents fear traffic diversion with higher volumes in side streets as well as an overall increase in traffic congestion. Local political leaders again take these concerns of their constituency very seriously and avoid supporting light rail. On the other hand, LRT is more popular among transportation and urban planners as well as architects. Therefore, the public is confronted with LRT proposals endorsed by transport professionals again and again without the actual experience of specific characteristics and advantages of this transit mode. For New Yorkers, LRT remains a means of transportation distant and inaccessible and far too visionary. This is obviously the result of living in a city that has not seen street railways for over 40 years. Importantly, the more that was known by the public about light rail as an option, the more receptive the listener became as these concepts were discussed and compared to other alternatives.

Therefore, the opening of New Jersey Transit's Hudson-Bergen LRT Line, immediately on the other side of the Hudson River, beginning in March 2000 is welcomed with great expectations. If New Yorkers will be able to see, ride and experience a successful operating LRT system in an urban setting only one mile away, they might become more comfortable with the concept of state-of-the-art transit.

In any event, informing residents, decision makers and others about the benefits of LRT is a critical and important step. Whether it is a professional journal published by the Transportation Research Board, a newsletter, like the "Streetcar News" that was published by the Committee for Better Transit (CBT), the work of organizations like the Village Crosstown Trolley Coalition (VCTC) or LRT presentations offered by the Institute for Rational Urban Mobility (IRUM) as well as the study in hand, all intend to provide more user orientated information about the LRT mode. Taken as a whole, these varied organizations might advocate and lobby for a proposal like the MTA's Lower Manhattan LRT Shuttle or the 42nd Street LRT Line and have the critical mass necessary for success. Once a line opened in Manhattan and a broad based coalition of professional organizations and citizen groups alike are established, further extensions will be much easier to achieve.

Further strategies to increase the likelihood of light rail transit in Manhattan include motivating other interest groups. To cite one example, better surface transit is of special importance for disabled persons, therefore corresponding organizations might want to support LRT. Environmentalists have a strong motivation to reduce petroleum fueled vehicles in the street and substitute electrically powered LRT vehicles for them. As such, the New York Power Authority has already shown interest in electrically powered trolley buses; they probably will have the same interest in light rail, too. Finally, light rail vehicle manufacturers and industry suppliers have a good reason to advocate LRT movements. By building a coalition of supporters, LRT can advance in New York City and set a positive example of transportation planning.

In the end, putting tracks in Manhattan's street is not just the introduction of another surface transportation system, but a millennium message from New York City: Let's bring people back to where they belong: not under, but in the heart of the city.

Final Comment

Working on light rail transit as part of a sustainable transportation network in an incomparable place like New York City provided me with many positive incentives for this student work. Analyzing the daily real world environment created an intense perception of "how the city works" while the advantage of total academic freedom permitted me to focus on visionary plans within this context for a system that, at least to date, has not been introduced.

Further, working with the Institute for Rational Urban Mobility, Inc. meant more than drawing up a study for university credits only. To provide research results for possible further practical use was a meaningful motivation. Additionally, the study's relevance to present conditions was a major aspect even though this resulted in a complication of obtaining needed data especially from the Manhattan East Side Transit Alternatives Study (MESA). Due to political reasons in connection with a proposal for a Second Avenue Subway, this report was not released until recently when this student study was almost finished.

Nevertheless, the following agencies have been very helpful: The New York Metropolitan Transportation Council (NYMTC), New York City Transit (NYCT), New York City Department of Transportation (NYCDOT), New York City Department of City Planning (NYCDCP). On the side of LRV manufacturers, Adtranz, Breda and Siemens were very cooperative. Technical support was made available by Konheim & Ketcham as well as Transportation Alternatives (TA) which also was exceptionally helpful by providing an appropriate workspace.

Finally, thanks to the extensive support and guidance of and critiquing by Mr. George Haikalis as mentor, the work was successfully completed.

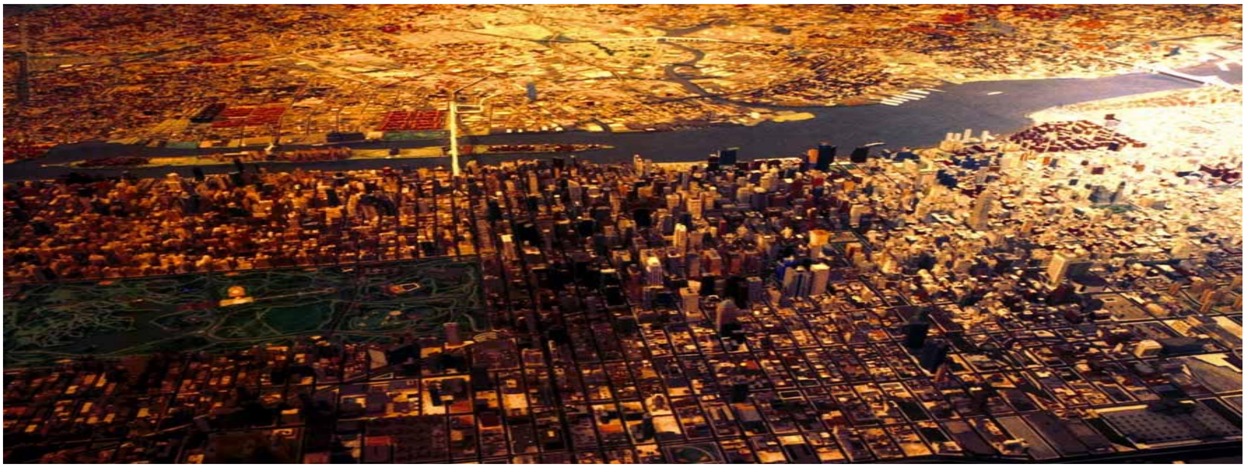
Appendices

A, B, C, D, E

Appendix A - Pictures

Lower Manhattan and the Lower East Side. Looking northeast. Brooklyn, Manhattan, and Williamsburg Bridge.

Manhattan's East Side. Looking south from Harlem. 1st and 2nd Avenue in the center. First bridge from the bottom: Queensboro Bridge.



60th Street Screenline. Looking east. Central Park, Upper East Side, Midtown, East River and Queensboro Bridge.

Pictures taken from the NYC panorama model at the Queens Museum of Art

Appendix A - Pictures

Busy curbcut at the NYU Medical Center on First Avenue. Looking north.

Long procedure: boarding an MTA bus with a wheelchair.

Preferring the cab over the bus. Typical scene in Manhattan.

The Brooklyn Bridge Lexington Avenue subway station. Express subway on the left, local subway on the right.

Interior of NYC subway cars.

Appendix A - Pictures

Second Avenue at St. Mark's Place. Looking north.

First Avenue and St. Mark's Place. Looking north.

Appendix A - Pictures

Second Avenue at 33rd Street. Looking northwest. Residential/Retail Mix along the avenue, high-rise residency and office buildings in the background.

The Queensboro Bridge ramp between 59th and 60th Street ending at Second Avenue. Looking west.

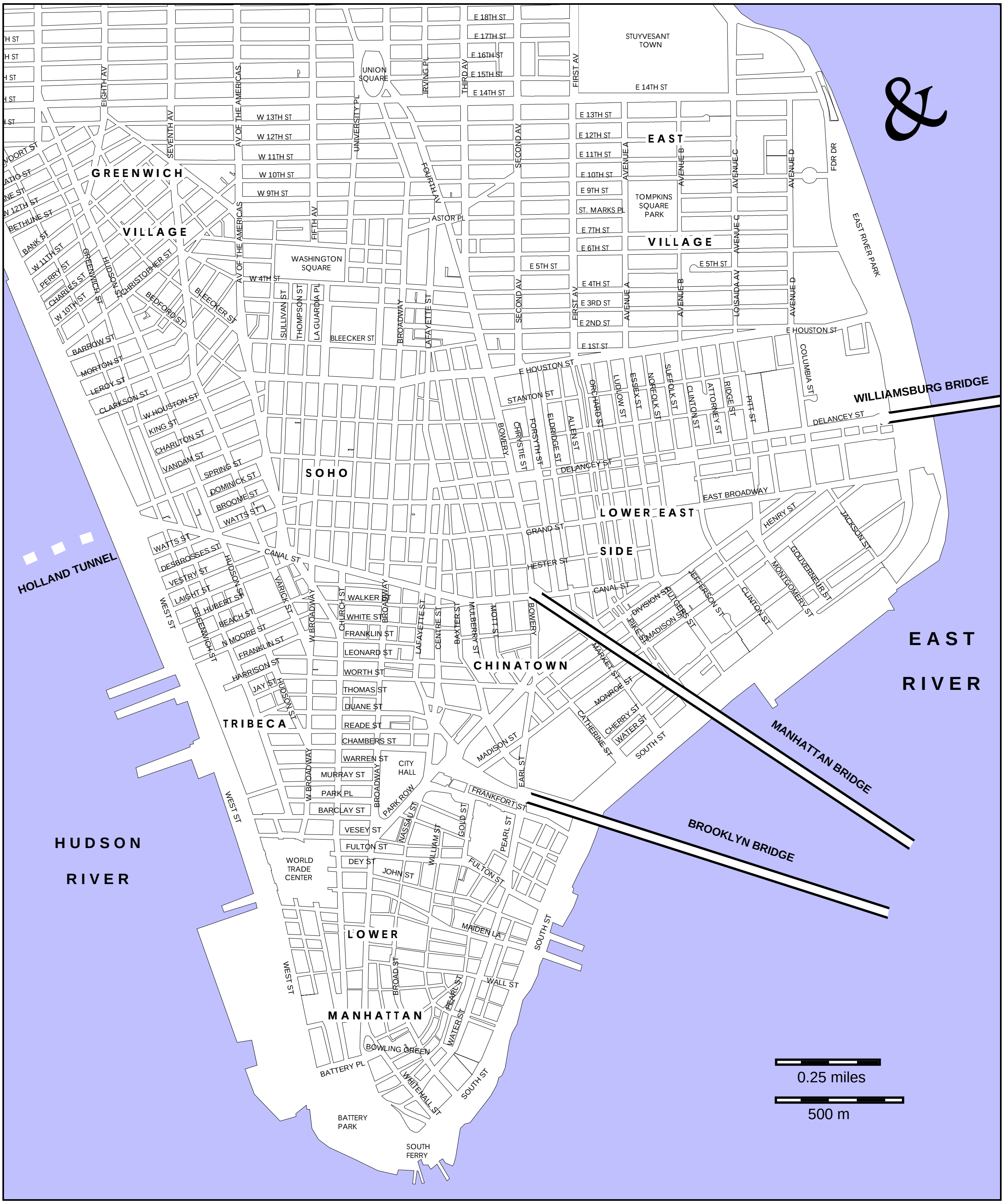
Appendix A - Pictures

First Avenue at 48th Street. Looking north. Exit of the UN underpass, originally designed for two-way traffic.

First Avenue south of 59th Street. Looking south. Bus lane along the eastern curb lane.

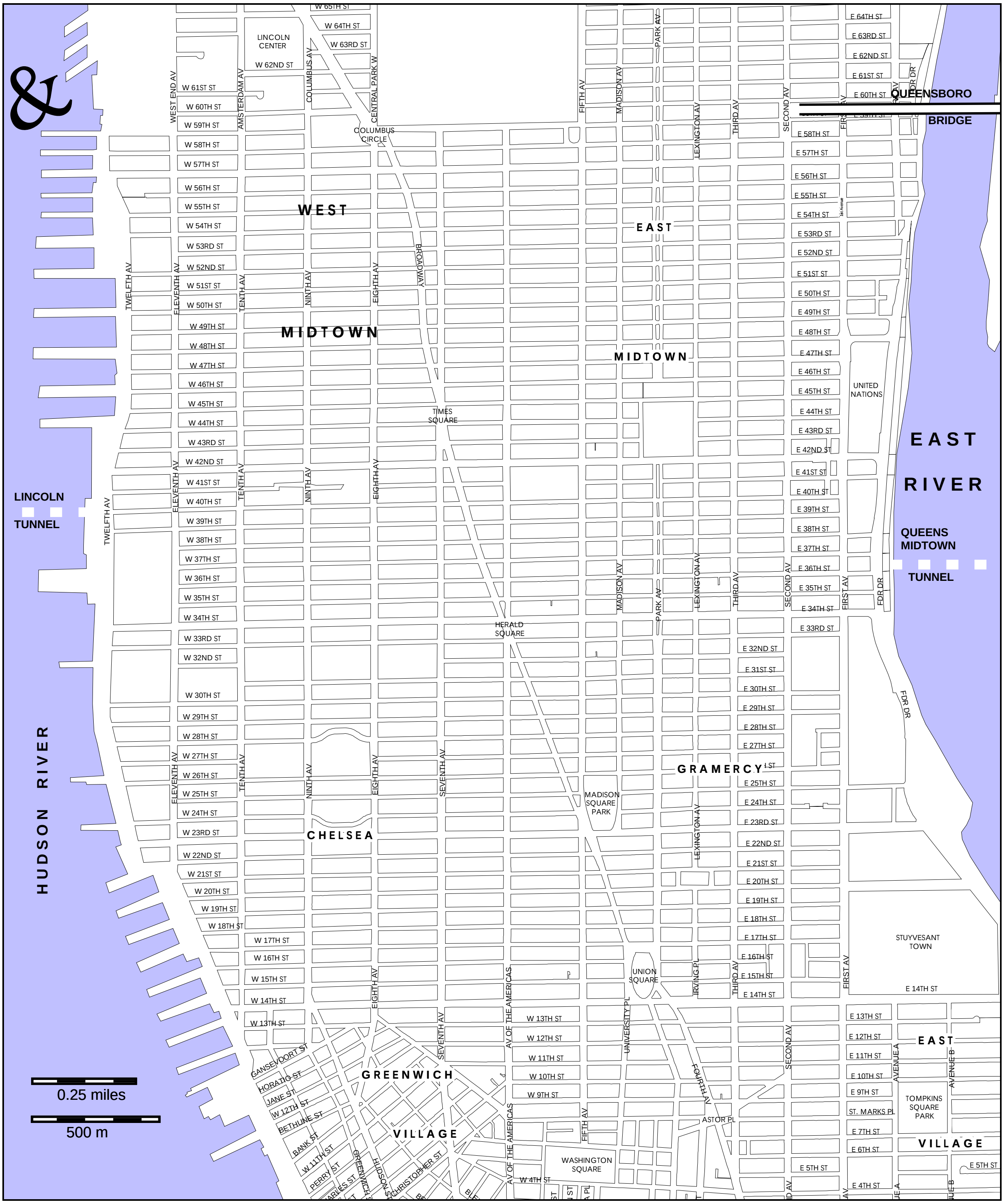
Appendix B - Manhattan Map

Map B-1: Manhattan south of 14th Street



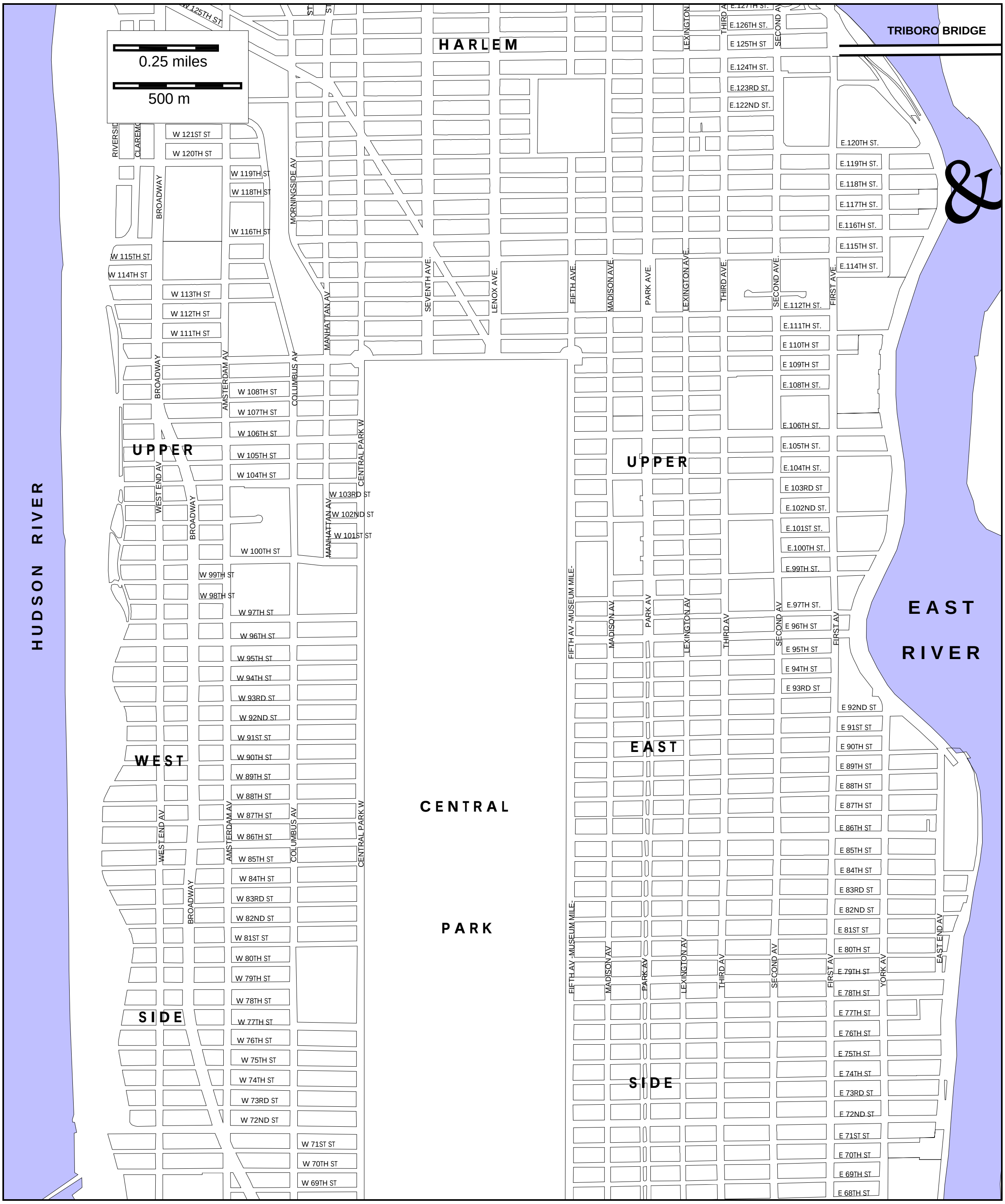
Appendix B - Manhattan Map

Map B-2: Manhattan between 14th and 63rd Street



Appendix B - Manhattan Map

Map B-3: Manhattan between 63rd and 125th Street



The Journey Time Model

This model is composed of two elements. First, a calculation for access times depending on the station frequency and second, a calculation for running times also depending on the station frequency. Waiting time is not included; it depends exclusively on the service frequency.

Table C-1 shows the approach chosen for the access time calculation for a station frequency from every 2nd to every 4th block. Representative origins and destinations along the avenue and the cross streets have been identified. Stations are assumed to extend over the entire block so that one station provides access to the LRT from two cross street intersections. For further simplification, only the two intersection points have been taken as "stations" and the following walking distances have been specified:

Only the walking time along the avenue, parallel to the LRT Line, was included. Walking times along 90 degree cross streets are not dependent on the station frequency. Furthermore, origins and destinations (O/D) on the avenue and the cross streets were assumed as concentrations around intersections. Therefore O/Ds on one block along an avenue are divided into either belonging to intersection one or two.

Accordingly, representative walking times (Column 3 "Time t [s]" in Table C-1) for stations every 2nd block are zero seconds. With a greater station spacing of every 3rd block, O/D concentrations with a distance of one block are included. For these a walking distance of an average of 60 seconds per block 240 feet (80 m) was assumed.

Finally the average access time, including access to and from the LRT station, was calculated in the last column.

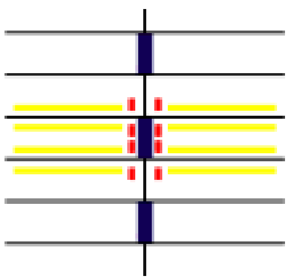
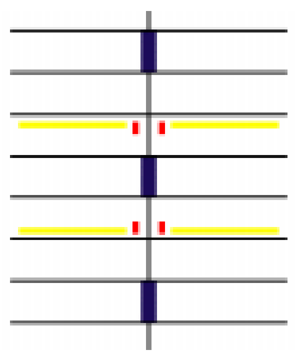
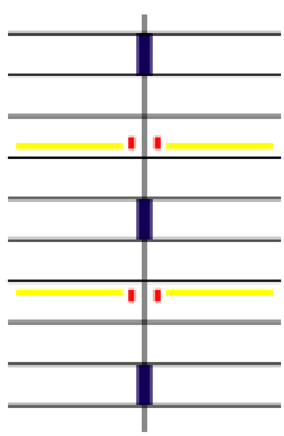
For modeling running time, a specific average trip length (for the East Side LRT Line, 35 blocks) was taken and the four running time elements, acceleration, constant speed, deceleration and station dwell time, were calculated. Not included was the fact that the higher the station frequency is, the lower the station dwell time becomes because of less passengers boarding and departing from the vehicles at each station. Table C-2 gives specific numbers for a 35 block length trip and following figures give an overview about the sensitivity of the model. It also includes a factor for the subjective journey time.

Table C-1: Access Time Model

LRT Station

Origins and Destinations (O/D) along one side of a cross street (A)

Origins and Destinations (O/D) along half of one side of an avenue (B)

Frequency N[a]	Additional to the next higher Station Frequency			Total Access Time T_T [s] to station	Average Access Time T_A [s] per trip
	Representative Catchment Area of one station	Time[b] t [s]	Amount of O/D per Station		
N = 2		0	8A + 8B = 8C	$T_{T2} = t \bullet 8C$ $T_{T2} = 0$ s	$T_{A2} = 2 \bullet T_{T2} / 8C$ $T_{A2} = 0$ s
N = 3		60	4A + 4B = 4C	$T_{T3} = (t_2 \bullet 8C) + (t_3 \bullet 4C)$ $T_{T3} = 240$ s	$T_{A3} = 2 \bullet T_{T3} / (8C + 4C)$ $T_{A3} = 40$ s
N = 4		60	4A + 4B = 4C	$T_{T4} = (t_2 \bullet 8C) + (t_3 \bullet 4C) + (t_4 \bullet 4C)$ $T_{T4} = 480$ s	$T_{A4} = 2 \bullet T_{T4} / (8C + 4C + 4C)$ $T_{A4} = 60$ s

a - Station Frequency in every n th block [n]

b - Walking Time of additional riders compared to the next higher Station Frequency

Table C-2: Access, Riding and Journey times for an average trip of 35 blocks, a dwell time of 20 seconds and a subjectivity factor for the access time of 1.5

Frequency N	Average Access Time T_A [s] per Trip	Average Riding Time T_R [s] per Trip	Average Journey Time T_J [s] per Trip
2	0	726	726
3	60	552	612
4	90	465	555
5	144	412	556
6	180	377	557
7	231	353	584
8	270	334	604
9	320	319	639
10	360	308	668
11	409	298	707
12	450	290	740
13	498	284	782
14	540	278	818
15	588	273	861
16	630	268	898
17	678	265	942
18	720	261	981
19	767	258	1025
20	810	255	1065

Figure C-1: Journey Time and Stop Frequency
Trip Length: 35 blocks, Dwell Time: 20 s, Subjective Access Time Factor: 1.5

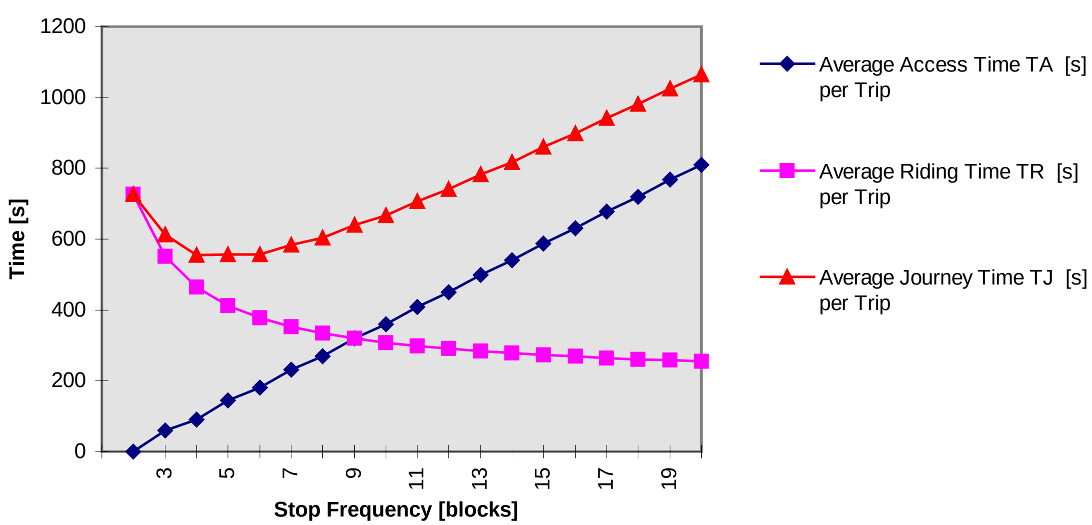


Figure C-2: Journey Time and Stop Frequency
Trip Length: 35 blocks, Dwell Time: 10 s, Subjective Access Time Factor: 1.5

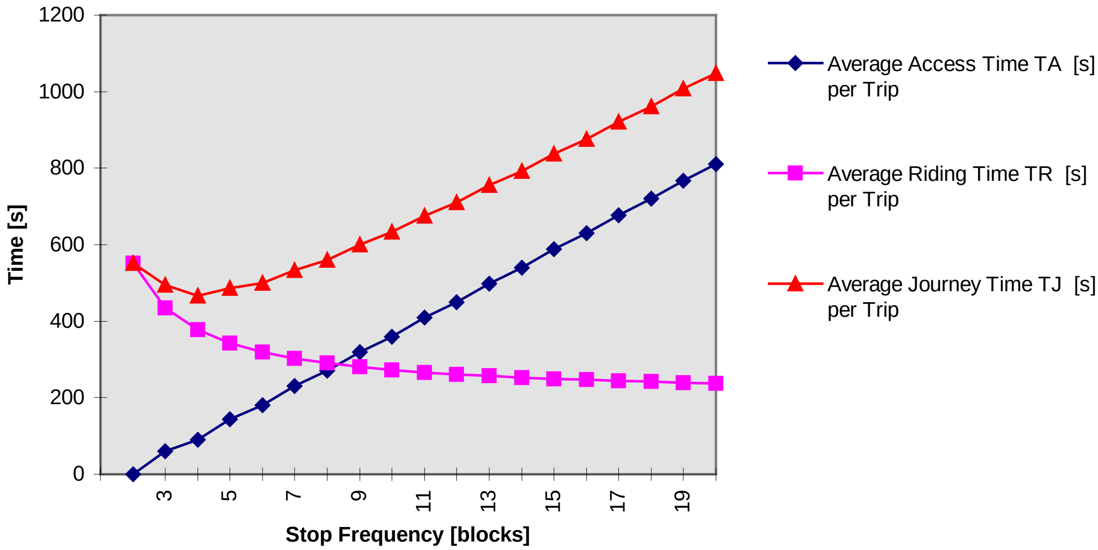
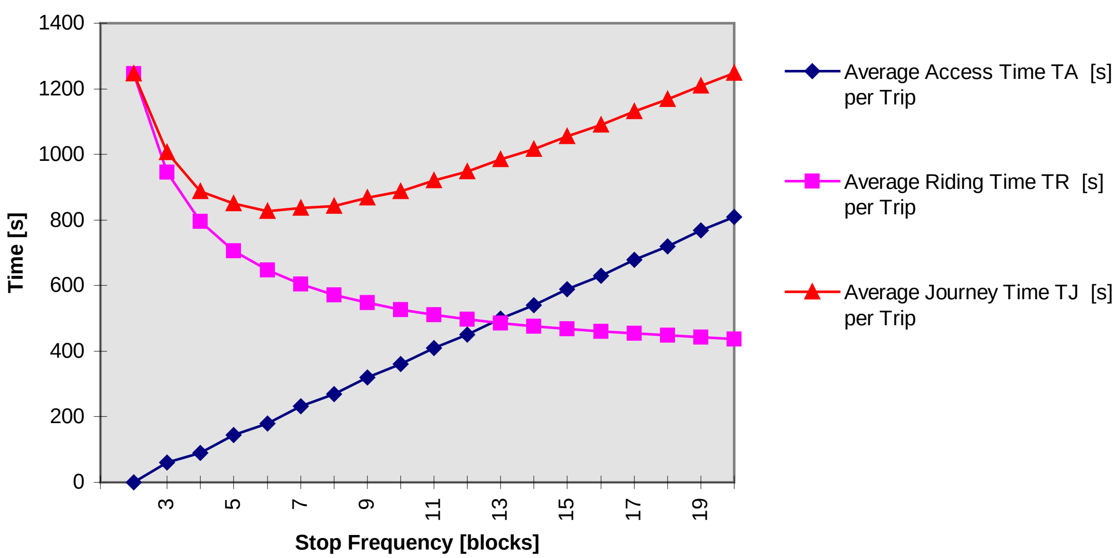


Figure C-3: Journey Time and Stop Frequency
Trip Length: 60 blocks, Dwell Time: 20 s, Subjective Access Time Factor: 1.5



Conversion Factors

Length

1 inch	2.54	centimeters
1 foot	30.48	centimeters
1 yard	91.44	centimeters
1 meter	39.37	inches
1 mile	5280	feet
1 kilometer	0.6214	miles

Appendix E - Addresses

Relevant Agencies

Columbia University
Graduate School of Architecture, Planning and Preservation
400 Avery Hall
1172 Amsterdam Avenue
New York, NY 10027
Phone: (212) 854-3056

Committee for Better Transit (CBT)
P.O. Box 3106
Long Island City, NY 11103
Phone: (718) 728-0091

Institute for Rational Urban Mobility, Inc. (IRUM)
One Washington Square Village, Apt. 5D
New York, NY 10014
Phone: (212) 475-3394, Fax: (212) 475-5051
http://www.geocities.com/CapitolHill/Senate/2891/

Institute for Transportation Systems
The City College
New York, NY 10031
Phone: (212) 650-8050, Fax: (212) 650-8374

Konheim & Ketcham
175 Pacific Street
Brooklyn, NY 11201
(718) 330-0550

Metropolitan Transportation Authority (MTA)
347 Madison Avenue
New York, NY 10017
http://www.mta.nyc.ny.us/

New York City Department of City Planning (NYCDCP)
22 Reade Street, New York, NY 10007-1216
Phone: (212) 720-3300
http://www.ci.nyc.ny.us/html/dcp/home.htm

New York City Department of Transportation (NYCDOT)
40 Worth Street
New York, New York 10013
Phone: (212) 225-5368
http://www.ci.nyc.ny.us/html/dot/home.htm

Appendix E - Addresses

New York City Transit (NYCT)
370 Jay Street
Brooklyn, NY 11201

New York Metropolitan Transportation Council (NYMTC)
1 World Trade Center, Suite 82 East
New York, NY 10048-0043
Phone: (212) 938-3300, Fax: (212) 938-3295
http://www.nymtc.org/

Regional Plan Association (RPA)
4 Irving Place, Seventh Floor
New York, New York 10003
Phone: (212) 253-2727, Fax: (212) 253-5666
http://www.rpa.org/

Technical University Berlin
Department of Track and Railway Operations
Sekr. SG 18
Salzufer 17-19
10587 Berlin
Phone: 01149-30-314-23314
Fax: 01149-30-314-25530
http://www.railways.tu-berlin.de/

Transportation Alternatives (TA)
115 West 30th Street, 12th Floor
New York, NY 10001
Phone: (212) 629-8080, Fax: (212) 629-8334
http://www.echonyc.com/~transalt/

Tri-State Transportation Campaign
240 West 35th Street #801
New York, NY 10001
Phone: (212) 268-7474
http://www.tstc.org

Village Crosstown Trolley Coalition (VCTC)
P.O. Box 409
Village Station
New York, NY 10014
Phone: (212) 475-3394 Fax: (212) 475-5051
http://www.geocities.com/broadway/2888

Light Rail Vehicle Manufactures in the US

Adtranz - DaimlerChrysler Transportation
(North America) Inc.
1501 Lebanon Church Road
Pittsburgh, PA 15236-1491
Mike Cassidy (412) 655-5422
http://www.adtranz.com/

Alstom Transportation, Inc.
1 Horton Street
Hornell, NY 14843
Charles Wochele (610) 666-6966 1199
http://www.transport.alstom.com/

Bombardier Transit Corporation
101 Park Avenue, Suite 2609
New York, NY 10178
Francine Dorocher Monin (514) 441-3190
http://www.transportation.bombardier.com/

Breda Transportation, Inc.
261 Madison Avenue
New York, NY 10016
Lucia Di Meglio (212) 286-8000

Siemens Transportation Systems, Inc.
701 Pennsylvania Avenue NW, Suite 720
Washington, DC 20004
Elaine Dezenski (202) 434-4821
http://www.sts.siemens.com/

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Haikalis, George . The Institute for Rational Urban Mobility, Inc. President. New York. NY. 03/20/99

Holguin-Veras, José. Institute for Transportation Systems. The City College. Associate Professor. New York. NY. 01/29/99

McNamara, Sue. Bike Coalition Philadelphia. New York, NY 06/14/99

Moscovich, José Luis. San Francisco County Transportation Authority. San Francisco. Director, Plans & Programs CA. 09/01/99

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