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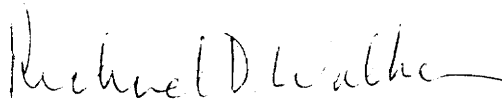
**A STUDY OF THE RELATIONSHIP
BETWEEN RAPID RAIL TRANSIT AND URBAN DEVELOPMENT**

by

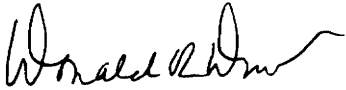
Hao Howard Chang

Thesis submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of
Master of Science in Civil Engineering

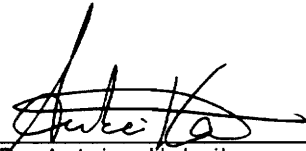
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**A STUDY OF THE RELATIONSHIP
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Hao Howard Chang

Dr. Richard David Walker

(ABSTRACT)

The thesis presents an opportunity to study relationship between rapid rail transit system and urban development through measuring various changes caused by the rapid rail transit improvement in Washington, D.C., Beijing, China, and Vancouver, Canada. Due to the reason that the three systems are all well-planned systems, they are not only the important parts of urban public transit, but also tools for guiding urban and regional development.

Three principal goals are identified for these systems: relieve traffic congestion; provide a transit alternative to the automobile drivers; and support a compact pattern of regional town centers out from an over-developed downtown area to form a polycentric urban pattern.

The rapid rail transit is found to serve a majority of riders going to and from work. It attracts not only former auto drivers but also new riders from other modes due to the fact that the system is a time and cost-saving transportation tool for people.

Joining other factors, rapid rail transit could shape land-use pattern, reduce decline of old downtown, and induce development. It influences society and economy positively in that region. Although there is no direct relation between the improvement and regional population growth, it influences the population re-distribution because it attracts new employment to its envelope and influence areas from other parts of the metropolis.

A good transportation system in a metropolis should satisfy the variety of needs for mobility engendered by a very heterogeneous population. A system which mainly depends on automobiles cannot meet the needs. A rapid rail transit system could compensate for the insufficiency of automobile. As a critical and irreplaceable part of an urban transportation system, rapid rail transit plays an increasingly important role.

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Thanks to my fellow graduate students and friends at Virginia Tech.

INTRODUCTION

1. STUDY PURPOSE

The purpose of this thesis is to find relationship between urban rapid transit system and urban development through measuring various changes caused by the rapid rail transit improvement. It presents an opportunity to study the effects of a major rapid transit improvement on travel behavior and the related effects of these travel changes on land use, social-economic activities, and urban physical forms comprehensively in three metropolitan regions -- Washington, Beijing and Vancouver. The effects of these systems on the three regional transportation networks, environment, human life styles, and public policy are also assessed.

The reason that the study chooses Metrorail of Washington, Subway Beijing and SkyTrain in Vancouver is that they are the typical cases in their countries: Subway Beijing is the first one in China, Metrorail is the single most costly civil construction projects ever conducted in U.S., and only the second rapid transit systems to be built

in the country since Depression, and SkyTrain is the world's longest, completely automated light rapid rail transit system.

There are many critiques about using the magnitude of rapid rail transit's expenditure to build a relatively short system. This study is also designed to appraise the effects of such a major transportation improvement comprehensively.

2. STUDYING METHODS

The study made use of a wide variety of evidence. A major effort was denoted to the assembly of available data and literature on the impacts of actual rapid rail transit systems in the three metropolises including historical, descriptive, analytical and policy sources and descriptive statistical data and investigation results.

The term rapid rail transit as used here refers not only to conventional rapid rail transit -- Metrorail of Washington, and Subway in Beijing, but also to light rail transit -- SkyTrain of Vancouver.

A major aspect of this study is to compare the difference of statistic data and survey results before and after constructing these systems in order to find the interactions between urban development and rapid transit improvement.

There are three common research models used in determine the effects of the rapid rail transit service in causing changes in every fields. The first is the "control area" model, and the second is the "before and after" model, and the third is the "with or without" model.

The "before and after" model assumption is that it is possible to take measurements prior to and after the initiation of a new transportation improvement such as

subway, compare the two measurements, and attribute the difference to the system. The staged opening of the three rapid rail transit systems make them difficult to apply this model in the usual approach. One method of handling such a time-dependent problem is to reduce the duration between the before and after periods to such a small increment that other effects would be minimized.

One problem with the "before and after" model is that over a short time span, there may be other forces at work besides the opening of rapid transit service. To compensate for this, one method used in this study is the "control area" model. This model is more appropriate for analyzing land use changes. It attempts to identify two areas which are alike in every way except that one has rapid rail transit service. This technique is limited by the fact that it is virtually impossible to find areas which are alike in every way than the availability of rapid rail transit service. Moreover, it is also possible that they could be influenced by factors other than rapid transit. Even so, a modification of the control area approach can be used to interpret growth patterns by comparing growth around certain rapid rail transit stations with growth patterns in the remainder of the region.

The last technique which has the potential to deal with the complexities of measuring impacts in a growing community is the "with or without" model. This model's assumption is that an urban region is a system undergoing many changes besides new transportation improvements. The model measures the observable conditions after the construction of a certain improvement and compares them to what might have happened without the improvement, or to the "most likely" alternative, which would have been a rapid bus system. It was felt that projecting alternative futures was so speculative that the inherent uncertainty could introduce much greater differences than the actual differences due to rapid rail transit.

3. STUDY FORMAT

This study is intended to summarize impacts of rapid rail transit improvements. The results of the study provide a great deal of descriptive analysis of the initial effects of SkyTrain, Metrorail and Subway Beijing. The data which can be brought to bear include Metropolitan Vancouver Origin Destination Survey of 1985, SkyTrain Rider Survey of 1987, Canadian Census and Greater Vancouver Regional Statistics, Metrorail Passenger Surveys of Washington Metropolitan Area Transit Authority (WMATA), Surveys of Central Area Commuters of Metropolitan Washington Council of Governments (COGs), U.S. Census, Census of Retail Trade in Washington, D.C., COG Regional Employment Census, COG Residential Building Permit File, Census Beijing, Public Transit Rider Survey of Beijing, Statistics of Subway Beijing.

Each of these data sources provide a different perspective on rapid rail transit impacts, and each has certain limitations. Combining these data sources provide insight into the effects of rapid rail transit impacts which would not be possible using each of these data references independently.

Within these chapters, the role of rapid transit in each situation has been analyzed; conclusions have been drawn regarding both the degree of transportation impact and the importance of other factors in interaction with each rapid transit improvement. The purpose of each of the remaining chapters is as follows:

Chapter 1: Metropolises and Their Transportation System

Overview the three metropolises and their transportation system, especially the rapid transit system -- the past, the improvements and the current situations.

Chapter 2: Effects of Rapid Transit on Ridership

Analyze the ridership growth of rapid transit; mode of access to and from the system; changes in the amount of induced and diverted travel; the effect of rapid rail transit on total transit level; classification of travel purposes, characters of riders.

Chapter 3: Rapid Transit and Urban Form

The three metropolises adopted the polycentric city pattern to direct their urban development. After analyzing the urban forms of three metropolises, this chapter focuses on how the rapid rail transit system help to achieve the planned polycentric pattern, and why the pattern is the best one which suit the rapid transit improvement, and how the pattern strengthen rapid transit's impacts.

Chapter 4: Rapid Transit and Land Use

The rapid transit's impact on different land uses is evaluated in this chapter, including residential, public, commercial, educational and recreational uses. The role of rapid transit and other factors are also evaluated.

Chapter 5. Rapid Transit's Effects on Society and Economy

Study interaction between rapid rail transit and the city comprehensively in different social-economic types: pure American type - Washington, D.C., semi-European type - Vancouver, and pure Oriental type - Beijing. The studying fields include population and employment, business and economy, environment, safety and crime, mobility, etc..

Chapter 6: Comments and Critiques

After comparing the difference of public attitude and government policies to the rapid rail transit system between U.S. and Canada (and European countries), this chapter comments upon the current situation and future of rapid rail transit in the U.S..

Given the broad study on the rapid rail transit and urban development persented in these chapters, a conclusion will make based on the studying results.

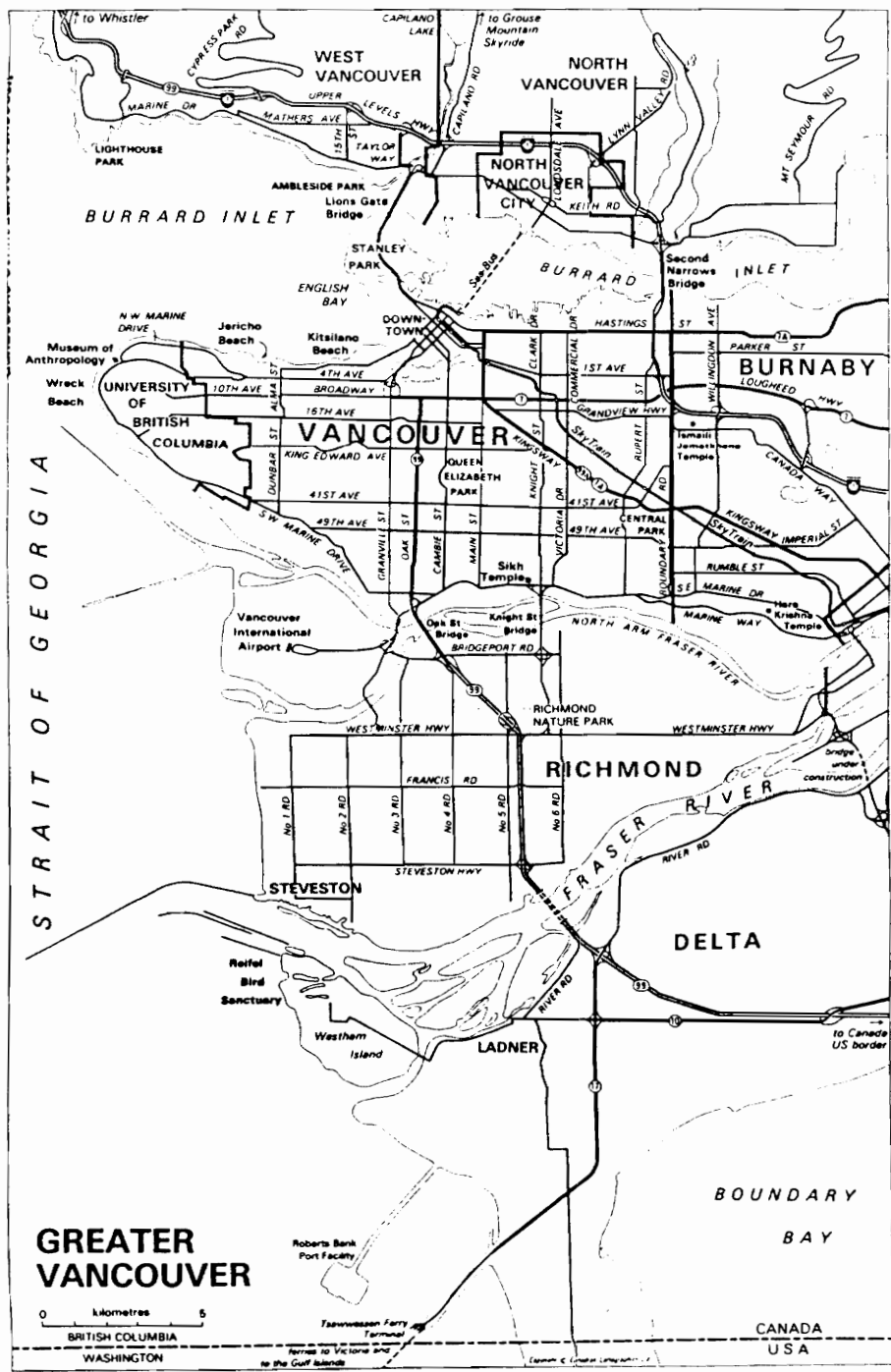
CHAPTER 1: METROPOLISES AND THEIR TRANSPORTATION SYSTEMS

1.1 *GENERAL SITUATION*

1.1.1 VANCOUVER

The Greater Vancouver is the third largest metropolitan region in Canada and the gateway of Canada to the Pacific. The Greater Vancouver Regional District had a population of 1.4 million in 1987. The location of Vancouver is the center of Lower Mainland of British Columbia at the mouth of the Fraser River (see Figure 1.1). The mountains are to the north of Vancouver, the sea is to the west. Burrard Inlet separates the North Shore municipalities (called West Vancouver and North Vancouver) from the downtown peninsula. English Bay, on the West End's southern shore, separates the peninsula from Kitsilano and Point Grey. Two big bridges connect the North

FIGURE 1-1: GREATER VANCOUVER REGIONAL DISTRICT



Shore to Vancouver -- the Lion Gate and Second Narrows. Three smaller bridges run south or southeast from downtown to the rest of the region.

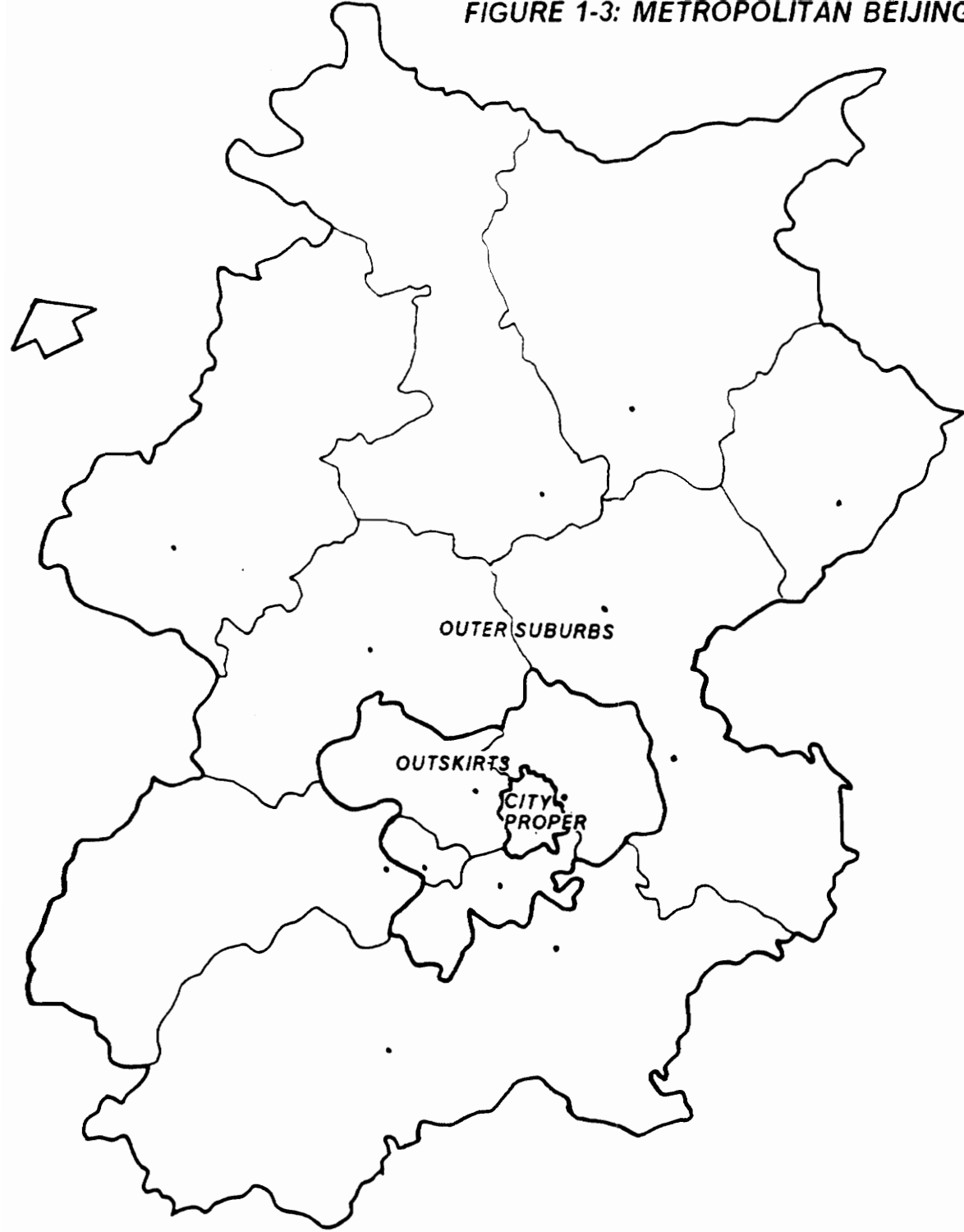
Greater Vancouver has changed from a compact city on Burrard Inlet to a large metropolitan region covering more than a thousand square miles. As Canada's third largest metropolis, Vancouver is acclaimed as one of the world's most beautiful cities, with one of the best climates. Yet its beauty is not man-made, but natural. Therein lies its vulnerability. Even though nature is stronger here than in most places -- high mountains to make subdivisions difficult, strong tidal currents to clean up the water, a sea breeze and frequent downpours to clean up the air.

Vancouver's national and world-wide connections, especially as expressed through its port and financial activities, imply that its character should show the effects of reciprocal relations with points elsewhere in Canada and overseas. Thus among Canadian cities, Vancouver is unique: it is made so by the mixtures of its sources of capital and population, by the nature of its economic base and institutional forms, and by its location.

1.1.2 BEIJING

Beijing, the capital of China, used to be called Peking, is located in the northern part of North China Plain. It is the second largest metropolis in China only next to Shanghai, with an area of more than 16,000 square kilometers and a population of over 9 million people. It was founded in the eighth century B.C. in approximately its present location, and retains the same general layout it had in 13th century A.D. today (see Figure 1-2). Geographically, Beijing occupies about the same position in China that New York does in North America, both being near the fortieth parallel and

FIGURE 1-3: METROPOLITAN BEIJING



enjoying the same climate conditions in the spring and fall. Unlike New York, however, Beijing does not have direct access to an important river or to the seacoast. The Grand Canal, which at one time provided access to the sea, no longer serves that purpose.

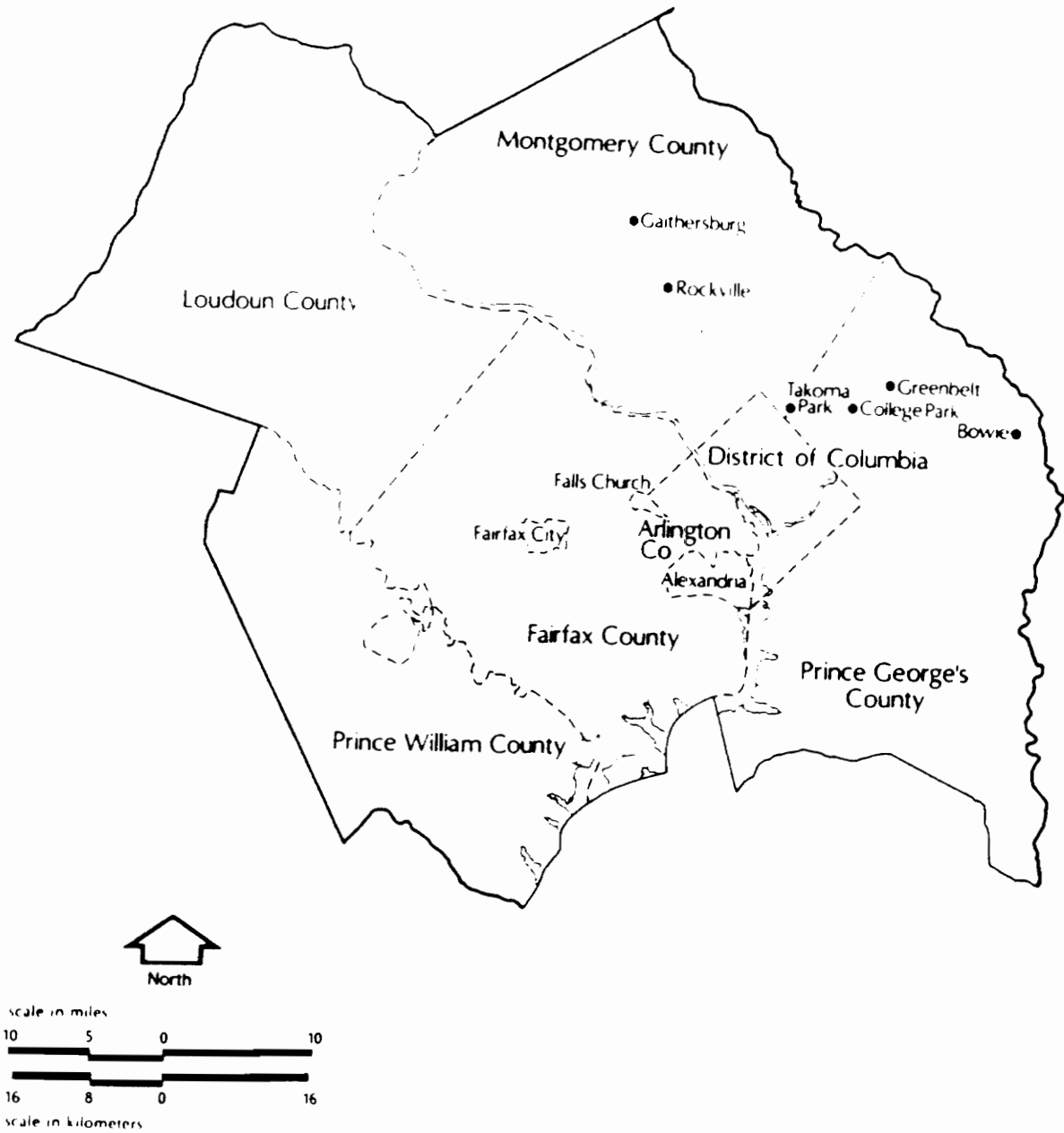
Beijing is a multi-functional city. The nation's governments and public agencies concentrate in central region of Beijing. It is the largest center of tourism, culture and higher education, finance and business, commerce and urban economy in North China with a well developed industry. Beijing becomes a blend of the new and the old in order to retain the nation and world-wide interest it creates because its unique character and the spirit of Chinese ancient civilization.

1.1.3 WASHINGTON

The Washington Metropolitan Region includes areas of 2,400 square miles in Maryland, North Virginia and District of Columbia. In 1984, population of metropolitan Washington is 3.4 million, including District of Columbia, City of Alexandria, Arlington County, Fairfax, Prince William and Loudoun Counties of Virginia and Montgomery, Prince George's Counties of Maryland (Figure 1-4).

The Washington Metropolitan Region has evolved around the nucleus of the original City of Washington in the District of Columbia which was established in 1791. The city grew slowly until 1960s. The region became the fastest-growing of the nation's nine largest metropolitan regions after 1964.

FIGURE 1-4: WASHINGTON METROPOLITAN REGION



1.2 LESSON FROM THE PAST

During the last half and the 19th century, North American cities were expanding rapidly due largely to industrialization and immigration from Europe as well as migration from rural areas within country. The rate of this expansion, which continued well into the 20th century, was of an unprecedented scale and is unlikely to be approached again. Coincident with this expansion was the development of increasingly better modes of urban travel.

It is abundantly clear from these historical examples that public transit had a major impact on the development of North American cities in the last 19th and the early 20th centuries. Continual improvements in transit technology during this period took the urban traveler from the horsecar to the modern subway within the space of a few decades; each new step dramatically increased the area which could be reached at a given cost and time of travel, and thereby the area in which the life and business of a city could be conducted.

This almost continual doubling and redoubling of accessibility was essential if the burgeoning populations of the cities were to be accommodated. During the time in question, the rate of migration into the city was staggering, and the growth in the nation's increasingly urban, manufacturing-oriented economy equally great. The lack of adequate transportation in the the city was a continual threat to this economic development, and traffic congestion unparalleled today was a commonplace in the central areas of major cities.

Under such conditions, the inauguration of each new transit service almost inevitably resulted in rapid expansion of the city along its lines. The rises in property

values created an active market in land speculation, including some abuses. Large fortunes in real estate were made, sometimes by “insiders” in transit development.

Examples of rapid suburban development were numerous at that time. Some examples of successful transit-oriented “new town” development are also in evidence. To a substantial degree these were dependent on other factors in addition to a transit improvement, such as land availability, site amenities and disamenities, and the existence of effective demand for development. Under all of these examples, however, is the fact that they were made possible only by transit service which was far better than any other means of access at that time.

The standard interpretation of this is that since the auto’s appearance, transit can no longer exert such a monopoly on access; the car is, after all, often much faster, more comfortable, and flexible in its ability to choose its routes and destinations. This leads to the view that we can learn little from the past to lead us to ways to generate land use impacts from transit improvement possible today. This may well be true. However, there may be another in this display of the history of transit improvements and its effects on urban development. Specifically, perhaps the scale of land use impacts reached by early transit innovations could yet be repeated, if situations can be found or created in which a transit improvement would provide a major increase in access over that presently possible. Examples may include mechanized downtown circulations, at a relatively small scale, and large residential areas served only by slow, simple public vehicles operated by present “transit dependents” such as youths, some of the physical handicapped and the elderly who cannot drive. These draw from history not just the simple linear progression of ever-faster, ever-larger urban mass transit opening ever-larger rural areas, but rather the need to look more specifically for different problems: urban travel functions in which the dramatic improvements in access of past innovations may still be possible.

1.3 HISTORY OF TRANSIT IN THE THREE METROPOLISES

1.3.1 VANCOUVER

Mass transit in Vancouver began very soon after Vancouver was incorporated as a city in 1886. The B.C. Electric Railway Company introduced one of the first and most modern streetcar services in North America. They were small electric streetcars. Later, transit augmented by larger interurbans on track extended out into the Fraser Valley and down through Lulu Island.

Modern vehicles replaced the old wooden-sided streetcars in the 1930s and '40s. After the Second World War, rail streetcars gave way to rubber-tired electric trolleys and diesel buses. In the 1970s, regular bus service was extended to the rapidly developing suburban areas around Vancouver. In 1977, the SeaBus ferry service across Burrard Inlet was started. Today, two catamaran passenger ferries link the North Shore (West and North Vancouver) and Vancouver, providing efficient transportation for several million people yearly while reducing congestion on the Lions Gate and Second Narrows bridges.

Buses are still in the picture, more than ever with the recent arrival of 200 modern trolleys, the first of a new generation of bus with rapid transit style electronics which provides smoother rides and use less electricity. SkyTrain rapid transit service which was introduced in 1986, heralded a new era in transit for Vancouver.

1.3.2 WASHINGTON

Washington's grand avenues remained unpaved until the 1870s when civic improvements including water and sewer lines were developed in the District. Horsecars were replaced by electric streetcars in the late 1800s and the city and suburbs became more closely linked by interurban electric trolleys. A system of express highways and parkways was developed beginning in the 1930s with the congressional action to establish the Baltimore-Washington Parkway. Various mass transit proposals were advanced as early as 1909 when the "Washington Post" called for a subway system. Washington and its suburbs were served in the first half of the century by an extensive streetcar network dismantled and replaced by buses in 1950s and 1960s.

Public transit in the city had been operated by the Capital Transit Company since the 1930's, when several private bus streetcar companies merged. During the World War II, the company operated 895 streetcars and 1,249 buses. But by 1955, the fleet was down to 508 streetcars and 858 buses.[1]

Capital Transit had been owned and operated by the Northern American Holding Company, a utility which was forced to divest itself of the transit company under the Utilities Holding Company Act. In 1949, a syndicate led by Louis Wolfson gained control of Capital Transit, and proceeded to disburse the company's War-time surplus out in dividends instead of reinvesting in improved transit. A 52-day transit strike during the summer of 1955 focused attention on the situation and there were many disturbing revelations, such as that in three of the five years under Wolfson's control, Capital Transit had paid out dividends exceeding its net income. Congress began looking into ways of revoking the company's franchise.[2]

The franchise for operation of the city's public transportation was acquired by D.C. Transit System, Inc., on August 15, 1956. As part of the franchise agreement, the corporation was obligated to initiate and carry out a plan of gradual conversion of its street railway operations to bus operation within seven years. In January, 1962, Washington's last streetcar had its final run. The first line of the planned 103-mile, 86-station Metrorail system was opened in March 29, 1976. The dream of two decades has become true.

1.3.3 BEIJING

In 1921, rail streetcars began to provide service in the inner city of Beijing. They gave way to buses and rubber-tired trolley in 1935. With the development of Beijing, mass transit service extended to all metropolitan areas. After 1972, the transit service areas served by the Beijing Public Transport Corporation almost covered all major residential districts, central employment districts and central business districts. Some suburban routes extended to several satellite cities within the metropolitan Beijing.

The China's first subway -- Main Line of Subway Beijing, built solely with Chinese materials and technology, was opened in September 1969 in Beijing. The second phase -- Loop Line of Subway Beijing was completed in 1984, and began its service at the same year.

1.4 REGIONAL TRANSIT SYSTEMS IN THESE METROPOLISES

1.4.1 VANCOUVER

Efficient public transportation is vital for the growth and economic health of any city. In Greater Vancouver, tens of thousands of people each day depend on the Vancouver Regional Transit System. Office workers and business people ride buses downtown. Shoppers and store owners take transit to suburban shopping districts and centers. Students need mass transit to reach classes on time -- and to attend to work and recreation after school and weekends. Culture? Scores of people keep the system alive at night as they turn out of symphonies, plays, movies and art exhibits.

The fact is, transit involves most human activity in the Lower Mainland -- anything that involved travel from one part of the region to another. An indication of the importance of mass transit in the area is the number of passengers who rode the buses in 1986-87 fiscal year -- 116 million -- the highest ridership in recent year.

BC Transit is a government corporation whose 3,500 employees operate transit services. The Vancouver Regional Transit System covers the most extensive transit service area in Canada - 1,400 square kilometers. It is possible to travel up to 65 kilometers in one general direction, to the area near the U.S. and Canada boundary.

This transit system carried 101 million riders in 1987-88 fiscal year, which is the third highest ridership in Canada after Toronto and Montreal. On an average day the Vancouver Regional Transit System carries approximately 350,000 riders. Residents

in the Greater Vancouver area are frequent users of their transit system, making an average of 80 rides per capita every year.

The Vancouver Regional Transit System is a unique land-sea-rail network of diesel and trolley buses, passenger ferries and advanced rapid rail transit. Through a well-designed, integrated system involving buses, SkyTrain and Seabus, this system links sixteen municipalities in the Greater Vancouver Regional District.

In the City of Vancouver, bus service is provided on a grid network with most routes operating at average 6 minute headway. Some routes in the city operate as frequently as every 3 or 4 minutes, even during off-peak times, while in suburban areas service frequencies range from 10 to 60 minutes. A total 649 diesel buses are used both on city and suburban routes and 246 electric trolley coaches are used in the city. This trolley fleet is the second largest in North America, after San Francisco. This system operates almost 24 hours a day, seven days a week. As the last of the night drivers come off service between 3:00 and 4:00 a.m., other drivers are reporting for the first runs of a new day.

Two 400-seat catamaran SeaBus ferries provide frequent service across Burrard Inlet between North Vancouver and downtown Vancouver. Since 1977 these unique ferries have successfully applied transit principles to sea vessels. They connect directly into the SkyTrain system in downtown Vancouver and to an extensive network of feeder buses in North Vancouver. SeaBus plies Vancouver's harbor between the downtown terminus of SkyTrain and the Lonsdale Quay area in North Vancouver with sailings every 15 minutes (30 minutes during evenings, Sundays, and holidays). Despite having to operate a frequent schedule in an often busy harbor, SeaBus has operated accident free since its inception and has only missed one trip in almost 11 years.

SkyTrain, the Vancouver Regional Rapid Transit System, is the world's longest, completely automated rapid transit system with the \$854 million (Canadian) capital cost for its first phase. The first phase was opened December 11th, 1985, and went into revenue service January 3, 1986. The integrated transit concept came into its own when SkyTrain came into service. The first phase of SkyTrain rapid transit line runs between downtown Vancouver and New Westminster. A total 15 stations are located along the 21.4-km line. The fully automated SkyTrain system, with 114 trains, forms the backbone on much of the transit system, with feeder buses providing access to and from most stations (Figure 1-5)

The SkyTrain Phase I line links four major municipalities, North Vancouver, Vancouver, Burnaby and New Westminster combined with SeaBus. The lightweight, linear-induction-powered vehicles operate on a primarily elevated guideway, with some at grade sections and a tunnel section in downtown Vancouver.

During an 18 month integration period, some 70 bus routes were realigned to act as high-frequency feeders to the rapid transit system. The Skytrain system now is fully integrated with bus services and most of the fifteen stations on the line have adjacent bus loops and auto drop-off facilities.

SkyTrain's automated four-car trains provide service with 3-5 minute headway throughout the day from 5:30 a.m. to 1:30 a.m. the next morning. A trip from New Westminster at one end of the line to Waterfront Station to connect with SeaBus takes approximately 29 minutes, is faster than a passenger car, and takes about half the time it used to take by bus.

1.4.2 BEIJING

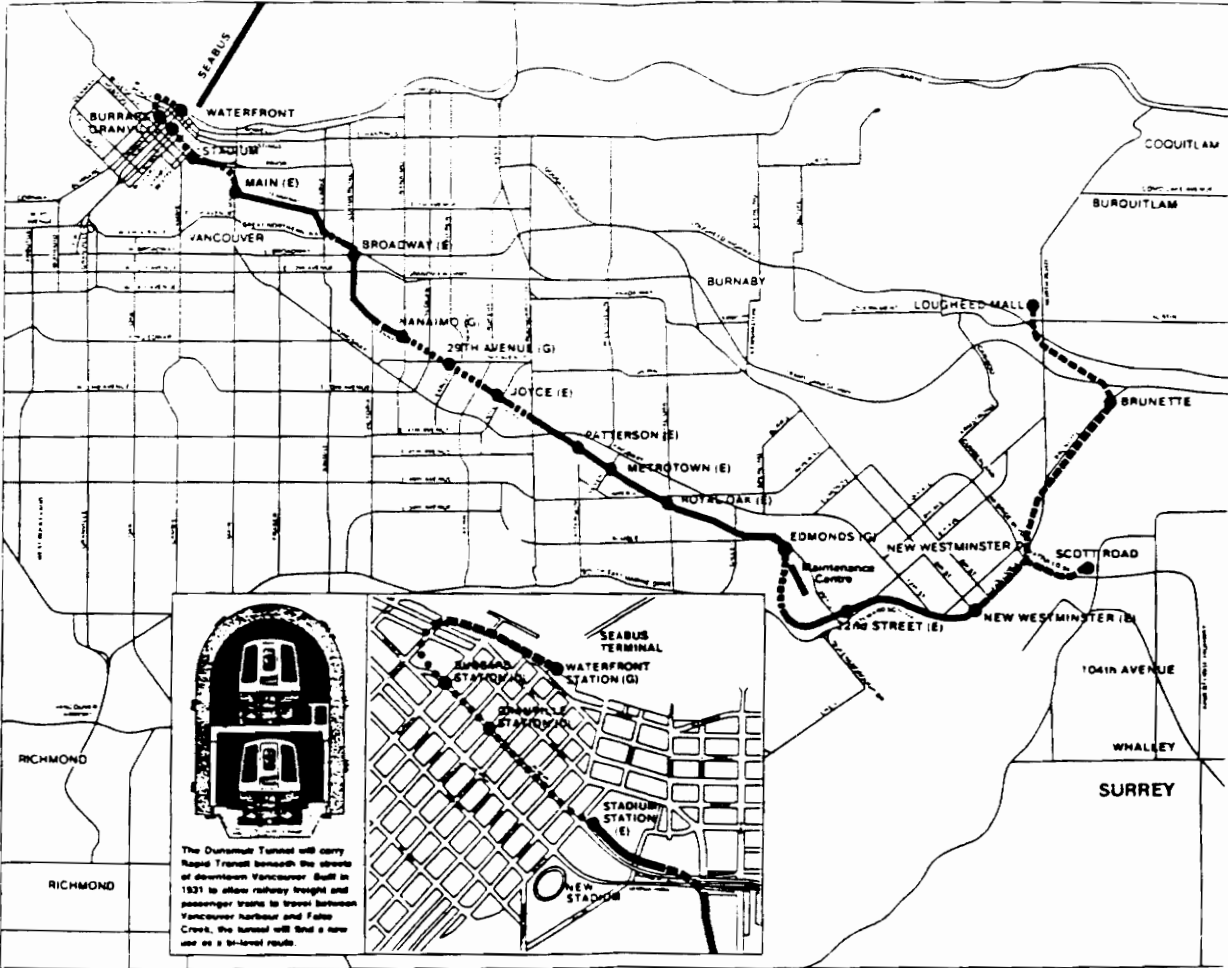
Urban transportation in Beijing has assumed more prominence currently; not only must the travel needs of the people be met, but also general economic activities such as urban construction and productivity must also be served. The principal modes of urban transportation in Beijing are public transit, and, of course, bicycles. Bicycles, like passenger cars in the United States, have the largest share of the modal split. Recent statistics indicate that in the metropolitan Beijing, with a population of 9 million, there are 5 million bicycles. People made more than 6 billion passenger trips totally in 1987, and 3.2 billion passenger trips made by cyclists.

In the metropolitan Beijing, where 3,928 buses, 534 electric trolley coaches, and 565 long-distance buses owned by the Beijing Public Transit Corporation, operate on 428 routes covering 15,313 km in length. The system carried approximately 8.5 million passengers to a daily average in 1987.

The first phase of Subway Beijing, the 23.6-km Main Line, began operation in September 1969. The construction of the second phase, the Loop Line, was started in 1971, tracklaying was finished in late 1980. The 16.1-km Loop Line was opened in 1982. It was built by the cut- and-cover method at a cost of \$600 million. To date, the two line rapid transit system with 29 stations intersectes at Fuxinmen (the Gate of Rejuvenate) Station (Figure 1-6).

The Main Line of Subway Beijing runs east-west parallel to and two block south of Changan Street, the Beijing's most principal arterial, from Beijing Central Railway Station extends westward into the western suburbs of Beijing, ends at the Pingguoyuan (Orchard of Apple) Station with 17 stations. Several stations have direct underground access to major commercial and cultural facilities and the Hall of Peo-

FIGURE 1-5: SKYTRAIN SYSTEM



LEGEND

- First phase, ALRT
- Elevated
- Tunnel
- At Grade
- Planned Extensions
- Possible Future Routes

Stations (U) = underground - 2
(E) = elevated - 9 15 total
(G) = at grade - 4
This system will be accessible to the handicapped with escalators and elevators at underground and elevated stations.

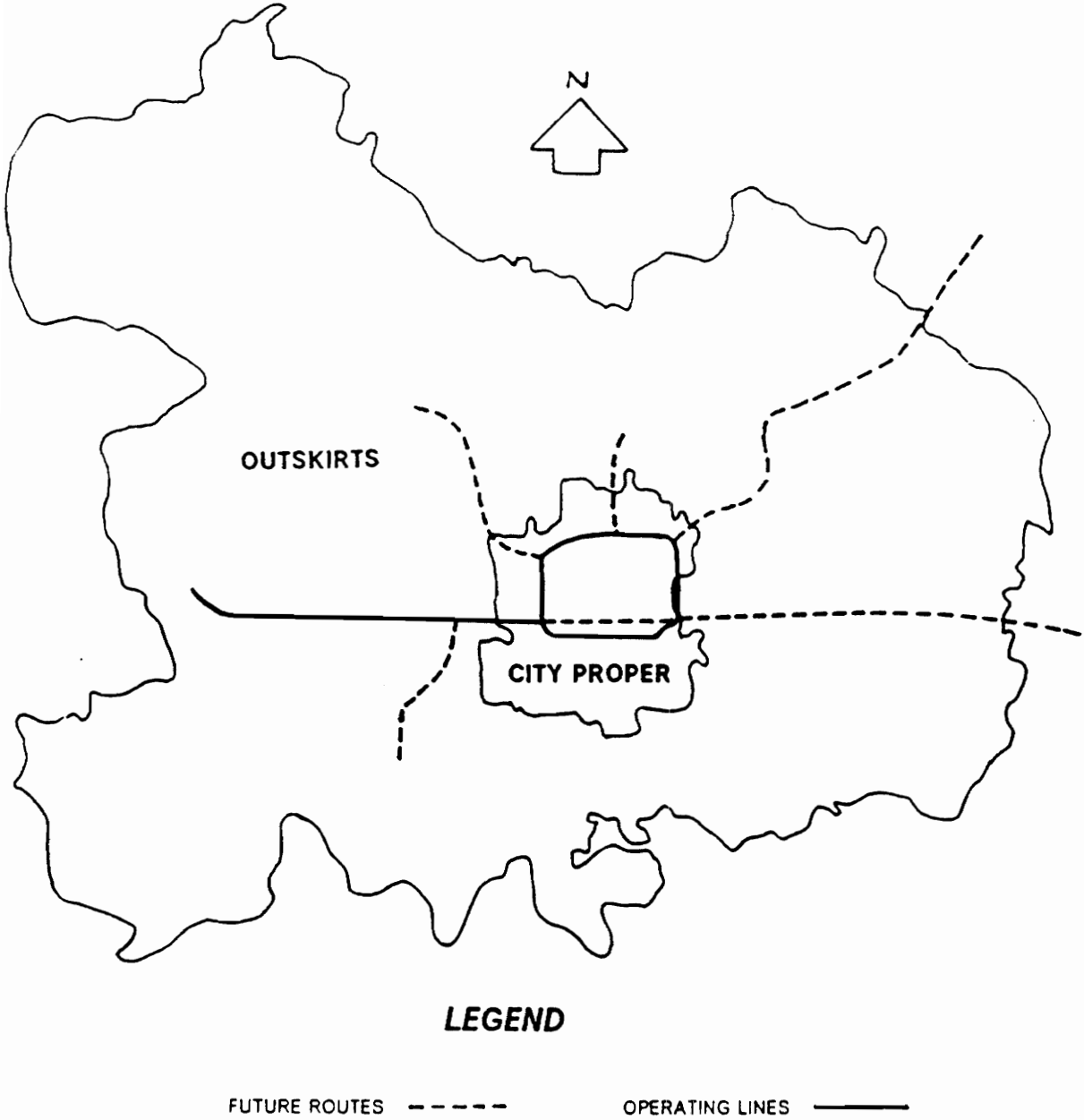
ple's Congress. The Loop Line begins also at the Beijing Central Railway Station, the eastern terminal of the Main Line, and loops north before rejoining the Main Line at Fuxingmen Station in western Beijing with 12 stations. It is located under the Second Ring Expressway of Beijing. After opening the Loop Line, the new Main Line service is from the Fuxingmen Station to Pingguoyuan Station. The Loop Line service starts and ends the Beijing Central Railway Station circuitly.

The service of Subway Beijing operates 21 hours a day from 4:45 a.m. to 1:30 a.m. next morning, seven days a week with five minute headway in peak hours and eight minutes in off-peak hours. One fleet consists with 6-8 train coaches with a driver at the first coaches.

Due to the shortage of budget, the city government cannot put more investment on highway construction. Thus, the increasing rate of traffic volume exceeds one time of the increasing rate of highway length. The mix of vehicles and bicycles on urban streets is perhaps the largest contributor to urban congestion in Beijing, although tens of thousands concrete fences separate bicycles with vehicles on major arterials. Bicycles tend to interfere with bus movements, especially at intersections, thus reducing the productivity of the already overcrowded buses. Congestion is so severe in Beijing that traffic flow cannot be sustained through three consecutive traffic lights.

During the rush hour, buses and trolleys operate at crush capacity, with about 10-13 passengers per square meter of floor space (1.08- 1.35 square foot per passenger), exceeds 9 passengers per square meter - the allowable maximum density. By comparison, U.S. passenger loading standards for bus transit vehicles use a range from 13 square foot per passenger (for Level of Service A) down to about 4 square foot per passenger under crush load conditions (for Level of Service F).[3] In while, the Subway Beijing system is also in the condition of over- saturation. The capacity of Subway in peak hour is 42,000 passengers, but actual riders exceeds 100,000 per

FIGURE 1-6: SUBWAY BEIJING TRANSIT SYSTEM



hour. It is a widely acceptable opinion that the public transit service will be at a standstill without the Subway Beijing system. The rapid rail transit become a indispensable part of Beijing's public transit.

1.4.3 WASHINGTON

The Washington Metropolitan Area Transit Authority (WMATA) operates the third largest rapid rail transit system and fifth largest bus system in the country. In 1986, the thirteen year of WMATA, the Metrobus system with its 1,500 buses, 370 routes and 11,000 bus stops serves half a million passenger trips daily. Beginning with 4.6 miles and five stations, serving 20,000 passenger daily, the Metrorail system has extended to 70 miles and 64 stations, serving almost another half a million passengers daily in 1986.

The combined bus and rail system is a critical asset to the region and the nation. Residents of the Washington Metropolitan Area, as well as visitors from the country and around the world, ride Metrorail daily and regularly express their appreciation for the safe, clean and reliable service.

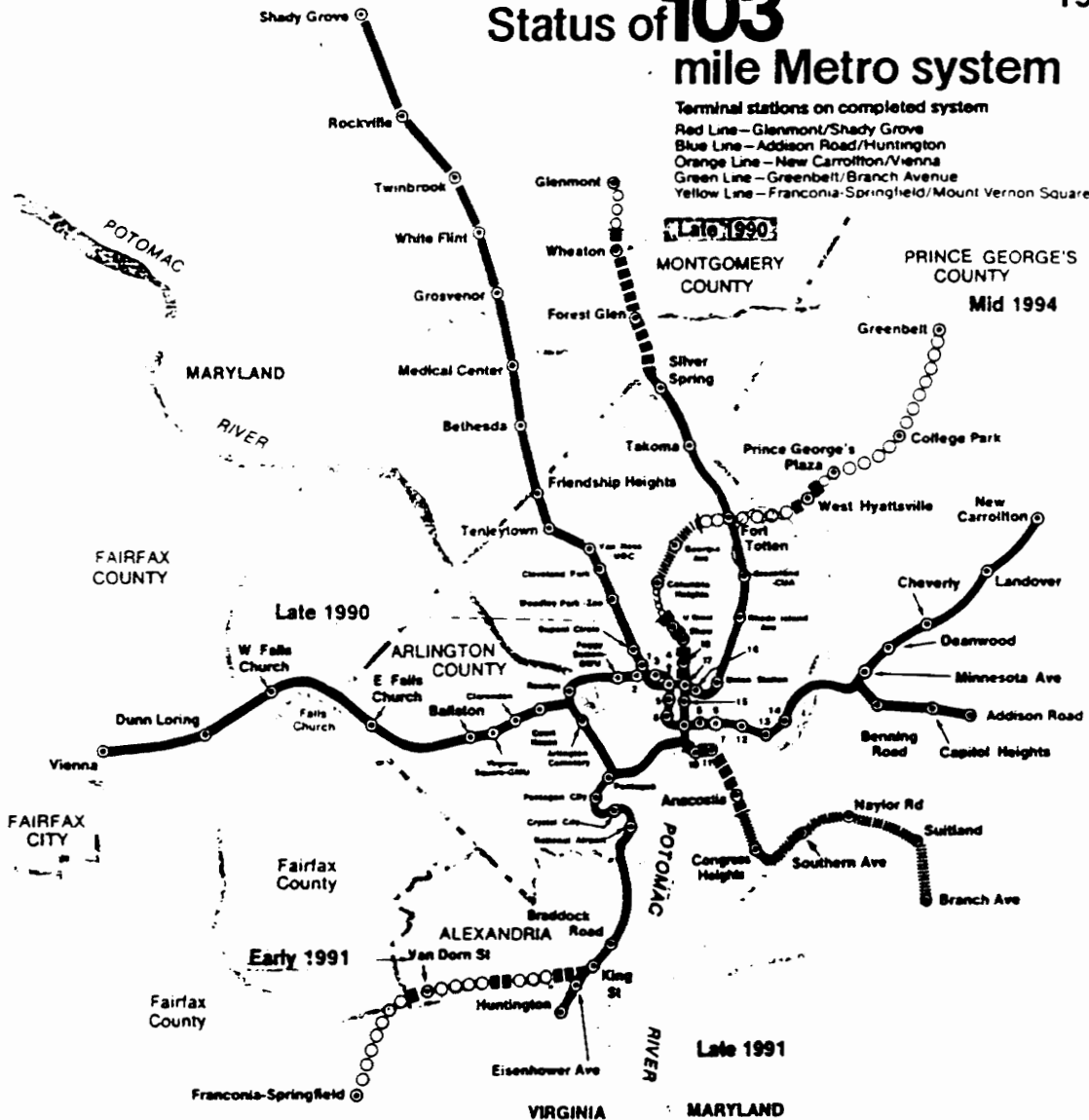
FIGURE 1-7:

December
1980

Status of 103 mile Metro system

Terminal stations on completed system

Red Line—Glenmont/Shady Grove
Blue Line—Addison Road/Huntington
Orange Line—New Carrollton/Vienna
Green Line—Greenbelt/Branch Avenue
Yellow Line—Franconia-Springfield/Mount Vernon Square-UDC



LEGEND

	Operating Lines	68.57 miles	64 stations
	Under Construction	10.66 miles	9 stations
	Under Final Design	13.99 miles	7 stations
	Remainder of System	8.75 miles	7 stations

1990 Projected start of operations for this segment based on approved schedule. Applies to all stations inbound from this point.

Total mileage—102.97

Total Stations—87

1. Farragut North
2. Farragut West
3. McPherson Square
4. Metro Center
5. Federal Triangle
6. Smithsonian
7. L'Enfant Plaza
8. Federal Center SW
9. Capitol South
10. Waterfront
11. Navy Yard
12. Eastern Market
13. Potomac Ave
14. Stadium-Armory
15. Archives
16. Judiciary Square
17. Gallery Place
18. Mt Vernon Sq-UDC



Washington Metropolitan Area Transit Authority
metro 600 Fifth Street, N.W., Washington, D.C. 20001

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1.5 GOALS AND OBJECTIVES OF RAPID RAIL TRANSIT

1.5.1 SKYTRAIN AND VANCOUVER

Although a lot of innovations have enabled expansion of the mass transit system over the years, including reorganizing the mass transit network, "people-moving" needs in Greater Vancouver have grown to where a new approach is needed. An all-bus network cannot carry the passenger volumes predicted for the long term. Thus, in 1980, the British Columbia provincial government decided that a rapid transit system would be built for Greater Vancouver.

The goal of the SkyTrain - Vancouver Rapid Transit System are:

- Expect to alter the overall distribution of travel in the Greater Vancouver Regional District.
- Aim to channel growth out of the congested metropolitan core and to promote greater job-housing integration by investing in SkyTrain.
- Cope with increased demand for mass transit service which has been affected by worsening automobile congestion, rising population and sprawling suburban development.

1.5.2 SUBWAY BEIJING

The first phase of Subway Beijing - the Main Line was planned and constructed in the time of preparing for war with the Soviet Union in 1960s. The initial goals of the system was:

- Establish a rapid underground transport system connecting the State Council, People's Congress, and Zhongnanhai (the Central and South Lake) - the leading body of Communist Party in central Beijing with the General Command of Chinese Armed Forces of West Hill in western suburban Beijing, to prepare against possible emergencies.
- Move residents of central city to suburban refuges as fast as safety as possible under the circumstances of nuclear war.
- Relieve the traffic congestion of rush hours.
- Provide a new mode of public transit to reduce the burden of buses and trolleys.

Due to the reason, the first phase of Subway Beijing was constructed by the Engineering Soliders of Chinese Army from 1965 to 1968. With the relaxation of the Sino-Soviet tension, the purposes of Subway Beijing were shifted to provide pure civilian use. The major objective of the second phase - the Loop Line, and other planned subway routes became:

- Provide a high-volume, frequent and reliable rapid rail transit system within the densely populated and densely built-up central region of Metropolitan Beijing.
- Intend to be a major long-distance commuting mode providing for suburban commuters.

- Relieve the overcrowded condition of public transit in Beijing

1.5.3 WASHINGTON AND METRORAIL SYSTEM

Washington's Metrorail system was planned over the course of two decades. Its primary goal was to reduce traffic congestion while providing an alternative to the automobile for the peak hour commuter. Rapid rail transit also offered a burgeoning metropolitan area the opportunity to guide its growth and development; and promised a means of preserving the beauty, dignity and economic viability of its central city, the nation's capital. Other goals, such as reducing air pollution, curbing energy use, and offering mobility for the transit disadvantaged were never seriously considered by decision-makers. They emerged too late to significantly affect the design of the system.

Some goals of Metro did change over the years. During the 1950's and 1960's the Washington region matured and the political and social values of the nation undergo a serious rethinking. Some of the Metro's goals changed as a function of these events. Other goals were tempered by the political process itself. Metro had to be sold to the Congress; it had to be sold to the local politicians and it had to be sold to the people of the region. This required coalition building and compromise. It required certain goals to be minimized and other politically saleable goals to be highlighted. Ultimately one goal became paramount: getting the system built.

1.5.3.1 A CHRONICLE OF CHANGING TRANSIT GOALS

As early as 1909, an editorial in the "Washington Post" asked, "Why not a real subway system for Washington?" While the question was posed several times subsequent to that, it was until 1955 that Congress attempted to answer this question by authorizing the Mass Transportation Survey (MTS), a study conducted by the National Capital Planning Commission and the National Capital Regional Planning Council to assess the current and future transportation needs of the National Capital area. The four year study recommended a plan which included 33 miles of rapid rail, 66 miles of express busways and 329 miles of freeways. It also established the goals that would, with some exceptions, be carried through two decades of decision-making, culminating in Washington's Metrorail system.

- Reduce traffic congestion;
- Provide an alternative to the automobile for the peak hour commuter;
- Provide a network of freeways such that people could travel quickly between any two parts of the region, even at peak hour;
- Preserve the beauty and dignity of the nation's capital;
- Preserve the economic viability of the central city; and
- Provide a skeleton around which the Washington region could grow and develop.

Perhaps the most significant goal was the reduction of traffic congestion, for from this goal, several of the others flowed. The MTS projected that because of population growth and increased trip lengths, the total number of daily persons miles would triple by 1980. It was feared that unless dramatic steps were taken, the metro-

politan area would undergo a complete transportation breakdown, with workers unable to get to their offices, retailers isolated from their customers, and the economic viability of the region undermined by immobility. This was particularly important to the federal government, which wanted to assure the accessibility of its institutions and the mobility of its workers. While one solution might have been a freeway system expanded to handle all automobiles, transportation planners in the Washington area opted for a balanced transportation system that would lure drivers away from their automobiles and onto public transit.

The idea of a balanced transportation system reflected another important goal of Metro's planners: that commuters should have a choice as to their mode of transportation. It also stemmed from a belief in the virtues of public transit for those who either did not have a car or did not chose to use their car.

In addition to its transportation goals, the MTS had several economic and land development goals. Washington, D.C. was the central city in a metropolitan area that was undergoing rapid suburbanization. Metro's planners were most concerned that the city not become "the hole in the donut" and they believed that a rapid rail transit system could become the focus of revitalization efforts.

That Washington was the nation's capital only served to magnify this notion. The city had a tradition of urban design that went back to the days of Pierre L'Enfant. It was believed that a subway system could forestall the necessity of running freeways through the monumental city and could preserve Washington's scenic vistas. Federal involvement also mandated high standards of design for the transportation system, because it was seen as a model of rapid transit for the nation and the world.

Finally, rapid rail transit was seen as a means of controlling urban sprawl by providing a skeleton around which the region could grow. It was understood that the use of land, the direction of growth and the distribution and density of population are

strongly influenced by the form and character of transportation facilities. It was also understood that rapid rail transit could be a powerful tool with which the local jurisdictions could formulate and implement their land use plans.

Over the years, Metro became more than the sum of its goals; it became a symbol for the maturing and unification of a metropolitan area, an example of successful functioning of mass transit in the nation's capital and a symbol of the revitalization of a decaying central city. The importance of Metro as a symbol cannot be overstated. One politician described her meeting with a group of Wall Street bond lawyers at which she asked if the region could afford a rapid rail system. Their answer was that the region could not afford not to have a rapid rail transit system.[4] The message is clear, if this city was to operate in the big leagues, it had to have a subway system.

1.5.3.2 THE GOAL SETTING PROCESS

The 1959 Congressional Hearings on the Mass Transportation Survey resulted in the National Capital Transportation Act of 1960, a law "to aid in the development of a coordinated system of transportation for the National Capital Region; to create a temporary National Capital Transportation Agency(NCTA); to authorize negotiations; to create an interstate agency; and other purposes." [5]

In the words of President Lyndon Johnson:

"Even today, this shifting population in creating massive traffic problems, with more than a million automobiles entering and leaving our city every 24 hours. Even with a full mass transit system -- on a regional basis -- that figure is expected to double by 1985. Without such a system, a complete breakdown in area transportation would be only a matter of time."

We simply cannot allow that to happen. Our goal -- the goal of both the Congress and the administration -- must continue to be a regional system of rapid rail transit.”[6]

That goal was achieved through establishment of the Washington Metropolitan Area Transit Authority (WMATA) which took the place of NCTA in 1967. WMATA was a regional compact of tremendous power limited by its source of power -- the local political structure in the region. It worked out a means of financing the system through jurisdictional and federal contributions, and it carried through construction of one of the largest public works projects ever conducted in the United States. Ultimately, WMATA also became an operator of both bus and rail transit, and had to deal with spiralling construction costs and massive operating deficits that had not been foreseen by the system’s planners.

The goals of Metro were highly personal in their origin, taking root from the experiences of the decision-makers involved. This was clear from the interviews conducted by MTS.[7] One participant spoke of his feelings that transit was necessary so suburban families would not have to keep two cars; another reminisced fondly about riding streetcars as a child; and another spoke of the horror she felt at seeing a ribbon of freeways that was slated to be built through the city she had grown up in and loved. While these people may have come to the same conclusions about the necessity for rapid rail transit, they did so for different reasons.

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CHAPTER 2: THE EFFECTS OF RAPID TRANSIT ON RIDERSHIP

2.1 OVERVIEW

2.1.1 SKYTRAIN IN VANCOUVER

In January 1986, SkyTrain began revenue service to serve travel demand in one of the area's most heavily-used corridors and bring visitors to and from the site of Expo 86. Service operates for approximately 19 hours a day using two to four car trains at frequencies of 3-5 minutes. During the Expo 86 World Fair, SkyTrain carried up to 120,000 passengers daily but post-Expo ridership has stabilized at approximately 55,000 per weekday.

The commencement of service on the SkyTrain system introduced substantial changes to the transit system and transit riders in the Greater Vancouver Region. In

order to determine the impact of SkyTrain, a survey of SkyTrain riders was undertaken during the week of March 23 to 27, 1987. The availability of results from the SkyTrain Rider Survey of 1987 and the Vancouver Metropolitan Travel Survey undertaken in 1985 provides the opportunity to provide a profile of SkyTrain riders compared with that of transit riders in general on the Vancouver Regional transit System.

2.1.2 SUBWAY BEIJING

In 1969, the 23.6-km Main Line of Subway Beijing was opened, and in 1984 it carried a total of 100 million passengers before the opening of the Loop Line. In 1987, the two lines carried 300 million passengers, took approximately 10 percent of the total transit riders, while the buses and trolleys carried 3,119 million passengers at the same period. As noted previously, the Subway Beijing have made the most of its capacity since 1985.

2.1.3 METRORAIL IN WASHINGTON

In planning the system, WMATA and its consultants did have to make some assumptions about regional growth and development. Most significant, perhaps, were assumptions about downtown employment. WMATA, using forecasts prepared by the Metropolitan Washington Council of Governments (COGs), assumed that employment in downtown D.C. would reach 502,900 by 1990, a growth rate of 1.13 percent per year through 1980 and 1.34 percent per year for the entire 1955 to 1990 period.[1] WMATA

also assumed that the population of the metropolitan area would reach 4.2 million persons by 1990.

Another basic assumption made by WMATA was that the primary purpose of the rapid rail system was to serve the work trip. This was emphasized by the consultant in a paper to area decision makers which noted: "The importance of a back bone rail transit system should not be allowed to obscure the fact that the rail lines cannot be extended to serve everyone for every purpose." [2] As a result, it was determined that no rail lines should be placed such that they would depend primarily on non-downtown travel for patronage.

The most celebrated achievement of Metrorail during its first four years was the high level of ridership. Ridership exceeded expectations on the initial downtown segment and grew continuously as the system gradually expanded.

2.2 TRANSIT RIDERSHIP CHANGE

This section focuses on the effects of rapid rail transit on whole mass transit system ridership levels including system wide ridership, corridor ridership and modal split.

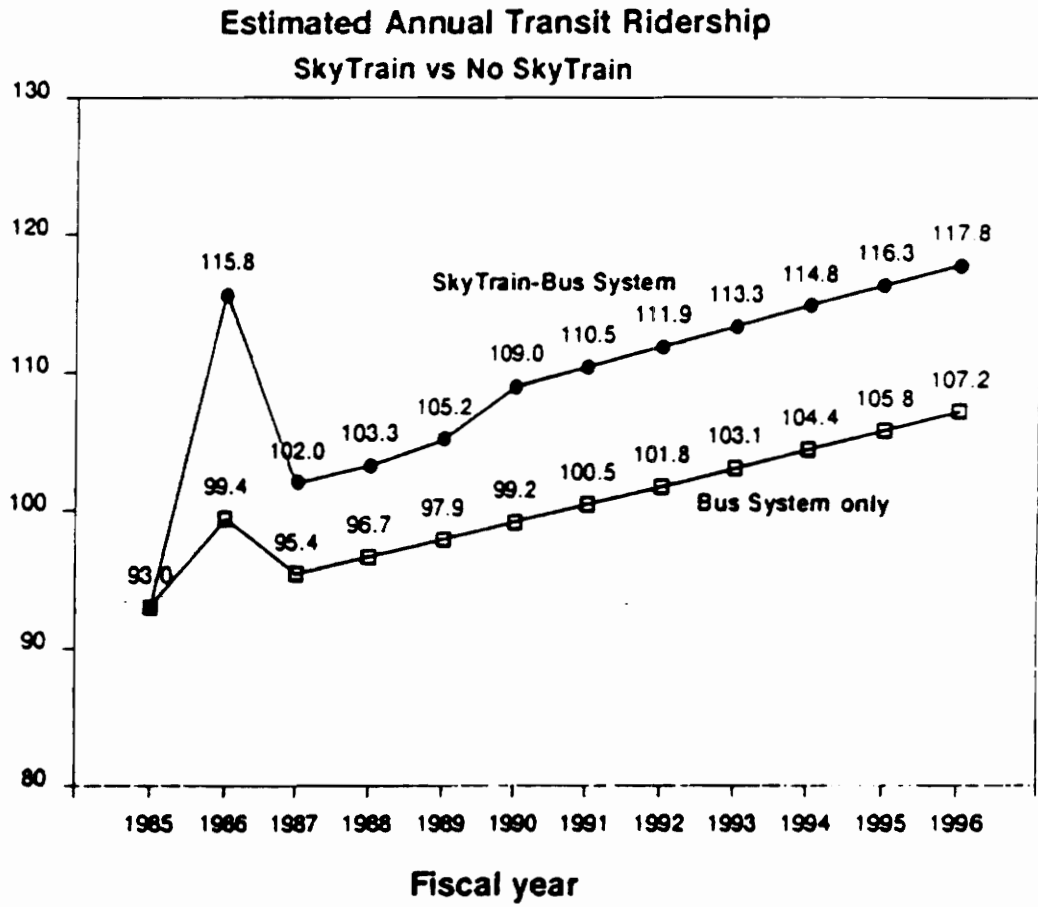
2.2.1 SKYTRAIN AND VANCOUVER

The impact of SkyTrain on ridership of Vancouver Regional Transit System can only be determined based on the difference between the regional ridership trend without SkyTrain relative to the regional ridership trends with SkyTrain.

A comparison of this system annual ridership using 1985 through 1987 annual ridership and estimates for the period from 1988 to 1996 is shown in Figure 2-1[3]. Comparing the annual system ridership for the SkyTrain and bus system with the bus only (no SkyTrain) scenario indicates that the first phase SkyTrain will result in an additional 7.3 million annual transit trips in 1989. With the second phase SkyTrain -- Surrey Extension beginning operation in 1990 ridership would be 9.2 million greater than it would be without SkyTrain.

Initial comparison between transit volumes collected by the 1985 survey and these collected in a follow up screenline survey conducted in November 1986 are provided. The results show that SkyTrain has resulted in a substantial increase in transit ridership on the Boundary Road (south) and the Main Street screenlines along the busiest transportation corridor in the region (Figure 2-2). During the morning peak period from the start of service to 9:30 a.m. transit ridership across the Main Street screenline into downtown Vancouver increased by almost 25 percent in 1985 from 12,010 to 14,982 passengers in 1986 after SkyTrain began operation, and by almost 22 percent during the evening peak period from 11,755 in 1985 to 14,328 passengers in 1986. At the Boundary Road screenline ridership increased by almost 140 percent from 2180 passengers in 1985 to 5294 passengers in 1986 during the morning peak period. Evening peak period ridership increased by almost 160 percent from 2191 to 5671 passengers.

FIGURE 2-1: ANNUAL TRANSIT RIDERSHIP



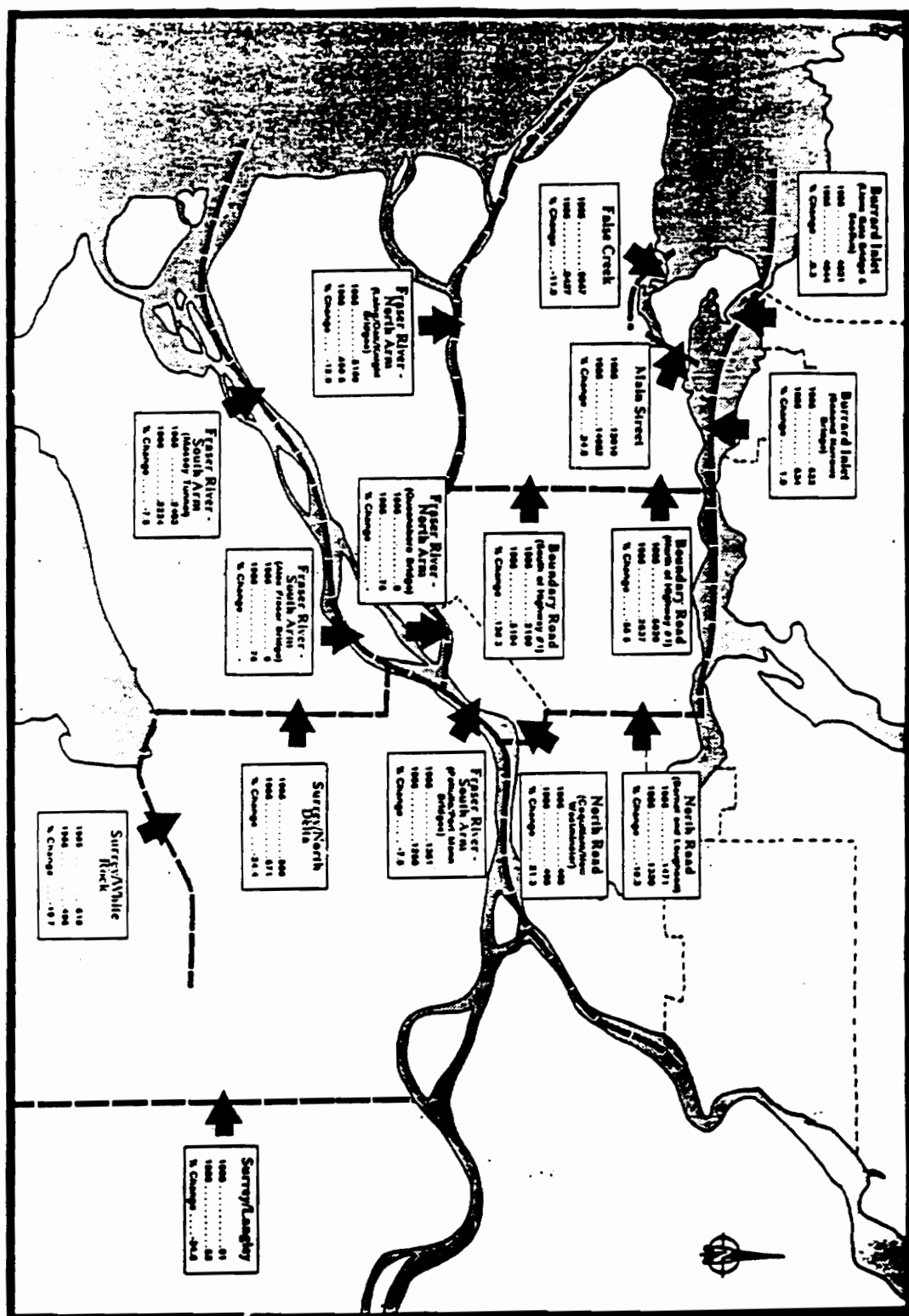


FIGURE 2-2-1:
Screenline Transit Volumes - A.M. Peak

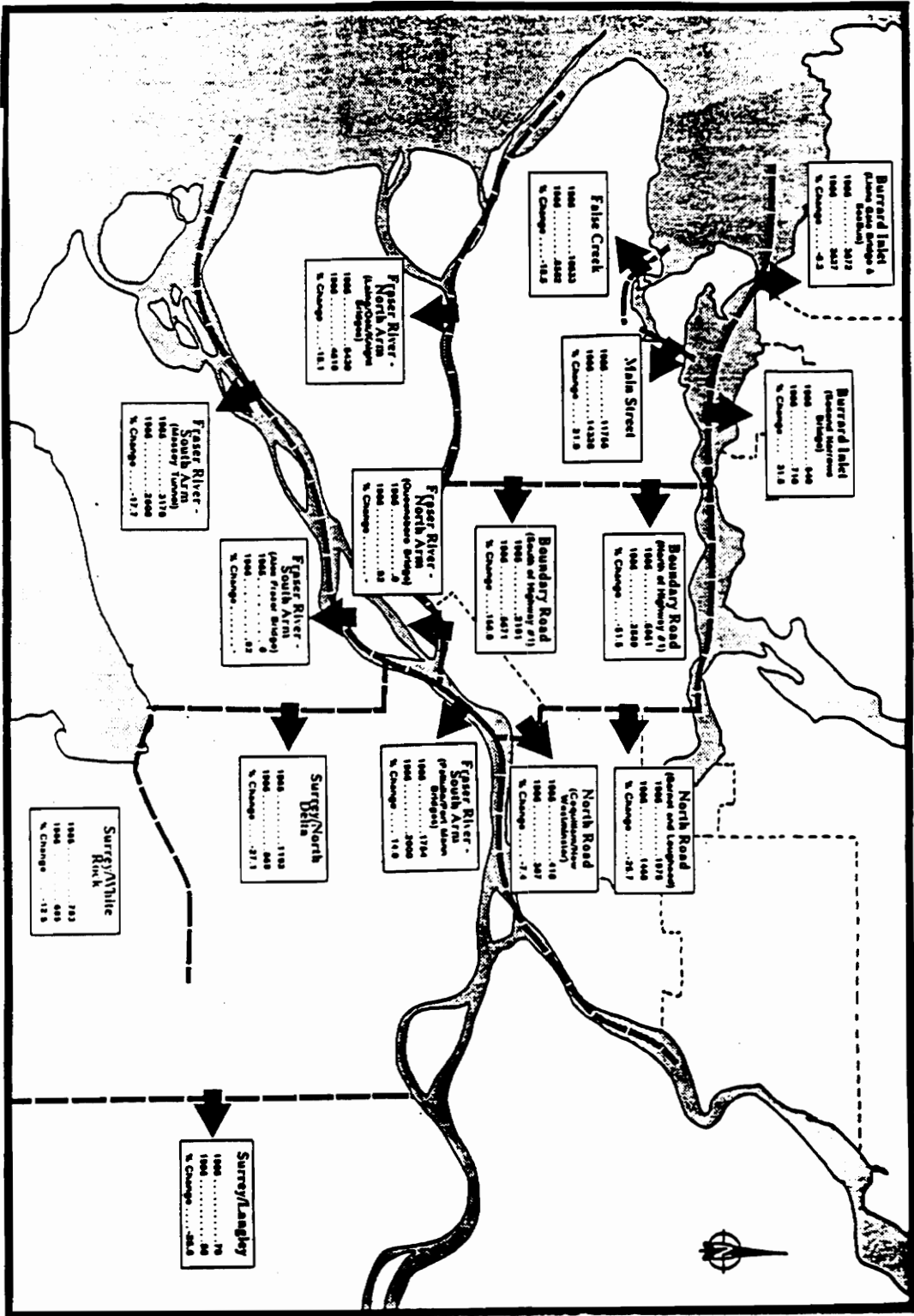


FIGURE 2-2-2: SCREENLINE TRANSIT VOLUMES - P.M. PEAK

Available sources shows that the percentage of peak period downtown based trips via transit changed from 46 percent in 1983 to 52.3 percent in 1987[4]. Obviously, SkyTrain influenced the travel mode of downtown based trips.

2.2.2 SUBWAY BEIJING

The ridership of Subway Beijing kept the level around 100 million annually in 1970s. The ridership increased slowly until 1980, especially after 1985 with the opening of Loop Line. The percentage of Subway ridership in total mass transit ridership increased from 3.7 percent in 1973 to 10.1 percent in 1987.

However, no evidence shows that Subway Beijing influences the modal split in the transportation system of Beijing. As noted previously, both conventional mass transit and Subway Beijing operate under the condition that actual ridership exceeds their design capacity. Travel by bicycle is the most important mode besides mass transit in Beijing (Table 2-1)

Chartered bus services have being expanded as were employer- or school-owned buses that provided transport to and from work or school since 1982. During the post-Mao time, the liberal communists control power and abandon the radical opinions. Due to the policy change, both private vehicle ownership and private operated paratransit have increased rapidly since 1978. Minibus operations, which started in 1984, are quite popular, providing convenient service. This involves the introduction of fixed route service without fixed stops and fixed stops without fixed routes.

TABLE 2-1: MODAL SPLIT CHANGE IN BEIJING

MODE	1979	1987	PERCENT OF CHANGE
BICYCLE	53.8%	57.2%	+ 6.3%
MASS TRANSIT	37.6%	32.3%	- 14.1%
CHARTERED BUS	0.8%	1.9%	+ 138.1%
WALKING	7.7%	7.9%	+ 2.6%
OTHERS	0.1%	0.7%	+ 600.0%

Note: Other modes include private car, motorcycle, taxi, minibus which is not operated by Beijing Public Transit Corporation.

2.2.3 METRORAIL AND METROPOLITAN WASHINGTON

The history of Metrorail ridership during its first four years has been one of spurts of growth with the opening of each additional segment and expansion of hours, and also continued growth during the interim periods. This pattern of continuous growth shown in Figure 2-3 stands in strong contrast to the historic seasonal bus ridership pattern, which typically peaks during the month of June, and then declines throughout the Summer and Fall to a low in December, after which it begins to build again. Further insight to the growth in Metrorail travel can be obtained by analysis of the ridership data for each line shown in Figure 2-3.

When the first section of the Metrorail Red Line opened from Rhode Island Avenue to Farragut North on March 29, 1976, ridership immediately reached 20,000 rid-

ers per weekday, more than double the projections for this small segment, which did not appear to serve many potential destinations. However, the Metrorail passenger survey taken that revealed that only one out of every eight trips were "new" trips.

Three years after the opening of the system, when less than one-third of the planned Metrorail system was operating, the system carried 26,000 riders daily, slightly more than one-third of the ridership projected for the full system.[5] The three Metrorail lines which entered the core of District of Columbia in 1979 added a total capacity of about 90,000 additional transit riders which could be carried during the peak period. This represents an increase of about one-third in transit capacity to the regional core.

As the downtown Metrorail network was expanded, the increases in Metrorail trips were matched by losses from the bus system. Some of the reduction in bus travel was attributable to a choice by passengers to take the faster mode, while in other cases the transit operator terminated bus routes at Metrorail stations, or eliminated competing routes.

Metrorail ridership for 1986 was 121.7 million, 10.7 percent above last year's 109.9 million. Bus ridership also increased over the previous year, from 135.4 million in 1985 to 137.1 million in 1986, 1.3 percent over the previous year. Combined bus-rail ridership increased from 210.7 million in 1985 to 220.4 million in 1986, a 4.6 percent increase. (Figure 2-4)

Table 2-2 shows that total morning peak period auto travel entering the D.C. core cordon declined by approximately 5 percent between 1977 and 1979. Auto passenger trips dropped by 4,300 inbound trips and auto driver trips dropped by 6,300 inbound trips. As shown on the Table 2-2, the change in peak period transit ridership is consistent and significant. The increase of more than 27,000 inbound peak period transit riders across the D.C. core area cordon represents a 30 percent increase in transit

riding in just a two-year period from 1977 to 1979.[6] Obviously, Metrorail reduces peak hour traffic entering D.C. core area.

Table 2-3 shows that in the Northern Virginia corridor morning peak period auto travel decreased by 6 percent while transit use increased by 44 percent. The same change in morning peak period travel at the Silver Spring count site of D.C. core cordon and New Carrollton corridor were also found. Metrorail helps to relieve the traffic along some major corridor between D.C. and suburbs in morning peak period.

Metrorail move participants in several big events such as celebrations, parades and many public gathering on the Mall, at the Capital and in Arlington. Metrorail carries 524,000 riders in the July 4 celebration in 1985. It could relieve the traffic congestion effectively in this situation.

Generally speaking, the Metrorail system in its period of initial operations has allowed substantial increases in travel to the central area without increases in highway capacity, supporting the principal goals of its planners. An estimated 100,000 additional automobiles, more than enough to fill all four lanes of the Capital Beltway bumper to bumper, would enter central area of Washington every day were it not for Metrorail. It is a lifeline of this region's transportation network.

2.3 RIDER CHARACTERISTICS

Data sources provide insight on who are the likely rapid transit riders and how well they have been served by these systems. In the following section, general characteristics of central area riders are described, along with some specific ana-

FIGURE 2-3: METRORAIL RIDERSHIP BY LINE SEGMENT

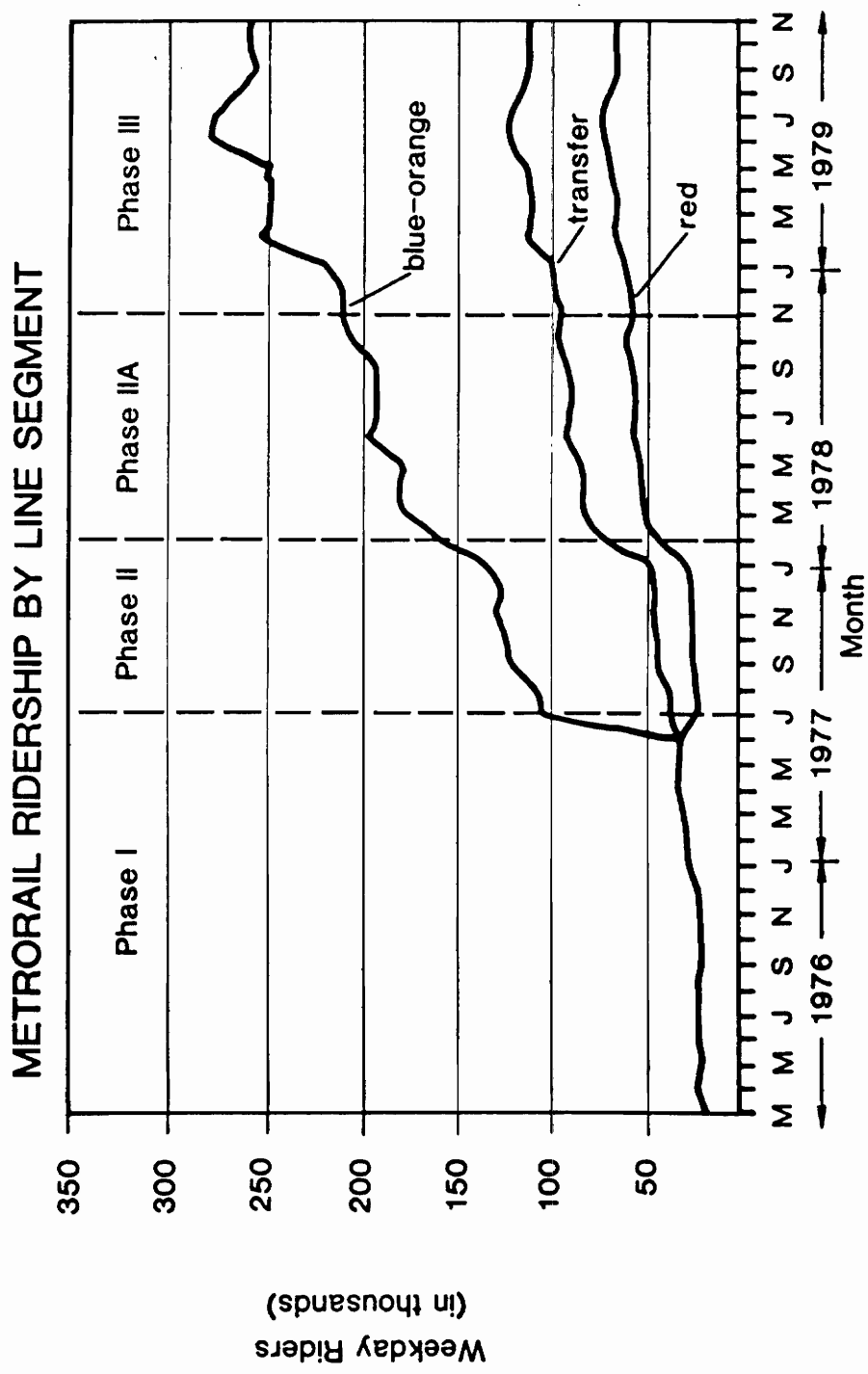


FIGURE 2-4: WMATA RIDERSHIP 1974 - 1986

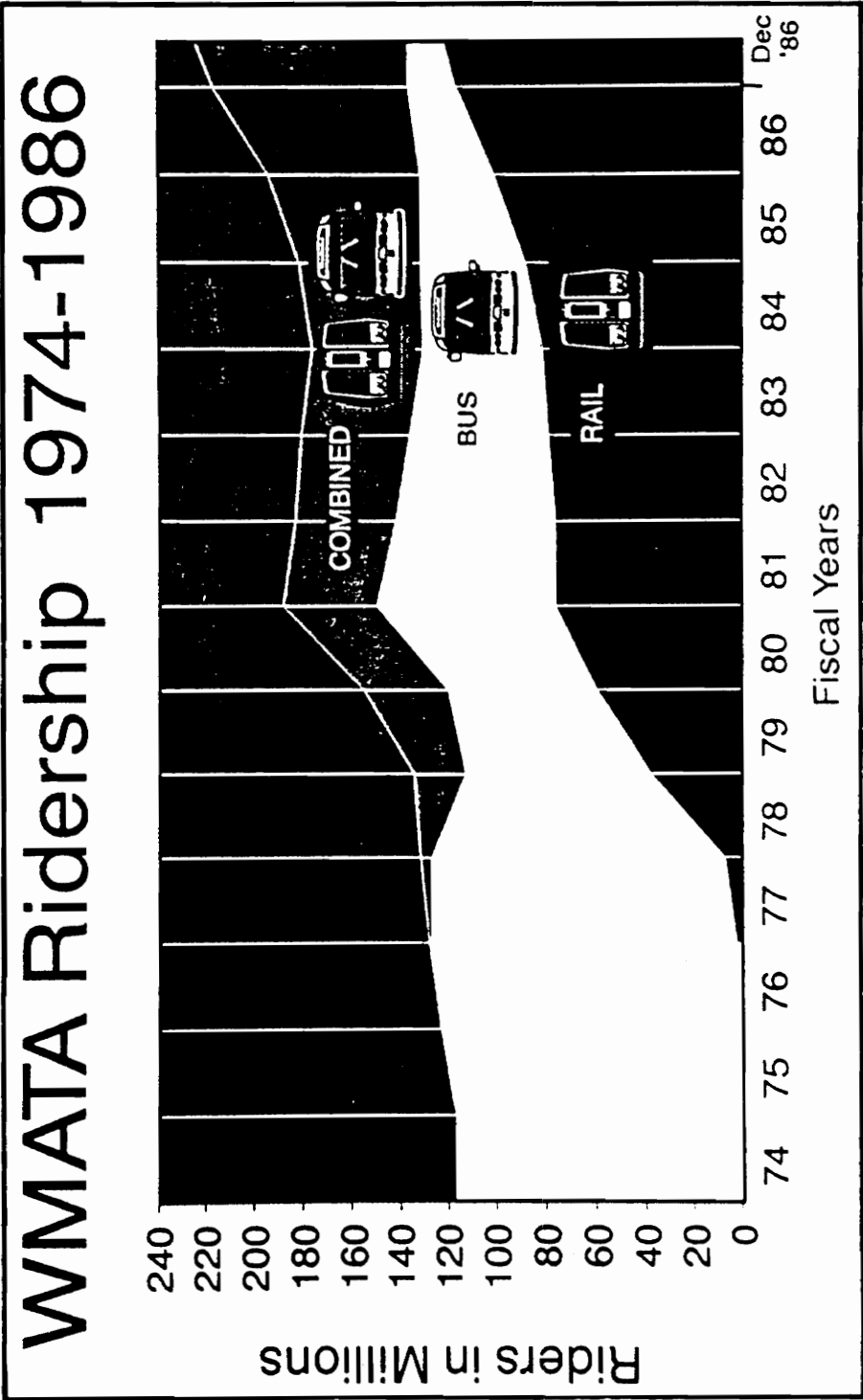


TABLE 2-2: PEAK PERIOD TRAVEL TO THE D.C. CORE
(6:30 - 9:30 a.m. Inbound Trips)

AUTO PERSON TRIPS	1977	1979	CHANGE 77-79
AUTO DRIVER	151,200	144,900	- 6,300
AUTO PASSENGER	72,500	68,200	- 4,300
TOTAL AUTO	223,700	213,100	- 10,600
WMATA TRANSIT TRIP	1977	1979	CHANGE 77-79
METROBUS	91,500	63,700	- 27,900
METRORAIL	2,600	57,800	+ 55,100
TOTAL WMATA	94,100	121,300	+ 27,200
PERCENTAGE TRANSIT	30%	36%	+ 6%

lyses of riders to the central area. An overall description will then be made of the characteristics of rapid transit riders in general.

2.3.1 SEX AND AGE PROFILE

The comparison shows that SkyTrain riders closely correspond to the sex profile of all transit riders. SkyTrain riders are 62.8 percent female and 38.2 percent male as compared to 59.3 percent and 40.7 percent respectively for the system as a whole.

TABLE 2-3
NORTHERN VIRGINIA PEAK PERIOD TRAVEL TO D.C. CORE
(6:30 - 9:30 a.m. Inbound Trips)

AUTO PERSON TRIPS	1977	1979	CHANGE 77-79
AUTO DRIVER	46,000	43,000	- 2,700
AUTO PASSENGER	25,500	23,800	- 1,700
TOTAL AUTO	71,500	67,100	- 4,400
WMATA TRANSIT TRIP	1977	1979	CHANGE 77-79
METROBUS	24,100	11,200	- 12,900
METRORAIL	--	23,500	+ 25,500
TOTAL WMATA	24,100	34,700	+ 10,600
PERCANTAGE TRANSIT	25%	34%	+ 9%

The average age for male SkyTrain and Beijing Subway riders are 36.5 years and 33.2 years respectively, and for females are 33.7 years and 31.8 years. The overall average age are 34.5 years and 32.5 years.

A comparison between the age profiles of Skytrain riders and all transit riders is shown in Table 2-4. The results show that SkyTrain riders tend to be more heavily concentrated in the middle age groups, age 21-50 years. Representation from the younger age groups (15 or less, 16-20) and the aged (over 60) tends to be lower for SkyTrain than for transit riders as a whole.

TABLE 2-4: AGE PROFILE OF SKYTRAIN RIDER

AGE GROUPS (YEARS)	SKYTRAIN RIDERS	ALL TRANSIT RIDERS
15 OR LESS	4.4 %	9.8 %
16 -- 20	12.0 %	18.7 %
21 -- 30	33.7 %	26.0 %
31 -- 40	21.4 %	13.5 %
41 -- 50	11.6 %	8.6 %
51 -- 60	8.6 %	7.2 %
OVER 60	8.3 %	16.2 %
TOTAL	100.0 %	100.0 %

2.3.2 VEHICLE AVAILABILITY

Vehicle ownership is a variable more likely to indicate if workers are captive to transit or if they may choose from several modes. Table 2-5 AND TABLE 2-6 shows the change of vehicle ownership and commuting mode to central area in Washington, D.C. before and after Metrorail.

In the survey for estimating Metro ridership patterns conducted by WMATA in June of 1979, 53 percent of all weekday Metrorail riders claimed that a vehicle was available for this trip. This is somewhat lower than the percentage reported above for work trips and suggests that a lower number of riders using Metro for non-work trips

TABLE 2-5
 AUTO OWNERSHIP & COMMUTING MODE TO CENTRAL AREA BEFORE METRO

PERCENTAGE OF	AUTOS PER HOUSEHOLD				
COMMUTING USING	0	1	2	3 OR MORE	ALL WORKERS
AUTO	10%	49%	71%	73%	57%
TRANSIT	74%	44%	27%	25%	38%
OTHER	16%	7%	2%	2%	5%

are "choice" riders. However, 51 percent of bus riders reported a car was not available for this trip.

In Vancouver, the majority of SkyTrain riders (56.8%) did not have a car available for the trip. This proportion of "captive" riders is considerably lower than the 79.5 percent for transit riders as a whole indicated by the 1985 Vancouver Metropolitan Travel Survey. It can therefore be concluded that a higher proportion of SkyTrain riders use the system by choice rather by necessity.

In 1987, the number of private owned passenger vehicles in Beijing was only 17,528. The car ownership is too small to consider in modal split. Thus, at least 90 percent riders of Subway Beijing is regarded as captive riders.

TABLE 2-6
 AUTO OWNERSHIP & COMMUTING MODE TO CENTRAL AREA AFTER METRO

PERCENTAGE OF COMMUTING USING	AUTOS PER HOUSEHOLD				ALL WORKERS
	0	1	2	3 OR MORE	
AUTO	9%	44%	66%	68%	52%
TRANSIT	74%	49%	32%	29%	43%
OTHER	17%	7%	2%	3%	5%

2.3.3 INCOME

The distribution of all Metrorail riders by income is shown in Table 2-7. The median income of all Metrorail riders is \$24,000. Although this is slightly lower than the income reported for all central area workers, it is considerably higher than the income of bus riders estimated at \$17,500 in June 1979.

TABLE 2-7
INCOME CHARACTERISTICS OF WEEKDAY METRO PASSENGERS

ANNUAL HOUSEHOLD INCOME	PERCENTAGE OF RIDERS (%)	
	METROBUS	METRORAIL
BELOW \$8,000	15	5
\$ 8,000 - \$15,999	31	24
\$16,000 - \$23,999	21	21
OVER \$24,000	33	50

2.3.4 EDUCATION

The education levels reported by Metrorail riders are shown in Table 2-8. A very high percentage of Metrorail and Beijing Subway riders are high school graduates, and most of Metro riders have been to college. This is consistent with the income characteristics, since income is generally correlated with education. It does, therefore, appear that Metro is fulfilling the goal of serving both the upper-income as well

as the better educated, many of whom may not be willing to come to the central area without Metrorail, and probably not by bus.

2.4 TRAVEL CHARACTERISTICS

2.4.1 ACCESS MODE

Riders were asked how they travelled to a SkyTrain station and from a station to their destination. As shown in Table 2-9 the most common modes to the SkyTrain station were bus (43.2%) and walk (39.7%). A total of 16.6 percent of riders access the system by car through either driving and parking (7.7%) or by getting dropped off (8.9%). At the destination end SkyTrain riders predominantly walk to their final destination (69.4 percent compared to 26.6 percent by bus and 2.9 percent by SeaBus).

As shown in Table 2-10, there is a sharp contrast between how people traveled to and from origin and destination stations during the morning peak in Washington, D.C.. The majority of Metrorail users in the morning peak period arrived at Metrorail stations by bus, the next largest category of riders arrived on foot, and the third one was by auto.

Planners expected that 75 percent of SkyTrain riders would take a bus to the station, but in fact it was about 50 percent. More people are walking or getting dropped off by auto at "kiss and ride" loops.

TABLE 2-8
EDUCATIONAL ACHIEVEMENTS OF WEEKDAY METRO PASSENGERS

EDUCATIONAL LEVEL	PERCENTAGE OF RIDERS (%)	
	METROBUS	METRORAIL
NO HIGHER THAN HIGH SCHOOL	26	11
SOME COLLEGE	27	23
COLLEGE GRADUATE	19	24
POST-GRADUATE	28	42

2.4.2 WALKING DISTANCE

A rule of thumb in transit is that most people won't walk more than 600 meters to get to a transit stop, but many SkyTrain and Subway Beijing riders are walking farther than that. The results show that riders who walk to the SkyTrain stations are prepared to walk much further than those who drive to the stations.

TABLE 2-9: ACCESS MODE TO RAPID TRANSIT STATION

MODES	VANCOUVER	BEIJING
BUS	43.2 %	54.4 %
WALKING	39.7 %	25.8%
BICYCLE	--	19.6 %
DROVE CAR/PARKED	7.7 %	--
DROPPED OFF BY CAR	8.9 %	0.1 %
OTHER	0.5 %	0.1 %

2.4.3 TRIP PURPOSE

Table 2-12 compares the trip purposes for rapid transit riders in three systems. The results show that 63.8 percent of SkyTrain trips, and 75.8 percent Subway Beijing trips, and 67.4 percent of Metrorail trips are work-related. School trips and shopping trips, however, are less significant trip purposes for SkyTrain than for the transit system as a whole. In Beijing, home-based trips constitute the overwhelming majority of peak period trips, and non-working related trips constitute the majority of off-peak period trips.

The Metrorail is found to serve a majority of riders going to and from work. The second most frequent trips were job-related trips, such as midday business travel,

TABLE 2-10
METRORAIL AM PEAK PERIOD MODE OF ACCESS AND EGRESS

TYPE	MODE			
	AUTO	WALKING	BUS	OTHERS
ACCESS	22 %	25 %	49 %	4%
EGRESS	1 %	89 %	9 %	1 %

with almost as many riders using the system between 9:30 a.m. and 3 p.m. as in the morning peak period from 6 a.m. to 9:30 a.m..

2.4.4 TRIP FREQUENCY

One of the advantages claimed for rapid rail transit is that, unlike a bus system, it is much easier for a potential riders to learn where the system goes. The effects of such a characteristic is that a rapid rail transit system should have a high per-

TABLE 2-11: WALKING DISTANCE TO SKYTRAIN STATIONS

NUMBERS OF BLOCKS	CUMULATIVE PERCENT (%)		
	ALL RIDERS	RIDERS WHO WALK	RIDERS WHO DROVE & PARKED
UP TO 2 BLOCKS	76.4	45.1	95.4
UP TO 4 BLOCKS	89.1	76.2	96.4
UP TO 6 BLOCKS	95.6	90.8	99.0
UP TO 8 BLOCKS	97.6	95.4	99.3
UP TO 10 BLOCKS	99.0	97.9	99.6
10 OR MORE	100.0	100.0	100.0

centage of occasional riders, as compared to riders who are willing to invest the effort to learn about the best transit route and schedule for them.

The theory appears to be supported by Table 2-13 which shows the distribution of Metrorail riders according to frequency. Approximately three-fourths of all Metrorail riders reported that they use the system four or five times a week. This is considerably lower than the comparable percentage on the bus, where 90 percent of passengers are regular riders.

SkyTRain riders were asked to identify how many one way SkyTrain trips they made one week and which days they used SkyTrain. As shown in Table 2-14, the ex-

TABLE 2-12: PURPOSE OF TRIPS MADE ON RAPID TRANSIT

PURPOSE OF TRIPS	RAPID TRANSIT SYSTEM		
	SKYTRAIN	METRORAIL	SUBWAY BEIJING
WORK	63.8%	67.4%	65.8%
JOB-RELATED	--	10.0%	9.6%
PERSONAL BUSINESS	8.4%	7.0%	5.7%
SHOPPING	7.7%	5.3%	6.9%
SCHOOL	8.7%	3.9%	5.1%
SOCIAL RECREATIONAL	6.9%	--	5.8%
OTHERS	4.5%	6.4%	1.1%

tensive use of SkyTrain for work trips reflected in the result that highest frequency of weekly trips on the system is nine to the times.

A profile of weekly ridership on the SkyTrain system was derived by asking respondents which days riders used SkyTrain previous week. The results show an even rate of SkyTrain weekday usage varying from 17.5 percent to 17.9 percent of total weekly ridership. SkyTrain usage decline substantially to 6.5 percent and 4.8 percent of total weekly usage on Saturday and Sunday respectively.[7]

TABLE 2-13: FREQUENCY OF TRAVEL OF METRO RIDERS

NUMBER OF DAYS RIDING TRANSIT PER WEEK	PERCENT OF RIDERS (%)	
	METROBUS	METRORAIL
LESS THAN ONCE A WEEK	3	10
1 - 3 DAYS A WEEK	8	14
4 - 5 DAYS A WEEK	62	66
6 - 7 DAYS A WEEK	27	10

2.4.5 PARKING BEHAVIOUR

As previously noted 7.7 percent of SkyTrain riders can be classified as park-ride users. The majority local streets while 22.4 percent park in a free lot and 12.5 percent in a pay lot. A total of 95.4 percent of parking locations are within two blocks of a SkyTrain station.[8]

Those who drive a car and parked at a SkyTain station, i.e. park-ride, and those who were dropped off by car were also asked their reasons for not using connecting

TABLE 2-14: TRIP FREQUENCY OF SKYTRAIN RIDERS

NUMBER OF TRIPS	PERCENT OF RIDER(%)	RANK
0 - 2 TRIPS A WEEK	18.3	2
3 - 4 TRIPS A WEEK	7.1	6
5 - 6 TRIPS A WEEK	11.0	3
7 - 8 TRIPS A WEEK	7.4	5
9 - 10 TRIPS A WEEK	38.3	1
11 - 12 TRIPS A WEEK	8.5	4
13 - 14 TRIPS A WEEK	5.1	7
15 - 16 TRIPS A WEEK	1.9	8
17 - 18 TRIPS A WEEK	0.7	10
19 - 20 TRIPS A WEEK	0.6	11
21 AND OVER	1.1	9

bus service. The most often noted factors were that the bus service was too infrequent (30.6 percent respondents) or that buses were too slow (23.3 percent respondents).[9]

2.5 RAPID TRANSIT IMPACTS ON RIDERSHIP

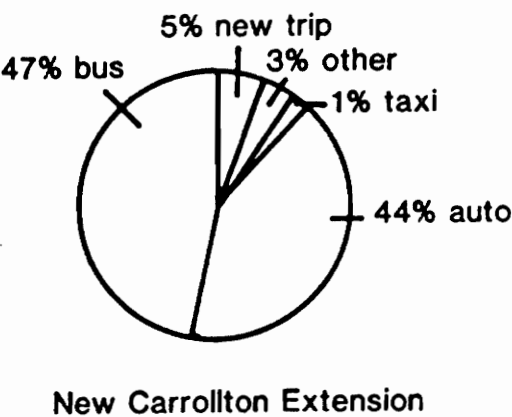
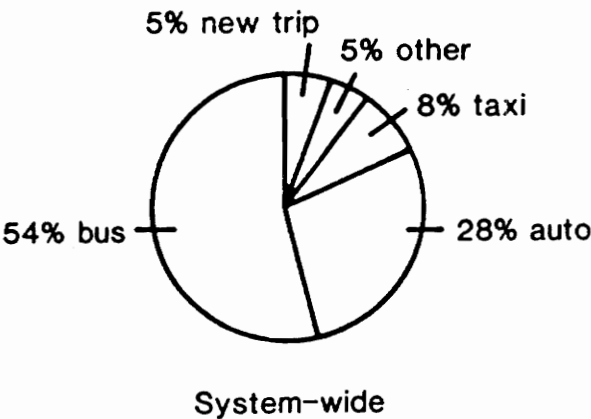
2.5.1 MODE OF TRAVEL

The 56 percent SkyTrain riders, the largest proportion, formerly used transit. The percentage of SkyTrain riders who appear to have been diverted from the private auto, 19.1 percent, is very significant and indicative of the comparably high level of service offered by SkyTrain. A further 20.3 percent of SkyTrain riders responded that they did not make this trip prior to SkyTrain. This result could be due to two factors: new riders attracted to the transit system by the presence of SkyTrain or changed origins and destinations since the introduction of the SkyTrain. These two figures do suggest a very significant growth in ridership in the corridor -- possibly as high as 70 to 80 percent.[10]

Recent origin-destination surveys in Beijing indicate that bicycles account for two-thirds of the urban trips in the peak period. Both mass transit use and bicycle use are subsidized by the government, so most commuters do have a choice. The high percentage of bicycle in modal split is the result of mass transit overcrowding. Many commuters avoid the use of mass transit, opting for their slowed, but more comfortable, bicycles, especially in spring and fall.

Figure 2-5 compares the prior mode of all riders with the prior mode of riders from the new stations of Metrorail Phase III (in the end of 1978). It appears that both of the suburban Metrorail extensions are capturing a higher percentage of former auto users and a lower share of transit users than the initial central area system opened in Phase I in 1976.

FIGURE 2-5: PRIOR TRAVEL MODE OF METRORAIL RIDERS



2.5.2 TRAVEL TIME AND COST

An important concern for commuters diverted to rapid rail transit from auto or other mass transit forms is what benefits the riders get from this service. Specifically, how do the time and cost characteristics compare with auto or bus? Since commuting patterns change very slowly in comparison to shopping or other non-work related travels, the most valid way to compare time and cost characteristics is to analyze work trips before and after the rapid rail transit improvement.

The analysis of commuting distance showed that there had been no change during this period for either auto or mass transit travels in metropolitan Washington. Therefore, the time cost comparisons can be assumed to be based on approximately the same commuting patterns before and after Metrorail.

Table 2-15 shows that the average reported commuting time to jobs in the core of D.C. did not appear to change for either of the primary modes by the fall of 1978, before the opening of the New Carrollton extension. However, the travel times for sub-modes within the transit category show sharp differences among transit riders after the opening of Metrorail, according to whether or not they used it.

Commuters who could walk both to and from Metrorail stations reported a travel time of only 31 minutes in average, considerably shorter than the average transit commuting time before Metrorail. On the other hand, those requiring a double transfer requires over an hour to complete their trips. It is likely that more Metrorail riders are in Metrorail only or Metrorail and bus categories, which should lower the average travel time for central area commuters.

TABLE 2-15: REPORTED COMMUTING TIME TO THE D.C. CORE

TRAVEL MODE	AVERAGE MINUTES PER TRIP	
	BEFORE METRO	AFTER METRO 1978
AUTO DRIVER	38	38
AUTO PASSENGER	39	39
WMATA TRANSIT	45	45
BUS ONLY	42	38
BUS AND AUTO	54	53
METRORAIL	--	49
METRORAIL ONLY	--	31
METRO AND BUS	--	52
METRO AND AUTO	--	49
METRO, COMMUTER BUS	--	63
METRO, COMMUTER BUS, AUTO	--	64
METRO, BUS, AND AUTO	--	82

The results of SkyTrain's survey got the same solution.[11] The results in Table 2-18 show that for 62 percent for all SkyTrain riders travel time had decreased and 20.7 percent travel time had remained the same as before. A breakdown by previous mode showed that for those riders who previously made the trip by bus only 15.2 percent showed an increase in travel time while 83.7 percent showed a decreased in travel time as a result of SkyTrain. For previous auto drivers 56.1 percent perceived a decrease in travel time.

Due to the economic development in the decade, the traffic volume increase rapidly in metropolitan Beijing. From 1978 to 1980, the vehicle traffic volume increased 64 percent and 92 percent respectively within the Second Ring Expressway (the central area of Beijing) and in the region between the Second and the Third Ring

TABLE 2-16: SKYTRAIN TRAVEL TIME

TRAVEL TIME	ALL SKYTRAIN RIDERS	PREVIOUS BUS RIDERS	PREVIOUS AUTO DRIVERS
INCREASE	16.5%	15.2%	43.9%
DECREASE	62.8%	83.7%	56.1%
SAME AS BEFORE	20.7%	1.1%	0.0%

Expressway. However, the investment on highway construction in Beijing only took 5 percent investment of capital construction. This ratio should be within 14 to 15 percent in order to meet the needs of traffic growth. Thus, the average speed of vehicles reduced to 20 kilometers per hour in central Beijing.

In 1987, the average commuting time of mass transit riders was 60 minutes, higher than 31 minutes for the chartered bus riders, 49 minutes for bicycle riders and 34 minutes for Subway riders. In a survey, riders of Subway were asked whether their travel time has increased or decreased or remained the same compared with their

means of travel before Subway Beijing. 74 percent riders reported that Subway reduced their travel time, and 21.6 percent riders remained the same while 4.4 percent riders responded having a increased travel time. The major reasons for increased travel time were the delay in transfer and the low productivity of buses and trolleys. Obviously, the Subway Beijing is a time saving tool for commuting.

The other factor of concern to commuters is the cost of the trip. For many people, the choice of mode involves a trade-off between the higher speed of an automobile trip and the lower cost of transit travel, especially if a parking cost is involved. As reported in Table 2-16, the average out-of-pocket commuting costs did not change significantly before and after Metrorail for transit riders. Transit commuters riding the bus paid a slightly higher cost to reach the central area, primarily because of a fare increase in July 1978. However, those using Metrorail only saved money in comparison to the pre-Metrorail condition. Transit riders requiring a bus transfer to reach Metrorail paid a higher cost than the average per-Metrorail commuters for their trips, even though there was a free transfer from Metrorail to bus on the way home. It appears that for central area commuters Metrorail is more expensive to use than the bus, but is probably cheaper than the auto for those commuters who switched.

The fare of Subway Beijing is ten cents for one trip in any length and free transfer. However, the fare of bus and trolley are at the range from five cents up to RMB\$ 1.5 (Chinese currency) depend on travel length. The Subway Beijing is a cheaper mode for commuting.

These facts clearly indicate that travel times of rapid rail transit are perceived as being competitive with the automobile and are considerably better overall than previous travel times by transit.

TABLE 2-17: AVERAGE COSTS OF COMMUTING TO THE D.C. CORE

TYPE OF TRANSIT	DAILY ROUND TRIP COST	
	BEFORE METRO	AFTER METRO 1978
BUS ONLY	\$1.44	\$1.37
AUTO AND BUS	\$1.87	\$1.59
METRORAIL	-	\$1.70
METRORAIL ONLY	-	\$1.12
METRORAIL & AUTO	-	\$1.71
METRORAIL & BUS	-	\$1.91
METRORAIL, BUS & AUTO	-	\$2.03
OVERALL AVERAGE	\$1.54	\$1.55

2.6 ATTITUDE TO RAPID TRANSIT

2.6.1 OVERVIEW

Determining public attitudes to various aspects of rapid rail transit is useful information for future planning and marketing of these systems. Attitudes were surveyed by asking riders to indicate their level of agreement or disagreement with a variety of statements concerning the rapid rail transit service. The following sections outline the results.

2.6.2 GENERAL ATTITUDES

To determine the general attitude of SkyTrain riders to the system, riders were asked to respond to two statements "SkyTrain service meets my transportation needs" and "SkyTrain is an asset to the community". The results shown a very positive attitude to SkyTrain and a satisfaction its capabilities as a transportation system. A total 81.1 percent agreed or strongly agreed that SkyTrain was an asset to the community and 75.9 percent agreed or strongly agreed that SkyTrain met their transportation needs.

Almost all riders who live in those communities near Subway stations felt the Subway service met their transportation needs. However, 11.3 percent riders who need transfer bus or trolley expressed the neutral or negative attitude due to the long walking distance between the Subway station and bus or trolley station.

2.6.3 RELIABILITY AND SPEED

SkyTrain riders were asked to indicate their attitude to the following statement "SkyTrain service is reliable". 88.4 percent agreed or strongly agreed with this statement indicating a positive response to the high frequency of service and low incidence of delays on SkyTrain. Riders also appreciate the fast travel time available by SkyTrain. A total of 89.2 percent agreed or strongly agreed with the statement "SkyTrain is a fast mode of travel."

2.6.4 TRANSFERRING AND STAFF HELPFULNESS

Public response to transferring between rapid rail transit and the bus-trolley system is a key consideration in assessing rider acceptance of the changes in travel patterns resulting from the conventional mass transit and rapid transit integration. Riders were asked to respond to two statements, "Transferring from SkyTrain to bus is convenient" and "Transferring from bus to SkyTrain is convenient".

As the SkyTrain offers a more frequent level of service than connecting buses it would be expected that riders would be more positive concerning transfers from bus to SkyTrain. A total of 68 percent of respondents agreed or strongly agreed about the convenience of bus to SkyTrain transfers as compared to 52.7 percent for SkyTrain to bus transfers.

Some Subway Beijing stations are not near bus or trolley stations. Many riders complained this inconvenience of transferring. One of the reasons for the inconvenience is the fact that Subway Beijing are neither owned nor operated by the Beijing Public Transit Corporation. It is believed that the problem will be solved by moving existing bus and trolley stations close to Subway stations to reduce the transferring distance in near future.

SkyTrain riders do not appear to reflect earlier concern about the public reaction to driverless trains. Respondents were also appreciative of SkyTrain staff. The majority of riders agreed or strongly agreed with the statement "SkyTrain staff are helpful".

2.7 SUMMARY OF FINDINGS

For the three rapid rail systems, ridership tends to be heavily concentrated in morning and evening peak periods, most of daily riders are traveling between their residences and jobs, especially for the suburban riders. Patterns of ridership tend to be heavily weighted in one direction. Most stations in downtown have a mix of peak and off-peak period arrivals, their stations primarily serve high percentages of either residents, shoppers or visitors than other stations. Virtually all morning peak period passengers walk from rapid transit stations to their destinations. Since most destinations are to jobs. Rapid transit ridership variations doesn't follow the traditional variation in transit use from season to season.

The increased rapid transit ridership in peak period go into and out of downtown being accompanied by a decline in peak period auto travel and traffic volume in major transportation corridors. The rapid transit systems in its period of initial operations has allowed substantial increases in travel to the central area without increases in highway capacity, supporting the systems' principal goals.

Rapid rail transit mainly attracts riders either destinations or origins close to stations. Riders are attracted because of travel time savings over buses, cost savings over autos, and parking advantages.

Changes in total transit ridership varied with the size of the line segment opened and with the extent to which new markets for transit were penetrated. Ridership growth projections were consistently exceeded. There was a reduction in the number of regional transit riders using buses and trolleys. A significant shift occurred in the orientation of bus passengers. Most rapid rail transit systems are used for work-oriented travel.

Most users arrive at rapid transit stations by bus during morning peak. Trips on rapid rail tends to be concentrated centrally oriented. Travel changes has been characterized more by increased transit use than by reduction of auto use or congestion. User travel time and cost changes were strongly related to the specific trip origin or destination.

Major differences exist in zone accessibility when trip purpose is work vs service. Travel times regionally are short and are linked more to highway than transit use. Time and total accessibility will change due to the rapid transit improvement.

The predominant use of Metrorail, SkyTrain and Subway are for long-distance commuting. Heaviest Metrorail users are white collar commuters. The impact of Metrorail on travel patterns is less than anticipated. Actual ridership exceeds projected ridership except the period from 1980 to 1982.

These rapid transit systems have increased travel capacities and travel in the constrained corridors it serves. SkyTrain and Subway Beijing are serving a large proportion of the trips it was designed to serve. Community support for the project is important for avoiding conflict. Supportive public policy can help shift demand into station areas.

Generally speaking, the conclusions that rapid rail transit is a useful tool to solve urban traffic problem is confirmed by the three systems in this chapter.

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10. Same as [7]
11. Same as [7]

CHAPTER 3: URBAN FORMS AND RAPID TRANSIT

3.1 THE CONCEPT OF POLYCENTRIC CITY

3.1.1 OVERVIEW

The three cities in this study have adopted regional development plans that call for the management of the location and timing of growth. These plans express the interest of local government in preserving the utility of the heavy investments they have made in sewers, highway, public transit and other public facilities as well as their interest in keeping the cost of constructing new public facilities within reason.

The theory that underlines these regional development plans is that if the local government can control the location and timing of four key types of public investments, then it will be able to shape the pattern of the development in directions that offer the greatest benefit to society as a whole.[1]

These "growth shapers" are transportation, utilities, open space, and major activity centers. To date, transportation has received by far the most attention of the four while the concept of major activity centers as a key growth shaping element of any regional development plan has been widely accepted by the planning profession.

It is widely believed that a city that has several relatively high density clusters of activity (i.e., the polycentric city) is better able to support a viable public transit system than one that has only one major center (i.e., the monocentric city).

At present, many cities contain one large center (i.e., the Central Business District -- CBD, or downtown) and a very large number of small clusters of activity located in almost every other part of the metropolitan region. This pattern of activity is extremely difficult to serve with rapid rail transit system because the origin-destination pattern of trips is so diffuse and diverse. A polycentric city contains a hierarchy of centers, ranging from the downtown, which is the largest one of the urban centers, to a few large regional centers, to community centers, to the small convenience neighborhood type centers. This urban form then becomes much more possible to design and operate a rapid transit system that can provide frequent and fast service that will lead to its efficient utilization. Cities which do have rapid transit systems can be considered to be evolving a polycentric urban form but they normally consist of one large center and a large number of small clusters around some (but not all) of the stations in the systems.

While the achievement of a viable rapid transit system has been an important reason for the inclusion of the major activity center element in regional development, there are other reasons why cities have found the system attractive. Expectation are that the creation of a polycentric urban form with rapid transit will

- Reduce the convergence and congestion problems associated with home-to-work travel in a monocentric city;
- Reduce total travel and hence the transportation energy requirements of the city while also aiding the improvement of air quality;
- Provide places other than the central city for low income people to live;
- Provide places having some urbanity in suburban areas; and
- Make the outer parts of the city more self-sufficient.

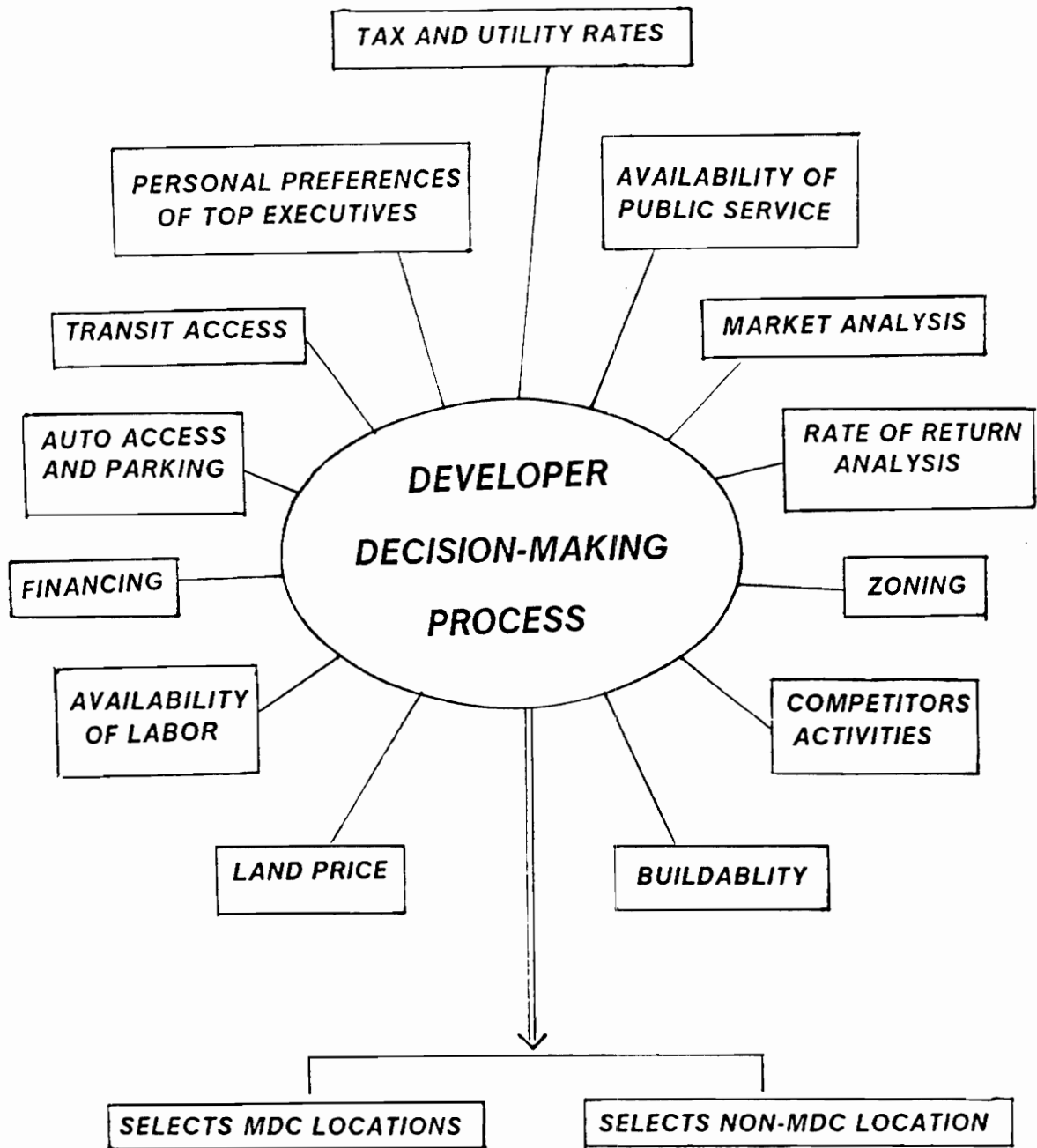
The term "major diversified center"(MDC) is often used to refer to the downtown and regional centers, defined as being miniature downtowns "including a large concentration of retail, service, cultural, entertainment and office facilities located within a relatively compact land area; blended with high density residential development and certain kinds of manufacturing, warehousing and research operations"[2]

3.1.2 ATTITUDES OF DEVELOPERS

To accomplish the objective of getting much of the new growth and relocations to select MDC locations, a large numbers of developers will have to be convinced that it is in their best interests to choose such locations. Forecasts of growth and change will show that several new developments and relocations of existing activities can be expected to occur in the future. The successful rapid transit systems would guide as much as possible of these actions into MDC locations or along major rapid rail transit routes.

These developers operate in a very complex environment as represented in a very simplified form in Figure 3-1. They are influenced by a large numbers of factors

FIGURE 3-1: DEVELOPER DECISION-MAKING ENVIRONMENT



as they conduct the decision-making process that leads to the selection of a location for their particular development. As indicated in Figure 3-1, transit access is only one of several factors which strongly influence the developer's choice of location. Give the strong dominance of the automobile and highways in American cities over the last several decades, it is probable that transit access is currently a very low priority factor in the thinking of most developers today, while in European, Canadian and Chinese cities the transit is a high priority factor due to their government choose another policy to treat the public transit differing from American policies. However, transit access will become increasingly important in the future as the cost of auto transportation rises due to increases in vehicle, fuel, tax and other operating costs.

As rapid transit access increases in relative priority, it will make those locations that now have it (or are proposed to have it in the future) more attractive, all other things being equal, than those which do not have it now nor expect to have it in the future.

3.2 ANALYSIS OF THESE THREE CITIES

As noted above, the radial corridor and polycentric pattern would be served successfully by the rapid transit, and the rapid transit would strengthen the trends of urban decentralization. Vancouver's urban form is a typical polycentric case. Beijing and Washington, D.C. are a combination of radial corridor and polycentric form both.

3.2.1 URBANIZATION PATTERNS

3.2.1.1 VANCOUVER

Greater Vancouver presents a unique opportunity. The historic image is changing yet it is a young city and still has enough undeveloped land to meet change without a need major alternations.

An important factor in the development of the Greater Vancouver Regional District is its unique topography. The barriers presented by the Pacific Ocean to the west, the Fraser River to the south, and the mountains to the north, presents significant transportation challenges. The location of the city tends to force development into downtown Vancouver, Metrotown and New Westminster.

These physical constraints, plus the continued growth of the region's population, have combined to generate suburban development in almost all relatively accessible and developable areas throughout the north bank of the Fraser River.

In March 1975, the Greater Vancouver Regional District (GVRD) published a plan, called *The Livable Region 1976-1986*. This plan sets forth a five-part strategy for managing growth in the Greater Vancouver Region. These strategy elements are as follows:

- Achieve residential growth targets in each part of the region;
- Promote a balance of jobs to population in each part of the region;
- Create regional Town Centres;
- Provide a transit-oriented transportation system linking residential areas, Regional Town Centres, and major work areas;
- Protect and develop regional open space.

The third element of this strategy directly calls for the creation of a polycentric city while the fourth element directly support the concept of transit-oriented transportation system.

These suggestion are supplemented by the following statement, which captures the essence of the rationale for the Regional Town Centres strategy in Vancouver:

"A fundamental purpose of the Regional Town Centres Program is to help balance population and employment in the various part of the region by decentralizing jobs to suburban municipalities. This objective has become even more important since the time of the Board's resolution. In the face of serious shortages of money and energy for transportation, we can no longer afford to transport growing numbers of people from suburban homes to downtown jobs. Therefore, we must either get Regional Town Centres started as a way to bring jobs, shopping and leisure activity closer to home, or suffer a serious decline in the accessibility of these activities to residents of the region." [3]

3.2.1.2 WASHINGTON, D.C.

Washington, D.C. is a planned city. Pierre Charles L'Enfant's 1791 Plan for Washington has been realized, its wide avenues and distant vistas successfully accommodating the growth of the Nation's Capital. Its framework of major avenues and open spaces overlaid with the rectilinear grid of local streets establishes the Federal presence in a finer mesh of local city life. The plan generates a series of axial perspectives which bestow prominence on national buildings, and the intersection of these perspectives provide city-scaled reference points for visitors and residents

alike. Extensive landscaping frames monumental views, while close-in urban parks offer more intimate relief. Through the manipulation of these essential elements, L'Enfant's Plan from its inception established Washington as the special city it is today.

L'Enfant designed Washington in the condition of Rome and Paris -- great western capitals of his day. He had the fortune to work on an undeveloped setting and the vision to provide a scale appropriate for the new capital. He also created a challenge for subsequent designers and developers: to guide the city's development through changing social and economic conditions while honoring the principles of its planned form.

The polycentric city concept was an important feature of the *Policies Plan for the Year 2000* published by the National Capital Regional Planning Commission in 1961. This plan defined several urban form alternatives and then identified a "radial corridor" (also known as "wedges and corridors") form as a preferred alternative. Within these corridors, major centers were identified, some in undeveloped location and others at existing suburban centers.[4] Believing that a rapid transit system would be needed to meet twentieth-century needs, the plan proposed that the strategic location of large federal employment centers in the transit-served corridors would lead to an orderly growth of original town centers.

3.2.1.3 BEIJING

Beijing, used to be called Peking, was founded in the eighth century B.C. in approximately its present location. The present city plan originated in the eleventh century A.D.. Beijing today retains the same general layout it had in the Ming Dynasty (1368-1644), square and symmetrical in the central district. In the center of the

city is the group of imperial palaces called the Forbidden City -- so named because the common people were forbidden to enter here -- which is the Palace Museum today. To the north of the Forbidden City is the Imperial City. A square 20-kilometer area outside the Imperial City is the Inner City (or Tartar City); it was constructed in 1397. The rectangular part of the city to the south is the Outer City (or Chinese City). These four "Cities" consists the central district of metropolitan Beijing. The central district is crisscrossed with main streets intersected by lanes called "hutongs". These hutongs are surrounded by the old fashioned residential regions. These hutongs are traditionally the homesite for many artists and artisans, as well as the sites of shops that serve local residents with their daily needs.

Most large scale modern residential communities, office complexes, universities and colleges, technical and scientific research institutes, national and local governments and public agencies, international financial and business districts, diplomatic office districts and alien residential districts as well as industrial parks scatter outside the central district. Due to the limitation of central Beijing in both the height limits and availability of land, more and more new developments are encouraged to move to the satellites in peripheral areas of the City of Beijing, especially the industrial parks.

While growth in suburban areas away from the central district congestion has been in office and manufacturing space, as well as in residential space, residential density in the central district continues to increase in areas with nearby shopping centers, schools and other urban amenities, in contrast to the suburbanization of American metropolises. Most residents of Beijing prefer to live in city centers, especially in the central district, and commute to work by mass transit and bicycles.

The Master Plan for Metropolitan Beijing is more advanced than those being prepared for other Chinese cities. It has been submitted to the State Council and the People's Congress for approval. The plan adopts the polycentric city pattern and

proposed new development in suburbs and satellites on the least productive land in agricultural surroundings. Industrial plants are limited in these satellites, located with reference to prevailing wind directions in order to reduce pollution in both the local metropolitan region. Housing for workers in the new industrial parks is located near the industries in order to reduce traffic congestion between central city and the satellites, but separated from them by a greenbelt. Transportation needs are reduced by encouraging walking and bicycle riding to places of employment for these workers who live near their working places and offices. Traffic arteries bypass the central district of Beijing to reduce the amount of internal traffic and the congestion that is so often associated with it.

Work to broaden the road around the Forbidden City was started in the 1950s. To ease traffic conditions, the city walls as well as 13 wall gates were pulled down and the four biggest archways at the Inner City removed. The stupid actions of the Communists have been criticized by professionals and publics although they admit it is a wrong decision. One decade ago, two expressways, the Second and the Third Ring Expressways, were built on the ruins of the old city walls to link the central Beijing with its suburbs. More than twenty overpasses -- seven triple-decked and rest double-decked -- span the expressways. Besides vehicle lanes the expressways have special bicycle lanes for Beijing's some five million bicycles.

Underneath the second Ring Expressway is the Loop Line of Subway Beijing. The circular subway system and the major above-ground roads combine to form a more convenient communication network in the central district.

3.2.2 THE URBANIZED NORTH AMERICA

In order to ascertain the present status of the polycentric city concept in the U.S., a survey of regional planning agencies in urban regions having a population of 500,000 or more was undertaken in late 1976 and early 1977 by the U.S. Department of Housing and Urban Development. Some information on this topic has also been obtained from two Canadian cities including Washington, D.C. and Vancouver.[5]

Although the results of the survey and site visits show that the polycentric city concept was a widely accepted notion among North American cities, there are some criticisms and problems against the concept.

A very important issue is that of community resistance to growth and increasing density in the outer city. As many studies of rapid transit station areas have discovered, people who live at low densities in single family houses do not like the prospect of high rise, traffic-generating buildings coming into their neighborhoods. Many suburban residents do not like the idea of "bring downtown" or "urbanity" to their neighborhoods. They would prefer to keep their environments as they are and travel by car to obtain whatever they need in the way of urbanity as often as they please. This issue can become highly politicized very rapidly and can be a major obstacle to any plan that calls for the extension of rail rapid transit systems and creation of major diversified centers. It can often boil down to a confrontation between community groups, regional interests and the owners of the property along the transit routes and/or in MDC locations. There are, of course, no way to avoid this kind of situation but by being prepared for it.

If the outer city center are developed as auto-oriented centers, the gasoline consumption might arise and the air quality in these area may become worse. If rapid

transit is provided in a timely and forceful fashion, these centers may be able to grow and become more dense without reducing the quality of the air appreciably. A well-designed transit service to and within outer city center is therefore probably an important precondition to the achievement of any substantial reduction of travel and air pollution within the urban region.

Basically, rapid transit systems probably offer the same type of growth inducing and densification potential in the outer city as they do in downtown areas. Sometimes, the land use effect might be greater in outer city centers because many of them are already growing faster than many downtowns. Thus the opportunity to "shape" growth with rapid transit investments may be greater in the outer city center than in the downtowns of many metropolises.

Each traffic mode -- bus, rail, paratransit and auto -- has its own hypothetical applications. The term "application" should be defined to be a major transportation function within a geographic location. Two major classes of rapid transit systems' applications consist of the defined area and corridor travel service. Defined area applications include airports, shopping centers, downtowns, universities and colleges, new towns, and industrial parks. A corridor application is the major link between any two defined areas.

3.3 CHARACTERS OF POLYCENTRIC CITY

3.3.1. CONSISTENCY WITH MARKET TRENDS

The trends in the location of people and jobs within the region usually indicate that there has been a rapid decentralization of both people and jobs from the central city of the region to the outer city. Furthermore, forecasts of the future overall distribution of people and jobs indicate that these trends are expected to continue at least until the year 2000. The majority of population and employment is now located in the outer city in most cases and that this majority is expected only to increase in the future.

Under these trends, people argue that the creation of major diversified centers (MDC) in the outer city is consistent with what the urban land market is already doing and that policies designed to implement the polycentric concept which is helped by rapid rail transit system are only intended to "shape" or "better articulate" what the forces that determine the nature of the urban land market are already producing. But, the high degree of clustering that is needed to create major diversified centers is not likely to be produced by the urban land market without some substantial intervention in the form of incentives, disincentives and direct participation from all levels of government. This "increased clustering" is one of the primary objectives that the rapid transit systems are trying to achieve and it will probably not arise naturally from the operation of the urban land market.

Generally speaking, it seems likely that office decentralization is not occurring quite as fast as retail, industrial, and population decentralization in many American cities. However, the rate is still great enough to give some credibility to the claim that the polycentric concept with rapid transit is consistent with the trend of the market, which is locating new retail/office space in our large urban regions.

3.3.2 REDUCTION OF TRAVEL REQUIREMENTS

Comparing with other five urban forms -- central, homogenous, radial corridor, linear, and satellite -- the multi-centered form (polycentric city) produce the least number person-hours of work trip and the shortest average work trip length of the six forms considered.

The rapid transit system, as a implementation tool for the officials, encourage the urban development of polycentric urban structure. Another major element of the rationale for the polycentric urban form is that it would reduce the total travel requirement of the city. This reduction would produce several side effects such as:

- Reducing congestion in the core of city;
- Improving air quality as a result of the reduced congestion;
- Fuel conservation because of shorter trips of all types; and
- Large patronage levels on public transit systems, which would also save fuel and improve air quality.

3.3.3 HOUSING DEVELOPMENT OPPORTUNITY

Obviously, these urban forms could provide places other than the central city for low income people to live. The social goals of dispersing the low income population in an urban region has been accepted in most metropolitan regions as being of paramount importance to the future viability of the central city. While the benefits that people can derive from living in neighborhoods with "their own kind" are generally recognized as being substantial, it is also clear that very large concentrations of low income people tend to produce very inadequate living environments. These notions lead to the concept of a "dispersed but clustered" pattern as being preferred for all types of income groups but particularly for those in the lower income ranges.

The rapid transit can contribute to the achievement of this objective if the provision of housing for low income people is included in the development plan for the "dispersed but clustered" pattern. Such housing could be subsidized from the values created by the development of the town center. Designing such housing into a center with the service of rapid transit would avoid many of the problems that have been encountered by public agencies trying to locate low income projects in the residential portions of suburban areas. The activities that constitute such a center need a certain number of lower level employees and they would find the task of filling these jobs and maintaining a low turnover rate much easier if some portion of the housing built in the center was designed for low income people. The major beneficiary of such a policy would be the central city as it could expect to begin to see some real prospects for a decline in its share of the regional total of low income people as the implementation of a successful rapid transit system progressed.

3.3.4 URBANITY

The polycentric city pattern could provide places having some urbanity in the suburbs. Some critics of the other city have noted their lack of urbanity and this is obviously something that a rapid system which connect downtown with major diversified centers can address directly. The term urbanity seems to be synonymous with the presence of good pedestrian spaces where one can find reasonably large numbers of people almost any time of the day. The major diversified center is intended to be a compact, convenient and integrated cluster of facilities and service. It would also be a place that offers a variety of social, economic, cultural and recreational opportunity to its users. Its vitality would be desired from the drawing together of people of different ages and socio-economic backgrounds in a compact urban setting by the convenient rapid transit. Of course, there are people who do not wish to see downtown come to the outer city not only the middle-to-high income people but also some low income people. The rapid transit provide them opportunity to live in outer city enjoying urbanity and to work or shop in central city.

3.3.5 SELF-SUFFICIENCY

The polycentric pattern makes the outer parts of the city more self-sufficient. Self-sufficiency is an old idea that is again gaining attention as the project for even higher prices for transportation energy threatens the viability of the low density outer city. Most parts of the outer city are still quite dependent on the central city and other parts of the regions for jobs and many types of goods as well as services.

This dependency can be measured in part by the population/employment ratio which shows the relationships between the numbers of people living in an area and the number of jobs located in that same area. Past statistics indicate that about forty percent of the population are employed in their living district in outercity, that is the population/employment ratio is $100/40 = 2.5$. Areas that have the ratios of about 2.5 are considered to have a good balance of people and jobs. Areas with ratios much greater or less than 2.5 are unbalanced and quite dependent on other areas.

There will be a very substantial demand for travel in Vancouver and Beijing in the future due to they have a high P/E ratio. To the extent that this simple measure is a good indicator of self-sufficiency and traffic demand. These ratios also suggest that the outer city is expected to become more self-sufficient while the central city becomes less self-sufficient due to its declining P/E ratios.

3.3.6 DISADVANTAGE OF POLYCENTRIC CITY

First and foremost is the argument that attempts to implement the centric city will kill the downtown by taking away its growth potential (if it has any) or accelerating its decline (if that is already in progress).

The second set of criticisms relate not so much to the desirability of creating large and dense outlying centers but to the feasibility of doing so. In some areas, transit agencies have recognized their vital interests in having such clusters emerge but few have chosen to work directly for policies that would encourage clustering to take place. Other feasibility issues relate to the actual implementation problems that would have to be solved in order to provide the incentives and disincentives needed

to get developers to choose locations in areas designated as major diversified centers.

The land assembly problem is another difficulty that critics use to argue that is not feasible to shape the market so that it will produce high density clusters.

Air quality questions are another source of doubt about the feasibility of implementing the polycentric concept. As long as the development plans for such centers are very automobile-oriented, they will run into great difficulty in terms of their projected violation of local air quality standards. The standards which exist today (if strictly enforced) effectively prohibit the creation of any additional large-scale auto-oriented clusters of activity in any part of the urban region.

There are some strong and valid arguments on both sides of the issue. As stated previously, my point-of-view will be one of assessing how the use of rapid transit might help to overcome some of the problems raised by the critics of the polycentric city concept.

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CHAPTER 4: RAPID TRANSIT AND LAND USE

4.1 *APPROACH*

In this chapter, land use impact is defined as a difference in land use with a major rapid transit improvement versus conditions which would have prevailed without that improvement under the "control area" model as noted previously. A conventional location-theory model is assumed, according to which the developer of land assesses the viability of a particular site based on many factors, including transportation access in general and possible access specifically by rapid transit as well. The key point is that many factors are involved.

The land use impact are limited within rapid rail transit system's envelopes or areas of influence. The envelope of SkyTrain and Metrorail is the area within 15 minute walking distance to rapid rail stations (0.7 mile or 1.1 kilometer), in Subway Beijing is within 20 minute distance (1.5 kilometer).

4.2 IMPACTS ON LAND USE

Generally speaking, rapid rail transit improvement exerts its influence on the following land use categories: residential, commercial, public use, educational and recreational, light industrial uses.

4.2.1 RESIDENTIAL LAND DEVELOPMENT

So many evidences indicate that rapid rail transit improvement could encourage residential construction, especially high-rise apartment construction. In Vancouver, Concord Pacific Developments Ltd. announced a 15 year plan for 10,000 dwelling units as a part of a \$2 billion project in former Expo 86 site in April 27, 1988. Also in Vancouver, two residential high-rises are under construction and three more are under active consideration as of May 1988.

In the edge of Outer City of Beijing, which includes the entire south, east and west just closing the Loop Line of Subway, government began the construction of three large public housing projects one year later of the opening the Loop Line of Subway. While housing development has not been limited to the environs of the line itself. These areas are served by several radial highways and two ring expressways in addition to the Loop Line of Subway. More construction occurred during 1979-82 close the Loop Line, but during 1982-84 more away from the Loop Line. However, in proportion to population, the housing development in the rapid transit-oriented communities nearer the Loop Line was greater.

4.2.2 COMMERCIAL LAND DEVELOPMENT

4.2.2.1 PRIVATE OFFICE

The statistics available on the distribution of regional employment and office space indicated that the area near SkyTrain have experienced substantial growth in office space.[1] Despite the continued concentration of new offices in downtown Vancouver, large and increasing proportions of office construction were occurring in the Metrotown and New Westminster. This is apparently due to New Westminster's history as an attractive and accessible area originally opened by highways and later strengthened by Skytrain.

On the Metrotown station in Burnaby, several office towers and corporate headquarters have recently gone up and a one-million square foot retail complex is now under construction. The Metrotown Centre, was a \$100 million project including department stores, shopping malls, hotels and office, was completed in 1986. As a part of this project, the Metrotower which is a office tower with 264,000 square feet office space and underground parking which could handle 2,900 vehicles, was finished. A special walkway will connect this complex to SkyTrain. A second phase plans for two high-rise towers, one for office use, the other an hotel.

In core Washington including downtown D.C., over 80 percent of of employment is classified as office (commercial and governmental), as the major "industry" in the region. One interesting fact is more than 85 percent new office space was added in Metrorail envelope. As of May 1982, seven major office buildings have been completed, and sixteen new buildings are under construction. Franklin Square will become the most important new office area in downtown D.C., served by the McPherson

Aquare and nearby Metro Center Stations of Metrorail. These facts could be cited for the consideration of rapid transit access in location decision.

4.2.2.2 HOTELS

By analyzing data provided by Office of Planning and Development of the Government of District of Columbia, one fact is found that majority of new hotels is concentrated the Metrorail station area both inside and outside downtown D.C., such as Rosslyn, Pentagon City and Crystal City Stations.

First Capital Place, completed in the fall of 1988, is a 125 room hotel and low-rise office complex, owned by Westwater Properties in New Westminster of Greater Vancouver. This project overlooks the Fraser River, is within easy walking distance of SkyTrain. Phase Two, comprising two hotel buildings, is scheduled for construction in about a year. Total cost is \$75 million.

4.2.3 EDUCATIONAL AND RECREATIONAL LAND USE

The project as "Burnaby 2000" the "School of the Future" will start its construction in the fall of 1989 for a comprehensive secondary school. Scheduled for completion by the fall of 1991, it will accommodate 1,500 grade 8 to 12 students, and provide latest state of art teaching and learning methods which will be considered and chosen as the project develops in order to meet the needs of students in the 21st century. Cost is about \$16 million (Canadian).

Bonsor Park, is a \$9 million (Canadian) recreation center, opened in April 1988, and said to be the largest of its kind in British Columbia. It is part of downtown

Metrotown area. It contains swimming pools, and extra size gym, a large senior citizens center, banquet rooms, racquet ball courts, and a day-care center. It emphasized the Metrodown philosophy: "Not just a shopping centre, but a social centre to meet the needs of residents and visitors." [2]

The Shijingshan (the Mountain with Stone Trial) Recreational Center is located in the area half block away the Main Line of Beijing Subway. It is said that the center is the second largest one in Asia only next to the Disney Land in Japan. The accessibility to Subway and availability of open land were the most important factors to locate the center in there.

4.2.4 PUBLIC LAND USE

The Municipality of Burnaby has completed a two-year land assembly for the construction of and \$18 million complex containing a resource library, civic square and two-level public parking lot. Close to Metrotown and Patterson stations of SkyTrain, this will allow park-and-ride commuters on SkyTrain.

In Washington, D.C., Metrorail has encouraged development around both Metro Center and Gallery Place station. The typical case was to build the Washington Convention Center to the north of this area. The Convention Center is the city's major economic development project as a part of downtown rehabilitation program. It is located on its downtown site because of the proximity to the two major Metrorail stations and retail core.

4.3 THE ROLE OF RAPID TRANSIT IN LAND USE

4.3.1 RAPID TRANSITS SHAPE LAND USE

Since Beijing Subway is a high-capacity system with a linear line and a loop line extending from the inner city through the outer city far out into the western suburbs. It is obvious that the Subway reshapes and will reshape the land use around this rapid rail transit system in Metropolitan Beijing. In particular, one might expect that suburban fringe development to be occurring more rapidly near the system stations than in other parts of the region not served by the system.

The metropolitan Beijing is a natural location for growth in any case. Subway's role is therefore that of an important number in a complex of pro-development force, because this rapid transit is the most important transportation tool for most commuters who depend on public transport. Thus, the place within reasonable access distance to Subway station with an attractive environment and available land at acceptable cost, attracts more and more investment and changes its original land use.

The coming of Metrorail caused major modifications to land use for the Silver Spring station area. The station area was replanned from general commercial and industrial to high-density mixed use in order to create a "Metro Center" west of the existing central business district. The revised plan call for a link between the two centers consisting of a civic and convention center, transportation center, a retail mall and an urban park. Residential developments nearby would be preserved, as well as

a portion of the existing railroad-related industrial uses. The plan has implemented successfully.

4.3.2 RAPID TRANSIT REDUCES DECLINE OF DOWNTOWN

The decision to build Metrorail was foundal on the desire by the city fathers to support the old Washington, D.C. downtown so that it would remain a viable center, as noted previously in one of the goals of Metrorail -- preserve the economic viability of the central city. Virtually many new development which could be associated with Metro concerned land use change has taken place in downtown. It is a widespread conviction that without the building of Metro, the downtown area would have continued to decline and give way to decentralization of offices and retail activities due to suburbanization of metropolis. The decentralization trend was already in progress before the Metro system was built.

For Washington D.C., the challenge of downtown revitalization is that it is difficult to get people who work in downtown office daytime back into downtown after returning home. However, people who are attracted by the diversified downtown evening activities and hotel customers play the substitute roles in the evening. As mentioned previously, most new hotels are near Metrorail stations, and a number of "old" hotels are within the walking distance to Metrorail stations in central D.C.. People who live in hotels would prefer Metrorail as transport tool comparing with the expensive taxi. Hotels stimulate evening and weekend activity, generate tax revenues at a rate almost five times that of a comparable office building, and private entry-level jobs for unskilled and semi-skilled workers.[3]

Construction of the Washington Convention Center was one of the major actions in revitalization of downtown as noted previously. Another case is the King Street station of Metrorail in Alexandria. Under the guidance of city government, the station is being used as the catalyst for redevelopment commercial area of Alexandria deteriorated downtown near historic Alexandria railroad station.

The new development in downtown Vancouver is dramatic both in its intensity and diversity. In addition to expansion of commercial and governmental office space, there has been a major strengthening of the downtown retail shopping role.

The SkyTrain system is helping to revitalize New Westminster's downtown, and servicing downtown Vancouver where the skyline is changing with multi-billion Canadian dollar projects.

In attempting to apply the Vancouver experience to other cities, it is essential to remember that the Vancouver CBD never experienced the degree of deterioration common in downtown area elsewhere in North American cities. The city's historical role as the major banking and corporate center of the West and the Pacific Basin, as well as the magnitude and importance of its tourist trade, served to keep downtown prosperous and interesting. With these advantages, suburbanization or outright decline in office functions has never been as serious a concern as in many other cities.

4.3.3 RAPID TRANSIT INDUCE DEVELOPMENT

The SkyTrain is creating an original downtown in Burnaby, in while the Subway Beijing accelerates the construction of suburban center -- Guchen.

A building boom is as underway around several downtown SkyTrain stations, in particular the Waterfront station where a World Trade Centre with convention com-

plex, international pavilion, and 700,000 square foot of prime office was completion. A two tower high-rise development near the Waterfront station began to construct for office and hotel with the \$200 million (Canadian) costs.

The SkyTrain also penetrates the site of Vancouver's 1986 World's Fair -- Expo 86, which upon its completion had been transformed into B.C. Place -- a master-planned new-town-in-town (82 hectares), featuring a mix of commercial, office and recreational uses along with 10,000 dwelling units. It is billed as the largest redevelopment project ever in North America. The B.C. Place will generate more than \$2 billion (Canadian) in direct capital investment, \$6 billion in spin-off spending and more than 28,000 person-years of employment. Construction has started at the end of 1988.

The Subway Beijing system appears to have had mixed success in its effects on land use. By far the most dramatic example is found in Bajaocun station where the Main Line service was an important and possibly decisive factor in the selection of that location for several major developments, although this development depended also on several other complementary factors: availability of a large tract of land at reasonable cost and the city of Beijing's active cooperation and ability to move quickly with the required zoning and other infrastructure were necessary.

4.3.4 RAPID TRANSIT AND REGIONAL DEVELOPMENT

The growth of the region as a whole has been affected. Metro, Subway and SkyTrain has influenced location decisions for federal and state officers more noticeably than for private business. New office construction within several Metro and SkyTrain area communities has been pronounced. New zoning codes has added incentives for office relocation.

Other impacts of note include the lines' contributory effect on the location of new suburban offices and apartment developments nearby, although the available evidence shows that office development has occur with equal or greater intensity in some other Washington, D.C. areas not served by Metro. It is clear that the rapid transit is a strong factor in local zoning decisions as well as in actual investments in regional level. It seems safe to say that development would be substantially less in amount and concentration in the communities along the right-of-way if these lines had not been built.

As in other two cities, the scale and specific nature of the transit-related development found shows rather clearly that no interregional investment shifts are involved. All the developments identified were essentially Washington or Beijing-based, and involved no consideration of other metropolitan areas as competing sites. Thus there is no indication of a net gain to these regions.

Recent major rapid transit improvements have played a key role in intensification of land use in station areas not only in the downtown but also in suburbs. The intensification would be strengthened when joined with other favorable forces.

Examples include the high-rise apartment development at several suburban stations, the location of large office complexes at several town centers within the Greater Vancouver Regional District. SkyTrain presents an in-between case, extensive low density residential development partly attributable to the rapid transit line has occurred in the corridor, with thousands of commuters driving to the transit stations. However, even most of the apartment development nearby are not within walking distance, and there is no high density development of the type most complementary to rapid transit.

It is clear that SkyTrain has influenced the nature and intensity of retail shopping activity in downtown Vancouver, as shown by the success of the direct connections to major store from the stations. Moreover, it has probably helped to increase the overall strength of the downtown relative to other areas for office as well as shopping activities. At the same time, other unrelated forces, such as the availability of developable land, and the Expo 86 have also played a strong role in the revitalization of the downtown area.

So far, Skytrain's impact on Greater Vancouver Regional District land use seem largely confined to the Vancouver downtown and to the areas along its route and its influencing areas near SkyTrain. Although it was one of several forces which led to a boom in office and housing construction during the the 1970's and 1980's, without SkyTrain the development would have probably occurred, but not to the same high degree.

4.4 JOINT DEVELOPMENT AND SYSTEM INTERFACE

4.4.1 JOINT DEVELOPMENT

Joint development can encourage increased transit demand, provide funding assistance, add to the tax base, provide job opportunities, and improve land use in the urban environment. Various institutional issues need resolution to encourage more joint development.

The joint development is defined by WMATA as follows,"(1) *The close physical integration of transit facilities with real estate development;* (2) *the disposition, by lease or by sale, of excess WMATA-owned or controlled real property interests including air rights, at or near a station area which, because of their close proximity to station facilities, have significant potential for commercial, residential, or related development. alone or in combination with adjoining real property interests to further the Authority's development-related goals and objectives.*"[4]

One of the joint development projects was at Van Ness-UDC station of Metrorail. Prudential Insurance Company of America in 1983 completed construction of a 7-story office and retail building at this station site, where Prudential leases the approximate 1.5 acre site from WMATA for an initial term of 50 years. Development will incorporate an underground level for kiss and ride as well as weather protected bus bays at the rear of the building.

In the Broadway station of SkyTrain, Intercon Development Ltd. acquired from BC Transit a triangle land to build three towers of mixed use commercial and residential complex. They would completely encase the SkyTrain elevated guideway north of Broadway Station. Company sound and vibration specialists have stated SkyTrain presents no problem in going through a building.

The federal government is committed to joint development as a means for enhancing public investments. Actual and potential delay discourages joint development. Financial institutions pay close attention to the uncertainty of having their funds tied up for long periods. Politicians fear project delay as a negative reflection on them. Transit operators fear delays in private development will also delay the transit improvement. The joint development process must include resident participation in planning projects that affect their neighborhoods.

Fragmentation of government institutions can impede joint development plans. Many agencies use inadequate planning and redevelopment coordination actions. Poor station design plans can lead to inadequate transportation coordination and ridership loss. All phases of joint development should be integrated from the beginning. Public and private agencies and groups should all participate in the planning process. Federal and state guidelines need clarification and coordination.

Historically, WMATA's joint development projects have typically included the "right" of system interface access to its joint developer. This right has been granted by WMATA as one of the "bundle of rights" conferred to the joint developer via a long-term lease. Additionally, consideration for compensation for system interface rights has been included within these joint development agreements. The distinction between these two concepts is that a joint development project under long-term lease, which includes the right of system interface, or direct access, along with a number of other rights, such as the leasing of air rights. On the other hand, the direct physical connection between station and nearby private or public development is a system interface project.

4.4.2 SYSTEM INTERFACE

A project that involves the direct physical tie-in of pedestrian, vehicular or visual access to rapid transit facilities from adjoining private or public development. Rapid transit tie-in facilities could include station mezzanines or entrances, kiss and ride, parking, or bus areas.

Vancouver has aggressively promoted deal-making around SkyTrain stations. It is a kind of system interface. At the Granville downtown station, the Bay department

store -- one of the three largest retail stores donated the sub-basement level of its building for an underground walkway connecting the station and agree to pay \$2 (Canadian) per square foot annually for retail space fronting on the pedestrian concourse. Unlike the direct store connections found in some U.S. subways, the Bay store is typically large and open continuations of the station mezzanine itself.

Downtown Beijing has an extensive system of underground passages connecting major buildings. This concept was adopted by the city before the Subway due to preparation the war with the Soviet Union. Now, partial Subway stations connect this system in downtown. It is an important factor in the pattern of downtown pedestrian activity, especially during winter and summer months. In major intersection of downtown Beijing, the Subway underground passenger connections also used as pedestrian walkway to cross that thoroughfares with heavy traffic, because those Subway stations usually locate at four corners of an intersection.

At the Main Street station of SkyTrain, where major redevelopment efforts were underway, a foreign consortium dedicated right-of-way across its property to the BC Transit Authority; in return, the company has agreed to pay a \$2 (Canadian) per square foot one time fee for building a hotel-retail complex on the site.

Developers, and especially the nearby department stores, saw the passages as an important benefit; some of the passages leaving the rapid transit stations are actually sales floors of the major department stores with direct connections. At the other end of the store. below-street corridors, some lined with display windows and small shops continue into the platform of stations. Thus the transit patron benefits from a warm, convenient walk to his or her destination, while the stores benefit from exposure of their merchandise to a large potential clientele.

In both of the Vancouver cases, deals were struck that benefitted developers by delivering customers directly to their sites while offering cash returns and potentially

higher ridership to Vancouver's transit authority. All of these deals concerned the change of land use purposes also. It must be concluded that the direct connections and underground passages are important ways in which the rapid transit system has provided an impetus for integrated design and function in adjacent areas of the downtown areas.

Overall speaking, the benefits of system interface (direct access) projects are as follows:

- Local government concessions resulting from relaxed zoning or other public requirements granted in recognition of system interface. Concessions could include density bonuses or reduced parking requirements.
- Change in use of portions of affected properties to a higher use offering greater economic return (i.e., through higher rents)
- Potential significant value can be created by system interface mutually beneficial to rapid transit authority and property owners
- More intensive use opportunities created by improved access -- convenience, more direct routing, and shelter -- generating increased rent potentials.
- Ridership amenities from the convenience and shelter provided by system interface. While these benefits will be captured largely by rapid transit users, system interface amenities may help maintain ridership.
- Induced ridership to the extent that system interface projects can generate new travel demand.
- Potential increased revenues obtained through negotiated agreements based on the benefit sharing concept.

The costs of system interface projects are:

- Start-up costs incurred in the design, planning and negotiation of system interface projects.
- Capital costs which might include passengeway and entrance construction and finishes, relocation of rapid transit equipment, escalators, and landscaping.
- Operating costs for maintenance, facilities, security costs, insurance.
- Administrative costs of the system interface program.

4.5 FACTORS AFFECTING TRANSIT'S IMPACT ON LAND USE

As with downtown development, a number of forces have been influential in complementing or counteracting the development potential provided by transit improvements. These include several already discussed as well as others. Among them are neighborhood opposition, social and physical characteristics of the area, ease of access to the station site, availability of developable land, and public policy toward development.

4.5.1 NEIGHBORHOOD OPPOSITION

In existing low-density residential areas, the placement of a transit station has often generated strong opposition among residents. This has sometimes led to the official imposition of tight controls on development in the area. As a result, irrespec-

tive of other factors favoring more intensive development, little if any changes in land use have occurred.

This factor has been powerful at several stations in suburban Washington -- almost everywhere stations have been or are to be sited such areas. Even in Vancouver, where transit-related development has been most intense, such areas are typically protected by zoning. In some cases the neighborhood residents have not been successful in comparing other forces such as the city's desire for increased taxes, but this is much less so today than it was during previous decades.

Thus, location of rapid transit station in low density residential surroundings may completely block rapid transit's impact on land use in the area. This suggests that if such intensification of land use is desired as a complement of rapid transit service, such established residential areas are poor choices. This does not mean that stations should be far from patron's home, but only that nearby small commercial centers or undeveloped areas are better for encouragement of land use impact. This often requires moving the proposed station only a few blocks. In such areas if redevelopment does occur the resulting disruption of the social environment can be severe, while if it is prevented much of the transit system's potential benefit is lost.

4.5.2 SOCIAL AND PHYSICAL CHARACTERISTICS

The station area's social and physical characteristics were found to be important factors. Transit's effect on land use appears to have been minimal when development of a scale and type necessary to be economically viable was not complementary to the surrounding land uses. For example, one of the stations in SkyTrain is situated largely in low-income neighborhoods of three- and four-story apartment blocks. Air

rights on the cleared areas above the situations are available and more intensive uses are permitted, yet almost no development has occurred. According to some local officials and observers, the primary reason is that construction costs allow only luxury high-rise apartments, and prospective tenants would prefer to live in other parts of the city.

Physical characteristics, particularly blight, have sometimes been added to social problems to render areas even less likely to be developed into uses complementary to the transit station. The Rhode Island Avenue station of Metrorail in old disadvantaged neighborhoods with low-income residents is unlikely to attract private investment despite their high-accessibility locations, although the area was planned for the purpose of intensive and imaginative high-density office and commercial development.

4.5.3 EASE OF ACCESS TO THE STATION SITE

Ease of access to the station site is a key factor. Where new transit stations are isolated from surrounding activity or available land, little development has occurred. This factor's efforts are seen most clearly in Washington, D.C.. In Washington D.C., the location of the rapid transit extensions in freeway medians in suburb has resulted in a separation of the station from any land which might be used for complementary development. This separation is as dramatic psychologically as it is physically; the station is connected to its surroundings only by bridges, escalators as well as long ramps over heavy traffic. Development in these station areas is as yet nil, with the main potential for activity resting in the stations parking lot air rights.

4.5.4 AVAILABILITY OF DEVELOPABLE LAND

Recent rapid transit developments have encouraged downtown development near stations, but only when accompanied by other factors. The demand for new office and retail space has accompanied (commercial) land development near stations. Land availability for development is a factor worth noting. The location of other facility improvements should be coordinated with transit improvements.

This factor has already been discussed in some detail. However, it is more useful to complement the earlier discussion with some examples of how this factor has been used to advantage.

In Beijing, Andingmen station site adjoined obsolete and underused wood and coal yards. These large tracts were in single ownership and were quickly developed into high-rise apartment and office structures compatible with their direct access to the subway. Similar examples occur elsewhere. The point, however, is clear; where large-scale land assembly was facilitated the potential for transit-oriented development was much enhanced.

Consequently rapid transit-induced development pressures, particularly at the Shijingshan terminal of the Main Line of Beijing Subway, are strong. As in other cities, the availability of land has also been a key force for complementing the rapid transit's impact potential on land use.

4.5.5 GOVERNMENT LAND USE POLICIES

Whether influenced most by neighborhood preference, infrastructure capacity, or other forces, the local government's objective and public land use policies con-

cerning the preferred or permissible forms of station-area development has in some cases been a particularly powerful determinant of what land use impacts actually occur. In Vancouver, allowance of very high densities of development (up to 12:1 in floor area ratio in two areas around downtown SkyTrain stations) provided a strong incentive to intensive development. The fact that relative small and well-defined areas were so designated, in contrast to the low densities allowed throughout most of the rest of the metropolitan area, further enhanced the power of this incentive. Since the region's demand for such development was strong, much of it then had to occur around the station -- where transit access provided an important added inducement. Thus transit and land use policy were fully complementary.

Private developers are most attracted to sites with appropriate zoning regulations and minimal institutional interference. Site locations that minimize construction problems and maximize pedestrian flow and commercial potential are preferred by private developers. The availability of unencumbered sites ready for immediate use by developers are preferable. Station entrances should be available to sites with the greatest developmental potential. The cost of the project is extremely important to the developer.

4.5.6 OTHER FACTORS

More generally, the Metrorail provides valuable evidence of the need for coordinated use of factors complementing rapid transit's own inducement to development oriented to its use. The Addison Road station is a particularly telling example of the kind of transit improvement which should not be expected to have land use impacts, since almost every possible factor worked against any such potential. Not only was

the rapid transit service itself not a major improvement, but also the characteristics of the area were (and are) such that only a massive renewal strategy could have a chance of success. Rapid transit alone cannot solve problems of these magnitude. The Friendship Heights station example, however, shows clearly how transit can be used with great effectiveness to transform an area when other factors support its potential.

In addition, the area were fully developed when the rapid transit line was built, and land costs were correspondingly high; at the same time, most were not attractive for new development because of their aging and sometimes dangerous residential and industrial character. Finally, there were not effective incentives to overcome these obstacles. Under such inhospitable circumstances any development potential attributable to a transit improvement could not surface.

4.5.7 RELATIONSHIP AMONG FACTORS

A consistent set of factors is involved in the generation of rapid transit's land use impacts, forming an empirical model on which predictions of impact may be based. As described earlier in this chapter, recent experience with rapid transit's apparent land use impact was found to exhibit some common properties from city to city and case to case. Many of the same casual factors were found again and again despite many differences in specific conditions from one example to another. These recurring may be combined to suggest a general model of the land use impact process.

A diagrammatic view of such a model is presented in Figure 4-1. In this model each major factor which was found in this study to encourage land use change fol-

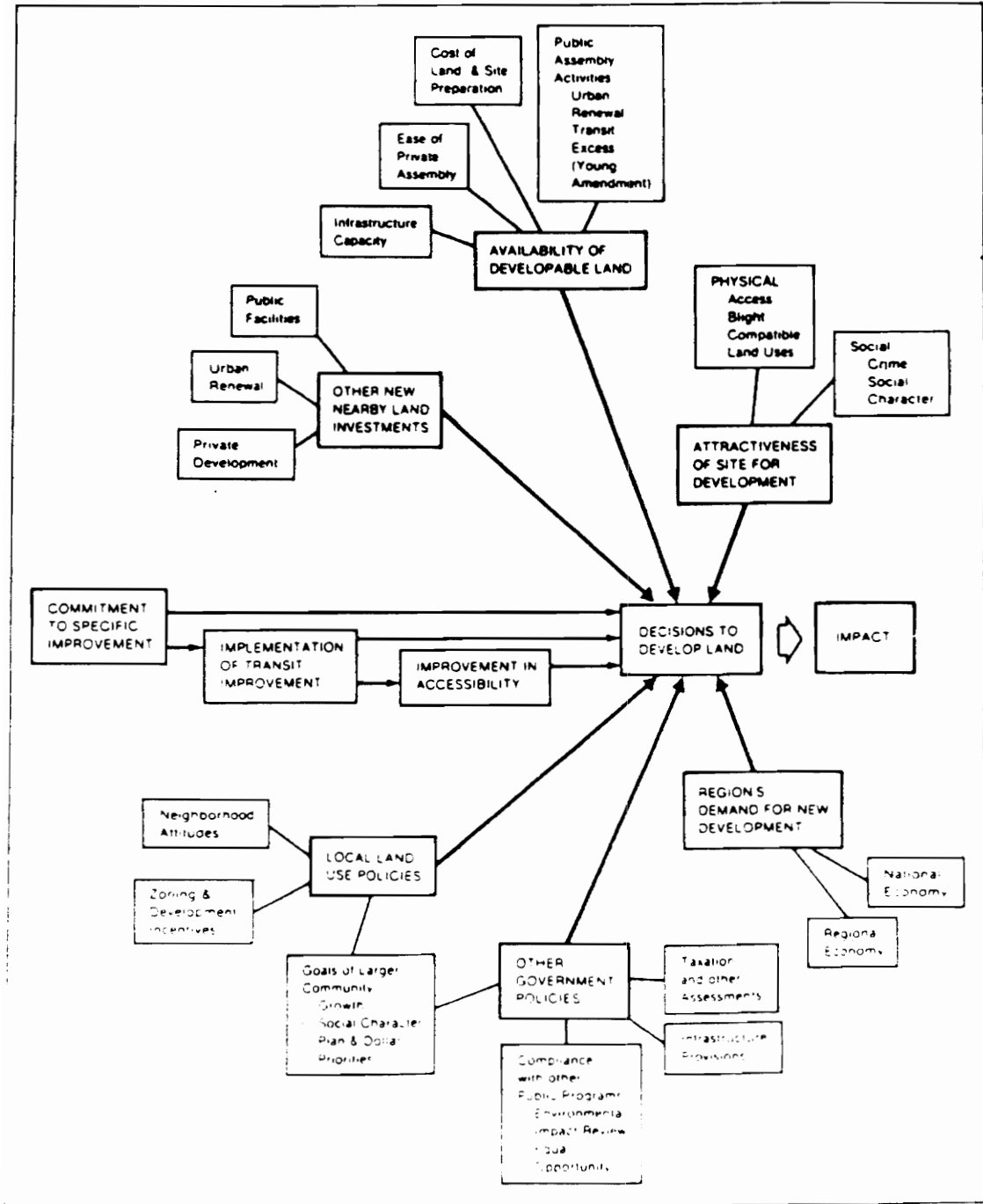
lowing a transit improvement is shown with its various components. The model illustrate clearly the scope of such factors in addition to rapid transit improvement itself.

This conceptualization of impact is still incomplete, for it excludes interactions among factors -- such as the effect of an impending or recent rapid transit improvement on land use policy. More generally, the beliefs of citizens, developers, and public decisionmakers in the likelihood or desirability of impact and the effects of such beliefs on many of the model's factors are also omitted. Such effects are of course important, but are unique to each situation.

Clearly the relative importance of each factor varies from one case to another. In general, however, the study's findings indicate that none can be ignored, for a serious deficiency in any one appears to be capable of limiting or even preventing land use impact. Thus to achieve desired land use impacts, all the factors should be made as favorable as possible. In some cases this may involve moving a proposed rapid transit station to a more advantageous location; in others there may be a need to coordinate policies in land use, taxation, urban renewal, and infrastructure with the transit investment.

With such an approach, various rapid transit alternatives can be evaluated on the basis of their ability to take advantage of each of these factors and their consequent relative likelihood of land use impact. Even more important, an understanding of the workings of these factors permits the use of rapid transit as an effective component in the continuing, integrated process of planning and guiding the development of our urban areas.

FIGURE 4-1: FACTORS INFLUENCING LAND USE IMPACT



4.6 RAPID TRANSIT AND LAND USE POLICY, CAUSE OR RESULT?

Local land use policy changes have often been instrumental in facilitating rapid transit's land use impacts. At the same time, the transit improvement itself has often provided the rationale needed for acceptance of such policy change.

A major "land use" impact of the rapid transit improvement was in the conviction which it generated in the minds of key decision-makers that it would create a potential for new development. The actual land use changes then occurred because of the actions of these decision-makers as well as the accessibility provided by the rapid transit system. However, the rapid transit lines were the source of both forces.

As just noted for Vancouver, land use policies have often been instrumentally in determining whether and to what degree complementary development would occur around rapid transit stations. The same is true, though to a lesser extent, with downtown development in Beijing. A reverse situation is found in Washington, D.C. where strict height limits have restricted the degree of density incentive which can be offered to prospective developers; some local planners and developers believe that relaxation of height limits at rapid transit stations would result in rapid development.

Local land use plans have been altered to attempt to focus development on station areas in Beijing. Local jurisdictions appear to have recognized the value that developers place on transit access and are hoping to capitalize on this to enhance the local tax base. Station area development has occurred primarily within 1 KM of the stations.

An important aspect of this situations and some others in which zoning and related incentives have been successful is that their power has depended on the "degree of advantage" they provided for the station site versus others elsewhere in the city. If a city was already overzoned (or if variances were easily obtained) to allow intensification of existing development at many competing locations, the inducement to develop at the transit station was correspondingly less. Both in Vancouver and Beijing , the rapid transit-area zoning incentives were part of a city-wide rezoning. In Vancouver, this include strict new limitations of development in many places. In Beijing, high-rise development of the intensity allowed around rapid transit stations and along their feeder routes was permitted as many other locations. However, Washington, D.C. was not already overzoned for intensive development in the manner of many cities in the United States.

Land use policies have also effectively prevented development at rapid transit stations, by restricting land uses to such low densities that no allowable development was economically viable.

4.6.1 LAND USE POLICIES OF THE TRANSIT AUTHORITY

Public Law 89-774, approved November 6, 1966, gives the Washington Metropolitan Area Transit Authority (WMATA) the authority to acquire real property. The transit authority is guided by the requirements which limit its development activities to lands necessary to construct the rapid transit system. In 1981 WMATA established an ambitious Station Area Development Program within a newly organized Office of Planning and Development.

It became increasingly evident that substantial advantages could accrue to WMATA's benefit by promoting more intensive development at or near appropriate station areas. These benefits include an increase in ridership and the provision for income to the authority. The specific goals and objectives of the Authority's development program, which provide benefits not only to WMATA but also to local governments and the Washington region, are:

Goals

- Enhancement of levels of rapid rail transit use;
- Conservation of petroleum-derived energy;
- Allocation of scarce resources more optional fashion;
- Reduction of urban sprawl; and
- Encouragement of good quality development.

Objectives

- Reduction of petroleum product use in the transportation sector;
- Substitution of greater numbers of auto trips with mass transit trips;
- Reduction of travel time;
- Addition of real property to the tax rolls;
- Increase in tax base;
- Improvement of cost-benefit ratios of public goods and services provided by local government; and
- Provision of revenue to WMATA for subsidy offset. [5]

Actions of the transit authority itself with respect to the sale or use of excess land and air rights are another important form of land use policy. These may have

important effects on the degree to which such land is redeveloped to complement the transit system, for example by offering long term leases in lieu of sales to reduce developers' initial capital requirements (Vancouver).

Beijing also encouraged intensive land development near some central stations by designing the subway structure to include provisions for support of very heavy buildings. This amounted to a "land use policy" encouraging developers to build such buildings, since no unusual foundation costs were then required during their construction. This was a gamble on behalf of complementary development which cannot always be expected to pay off.

Also important is the fact that the official land use plans for many of these town centres in Vancouver had been developed before constructing SkyTrain without regard to encouragement or control SkyTrain impact. As a result, until formal plan revisions several years ago, developers had to request variances for every proposed project. Only recently have these plans specifically included provisions to encourage development at the SkyTrain stations.

Several other development-related factors have been major influences on the location and kind of development which has taken place throughout the region to date. For example, no major extensions of water and sewer services have been provided, thereby often limiting development to areas already served. The zoning policies of municipalities -- seeking less residential and encouraging more industrial development as a tax base -- have also affected development patterns in some locations.

Conditions of excess and air-rights land sale or lease have also acted as implicit land use policies. Vancouver's approach has been to get the land back into use in the underground section in downtown as quickly as possible, and so has encouraged development in many ways (although revenues from land leases have still been very significant). One contrasting example is Washington, D.C., where the Metrorail oper-

ator has negotiated one air rights lease with provisions for profit-sharing with the developer. This approach may restrain development if not sensitively applied, but the Washington case deserves careful attention as a possible model.

4.6.2 FEEDBACK -- EFFECTS OF TRANSIT ON LAND USE POLICY

Evidence shows that rapid transit has often influenced land use policies. In many cases the inauguration of a major new rapid transit improvement has provided the rationale for changes in land use policy to complement the transit service. In fact, this has occurred in most instances of new intensive development around rapid transit stations, and may represent one of the most important ways in which a rapid transit improvement may influence land use.

Land use policies generated largely by the advent of a new rapid transit improvement include examples in Vancouver, Beijing and Washington, D.C.. In Beijing, as already noted, the rezoning for intensification of development at rapid transit stations arose several years after the first subway segment's completion and was directly attributable to it. In Washington, D.C., many of the communities to be served have conducted detailed studies of Metrorail's land use impact potential and altered their zoning in response. Also on Vancouver, support for downtown renewal plans for intensive high-rise redevelopment were largely dependent on the rapid transit improvements.

Criteria for corridor and station site selection should be expanded to include the full range of land use impact factors identified in this study. The land use impact potential of a rapid transit station could often be improved dramatically merely by moving it a few hundred feet to a new location where other factors are more favorable.

Federal policy should encourage the use of such site-specific assessments as an important element in the demonstration of likely land use benefits.

The views and knowledge of the land development industry should also be incorporated into comprehensive urban planning as well as into transit planning. Early involvement of the development perspective in the transit system location process would ensure proper consideration of a number of key factors in land use impact which are not now commonly included. Some of these, as noted earlier, include the ease of land assembly for redevelopment, access to the site, cost of site preparation, and development potential of the immediate surroundings.

In fact, the power of zoning is most significant when it is used in this manner, since its effect is absolute: development is forbidden, no matter how it may be encouraged by other forces including rapid transit. This is a substantial loss in potential regional development impact, and suggests that locations likely to have such constraints should be avoided as rapid transit station sites wherever possible if major new station-area development is a objective.

Despite the limited to date, however, the evidence suggests that impacts in the future may be more substantial. Zoning policies supporting station-area development are now enacted, and as the urban area grow outward these locations will become increasingly attractive for such development.

4.7 SUMMARY

Formal and informal theories abound regarding the relationship of land use and transportation. None is of adequate scope, precision and empirical relevance for

practical use in the study of rapid transit's land use impact. From among these this chapter has adopted the hypothesis that such impacts are dependent on many non-transportation factors in addition to the access, travel time and cost benefits of the rapid transit improvement. Moreover, the study has focused on the decisionmaking process of the land developer rather than the ultimate consumer. Thus the study has sought to identify the factors of significance to the developer and the combinations of factors under which development is likely to occur or not occur. Finally, this chapter try to find how rapid transit improvements seem to interact with land use.

The purpose of the present chapter is to bring together the results of these metropolises and system-specific studies and seek out more general conclusions which might be relevant elsewhere in the future.

In the cases in which development has occurred, other factors in addition to rapid rail transit tend to be important. Most important has been the role of other public policies, particularly zoning and the use of urban redevelopment powers as a means of assembling land. Community support has also been shown to be essential; residential opposition to rapid transit-related apartment and office development has resulted in downzoning and prevention of development even when other factors appeared positive.

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CHAPTER 5: THE EFFECTS ON SOCIETY AND ECONOMY

5.1 *APPROACH*

Rapid rail transit touches all members of the community. It carries commuters, non-drivers, shoppers, students, the handicapped and senior citizens. It free city centers from noise, air pollution and traffic congestion.

Efficient rapid rail transit acts as an engine of economic development in urban and suburban town centers. Rapid transit encourages economic growth both directly and indirectly, stimulates life and movement, and has an appreciable impact on social and cultural development. While rapid transit cannot and would not claim responsibility for all development within its region or envelope. It acts as a major catalyst in assisting economic and social development. Rapid rail transit improvement would influence the metropolitan population and employment distribution, housing con-

struction and its market values. This chapter will reach a solution based on common ground of these different systems.

5.2 POPULATION AND EMPLOYMENT

The changes of regional population, households and employment of the three metropolitan areas are analyze below. The analysis will focus on the population growth in the SkyTrain influence area before and after SkyTrain Phase One, while pay more attention on the population-household density change in the Subway Beijing's influence area. Then, the analysis will compare the results of three forecast model and actual change before and after Metrorail.

5.2.1 VANCOUVER AND BEIJING

The census of Canada shows the consistent population increase in both the City of Vancouver and the Greater Vancouver Regional District. The population increase from 1,268,183 in 1981 to 1,405,300 in 1987. The growth rate during 1981 to 1987 was 10.82 percent in Greater Vancouver comparing with the 5.5 percent national growth rate. Current growth rate per decade in the region is 21 percent.

The overall of population distribution within Greater Vancouver is that more and more move southwards, south-eastwards and eastwards. The net population gain within the influence area of SkyTrain and its future routes increase obviously as showing on the Figure 5-1.

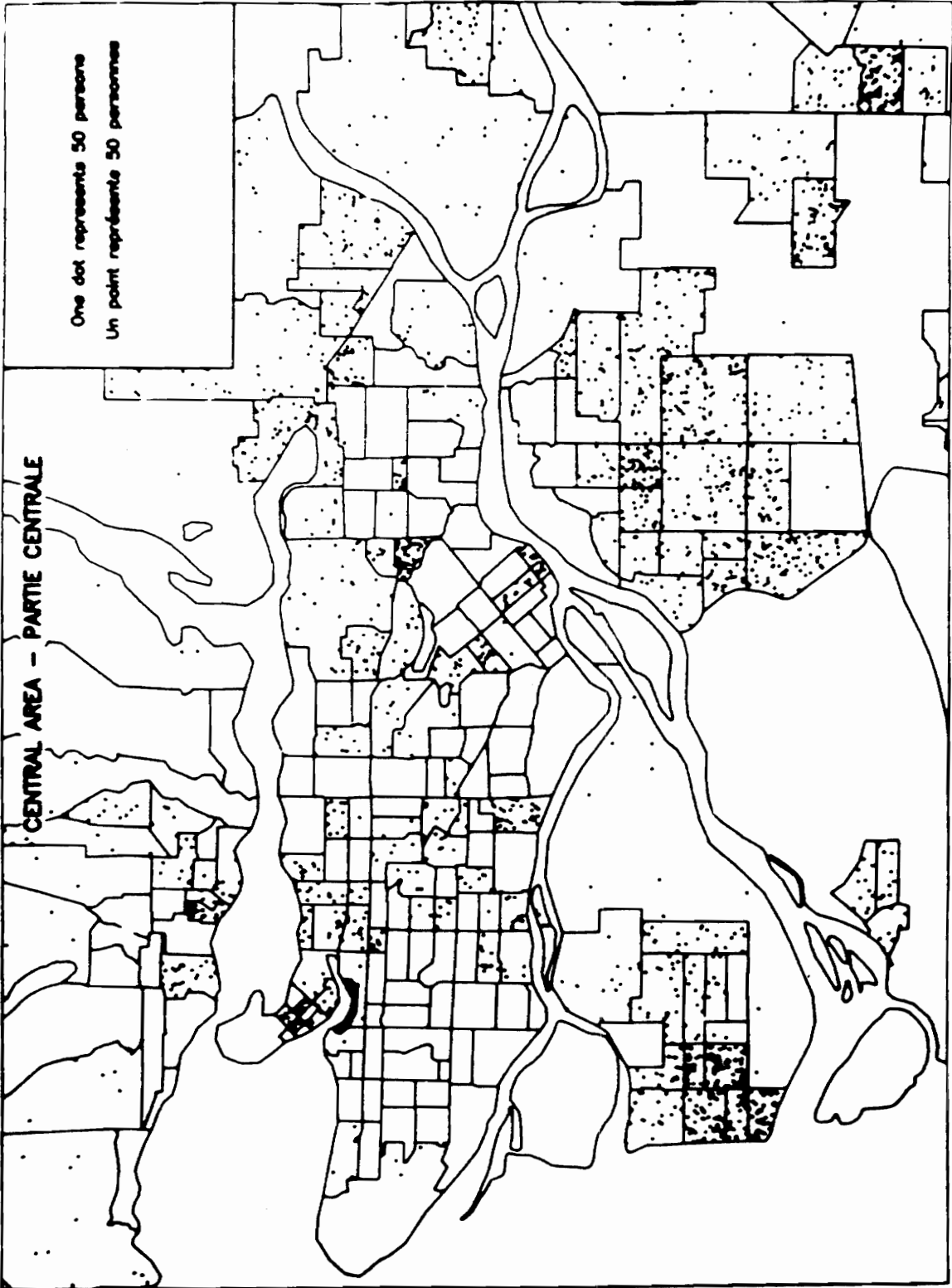


FIGURE 5-1: NET POPULATION GAIN IN VANCOUVER

In Surrey, a community in south part of the region, its population will reach 282,000 by 2001 (present population is 178,000). The SkyTrain extension is under construction south over the Fraser River to Surrey. The extension will open in February 1990. This extension is expected to have a significant impact in travel from south of the Fraser River as bus service are integrated with the extended system and commuters currently facing the traffic-congested crossings of the Fraser River are provided with a rapid transit alternative.

Metropolitan Beijing has a 9.93 million permanent residents in 1987 and 1.2 million floating population including persons on business trips, tourists, alien residents, builders, peddlars, etc. The population of this region in 1979 was 8.49 million, in 1948 was 4.14 million. Migrations from rural areas and high natural growth were two major factors which caused the dramatical population growth in Metropolitan Beijing. Today, the City Government of Beijing limits migration into the city strictly. By projections, population will exceed 10 million at the end of this century in Metropolitan Beijing

The Metropolitan Beijing is one of the highest-income regions in the nation, with a well educated population and a substantial number of jobs in key decision-making as well as highly technical positions. Because the city and nearby municipality governments adopted a policy encouraged new high rise apartment construction near existing mass transit routes, especially the Subway Beijing lines, the population density increases from 0.2 person per square meter to 0.7 person per square meter in the Subway influence areas.

Because the majority new construction activities concentrate in the envelop and influence area of Subway Beijing, approximately 74.3 percent construction jobs are attributable to this related development. About 59.8 percent new jobs in both private owned businesses and private agencies, and 52.4 percent new jobs in both public

owned businesses and public agencies are located within the areas, especially around stations.

5.2.2 WASHINGTON

The population of Washington Metropolitan Statistical Areas (MSA) changed from 3,040,000 in 1970 to 3,429,000 in 1984, while the residential population of District of Columbia dropped dramatically from 757,000 in 1970 to 623,000 in 1984 as showing as Figure 5-2. The Metropolitan Washington Council of Governments (COGs) did several forecasts of regional population, households and employment from 1980 to 2000. COGs' forecasts known as:

- Empiric 6.2 Modified -- adopted in 1973 before Metrorail;
- Round I Cooperative Forecasts -- adopted in 1976 when the first Metrorail segment opened; and
- Round II Cooperative Forecasts -- adopted in 1979 when Metrorail had reached suburban areas.

For this analysis, jurisdictions have been grouped into three categories as follows:

- Central jurisdictions -- District of Columbia, City of Alexandria and Arlington County;
- Inner suburbs -- Montgomery, Prince George's and Fairfax Counties;
- Outer suburbs -- Prince William and Loudoun Counties.

FIGURE 5-2.

CHANGES IN REGIONAL FORECASTS BEFORE AND AFTER METRO

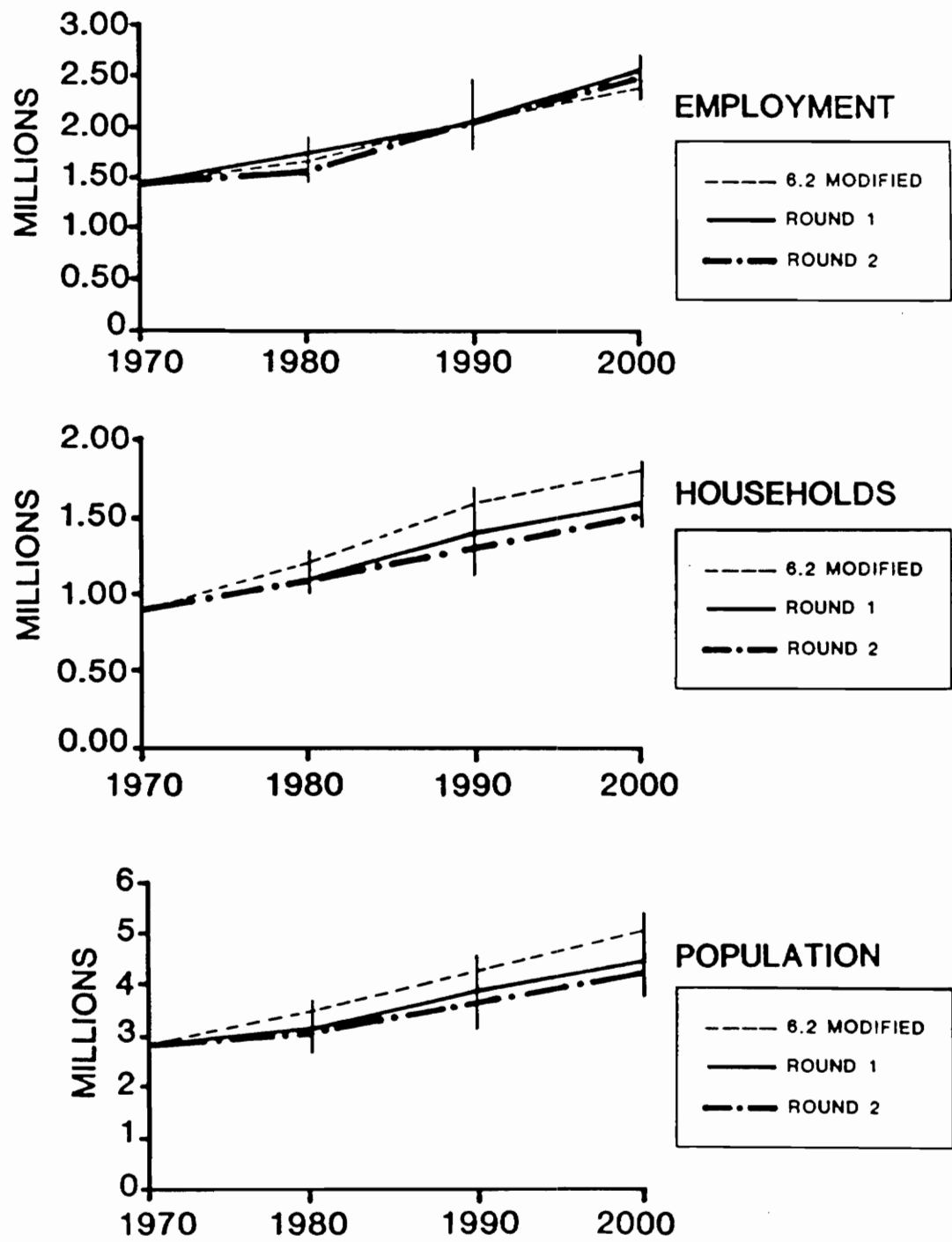
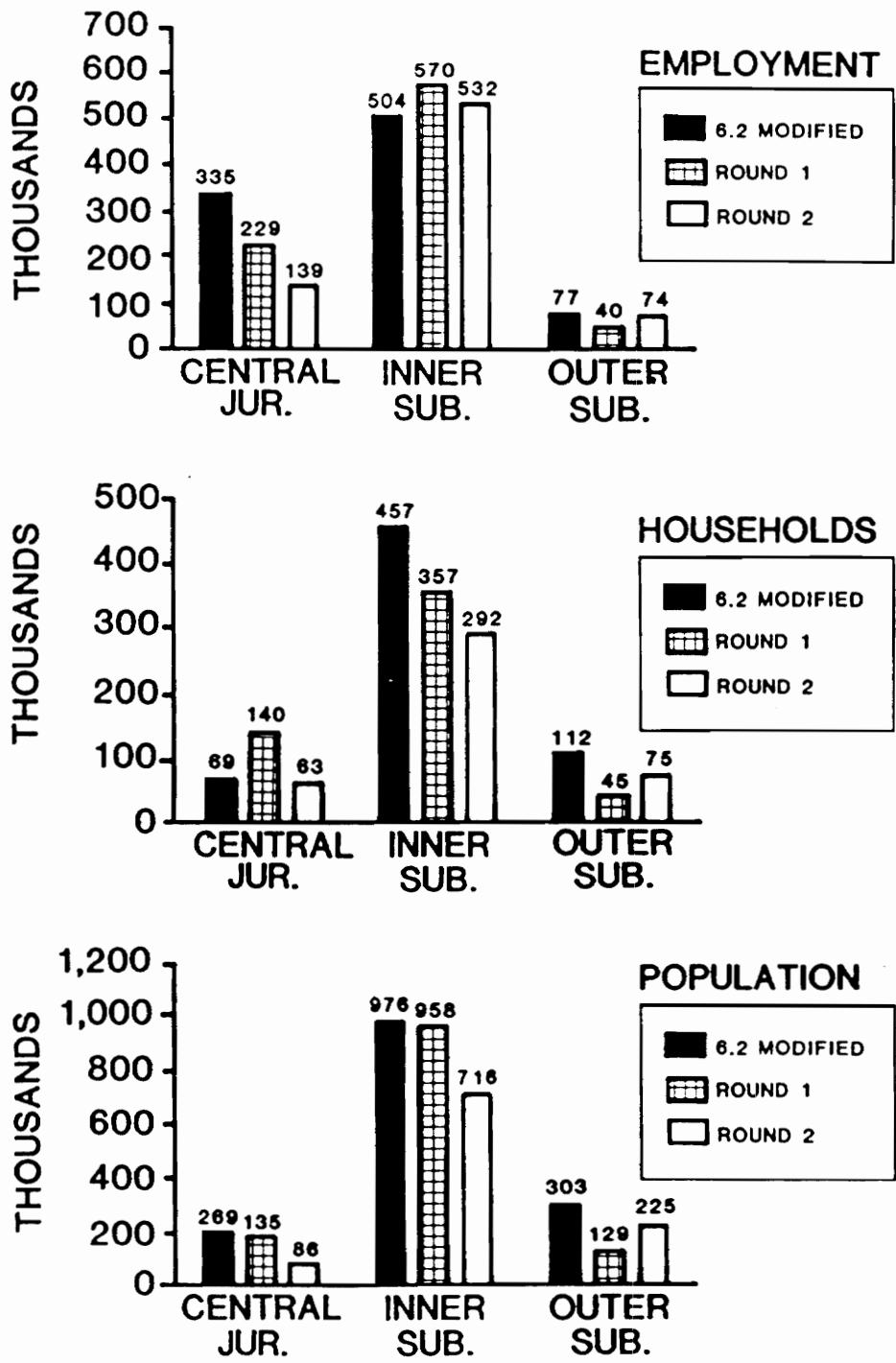


FIGURE 5-3: CHANGES IN FORECASTS BEFORE AND AFTER METRORAIL



For each set of forecasts Figure 5-3 shows the amount of change to occur between 1980 to 2000 for groups of jurisdictions. Conclusion on changes in forecasts are as following:

- Population growth forecasts have dropped dramatically since the period when Metrorail was planned.
- Compared over time, central jurisdiction see greatly reduced rates of growth in population and employment, but not households.
- Expectation and employment increases by the year 2000 have declined, but not as much as those of population and households.
- For the inner suburbs, similar declines are expected in population and households growth, but not employment growth.

Approximately 23,500 construction jobs are attributable to the Metrorail system and related development, and more than half of all new jobs in the region are located near Metrorail stations. That is the direct contribution of Metrorail to the region in employment.

5.2.3 OVERVIEW

Obviously, rapid rail transit improvement did not influence the regional growth of population and household within its influence areas, For Vancouver and Beijing, rapid rail transit improvement tend to condense population density and to increase households due to mass transit is an important transport tool for residents of the two metropolises. No evidence could support the conclusion in Washington, because most people are not transit-dependant riders. The common ground of the three cases

is that the population increase in the rapid transit envelopes is the results of redistribution of population within these metropolitan areas.

Recent experience provide no evidence that any rapid transit improvements have led to net new urban population growth. Because of the many ways in which cities differ, it would be impossible to isolate and identify with any confidence the effect of a specific rapid transit improvement on a metropolitan area's population. Any comparisons would be seriously confounded by the effects of factors not related to transit.

Other evidence includes the changes in population growth rates among cities in recent years. U.S. and Canada Census figures indicate both in 1970 and 1980 a shift away from the large cities to smaller cities, none of which have rapid transit systems. Population is also continuing to shift from central cities to their suburbs, but these are not interregional movements.

The short term impact of new employment opportunities on existing local unemployment depends primarily on the type of unemployment in the community and the characteristics of the labor force required by new firms. The impact of land development on employment, housing, income and other areas can be assessed with greater reliability at the regional rather than local level. With the exception of the local public sector, second-order employment estimates should be considered only at the regional level. It is extremely difficult to predict, future long range growth in specific industries which do not depend on local natural resources or the local market. Thus, all analysis should be based on existing data assembly, nor the projection or forecasts.

In general, the migration of population is more likely to be motivated by considerations more immediate than rapid transit, such as the possibility of better employment or a safer and more attractive place to live. It is therefore probable that

rapid transit's interregional effects depend on its ability to influence the rate of job-creating investment in its metropolitan area. However, relatively little of the country's basic employment is free to migrate, being fixed by prior plant investment, materials supply, and regional markets. Of the employers who can choose to establish facilities in one city rather than another, it is hard to imagine that one city's rapid transit facilities could be a decisive and consistent element in their choices.

5.3 BUSINESS

COGs' travel studies found that 19 out of every 20 Metrorail commuters were destined to core area of D.C., a fact indicating how interrelated the fate of downtown is with the future of Metrorail.

5.3.1 SMALL BUSINESSES IN DOWNTOWN AND METRORAIL

Downtown area contains the greatest concentration of rapid transit stations in both Vancouver and Washington, D.C., giving it unparalleled access from throughout the metropolitan region. Current statistics show that the majority of new businesses moving into the area from elsewhere qualify as "small business" in the office, retail, and service categories. A business is considered small if its net worth does not exceed \$6 million and its average net income after taxes is not more than \$2 million annually.

The accessibility is very important for small businesses. Existence of small businesses in downtown D.C. is critical for downtown revitalization. They not only represent a major source of employment, but provide the needed diversity to attract riders into downtown. Thus, Metrorail helps small businesses by send more and more people to downtown, while that small businesses attract more and more customers would increase Metrorail's ridership.

5.3.2 TRENDS IN RETAIL SALES

In last two decades, a trend was that retail business in the three central jurisdictions of metropolitan Washington actually declined, and that the majority of regional sales shifted to the suburban jurisdictions by 1972. Because major retailers were quick to follow the trend that population growth moved to the suburbs.

The Metrorail system serves 12 out of total 27 major retail centers and downtown D.C. (amount 48 percent) in Metropolitan Washington, in while 20 major retail centers (about 78 percent) are within 1.7 mile envelope of Metrorail system. However, the importance of Metrorail access is less than bus access on the location decision of retailers.

Analysis of detailed data shows that most of the older retail centers in suburb have peaked in sales volume, and that newer centers are absorbing the sales growth. More of the increase in sales at major retail center moves from growth in existing centers. It is apparently that the suburban prosperity counterparts to the sales decline in downtown D.C. as the population moved to the suburbs and new shopping centers opened to serve their demand for retail goods near homes.[1]

A survey of shoppers indicated that a possible shift in shopping patterns favoring the downtown areas was occurring. The survey indicated that Metrorail was used more frequently for shopping for personal items than groceries, furnitures or applicantes. Firms selling large or bulky items would not be benefit as much from Metrorail as those firms selling smaller items.

Changes in physical conditions affecting household current expressed satisfaction with neighborhood shopping opportunities and number of households potentially affected.

In both Washington and Vancouver, this study found that people who shop in downtown did so during the day. However, people who shop in malls shop during day and evenings. The downtown is the most attractive shopping location only to those who live near the downtown. The greatest advantages of downtown shopping are quality and variety of goods. These amenities are perceived as being much greater in the downtown than suburban malls. New shoppers to downtown Vancouver are primarily from the suburbs by SkyTrain.

About 78 percent of business, both private owned and public owned, both in downtown Beijing and in suburbs, surveyed along Subway Beijing reported increased sales. Some stations benefited certain types of business -- eating and drinking places, recreational facilities and food stores near some newly developed city centers, employment regions as well as residential areas.

5.4 CONSTRUCTION ACTIVITY

5.4.1 VANCOUVER AND BEIJING

Many economists use the three-to-one multiplier ratio for determining the possible economic impact in globe terms or the "trickle down effect", although many other economic factors should be considered for an accurate measure.

The data which is provided by the BC Transit shows that the total investment within SkyTrain envelope from 1985 through 1988 is \$4,846.5 million (Canadian). It is general safe to say, that the trickle down effect of at least 4 billion spending in construction and development is in the neighborhood of about \$15 billion in Greater Vancouver. The statistics shows that the multiplier rate is 4.3:1 in Beijing, higher than the three-to-one.

Since many large public housing programs and rehabilitation of old communities were in progress while the Subway Beijing was under construction, approximately three fifth of new dwelling units and apartments were in locations within the Subway envelope. A total 78 percent of new office buildings are also located within the envelope.

At least 25,456 residential units are building within SkyTrain envelope. Some of them has been completed, some of are under construction. Majority of them are located in downtown Vancouver, and other town centers along the routes of SkyTrain. The impact of SkyTrain on housing development is largely a factor of the degree to which home buyers, renters or shoppers perceive the accessibility advantages of the system.

5.4.2 WASHINGTON

Residential construction activity is an indicator of change in household locations. The data presented here were extracted from the "Residential Building Permit File" maintained by COGs Department of Human and Public Safety. The file lists information on residential building permit authorizations issued by local governments in the metropolitan region.

A total of 274,068 housing units were permitted from January 1970 to December 1980 in the metropolitan Washington. Almost 60 percent of all residential units, or 162,677 units, were high-density housing, i.e., townhouse, multiplex, and multifamily dwelling units, authorized for construction. However, the number of permit authorizations issued in the region declined from 1977 till 1983.

During the period, the inner suburbs issued the largest share of housing permits. Since 1972, Fairfax County has had a largest volume of permit activity of any jurisdiction in the metropolitan Washington.

Within the envelop of Metrorail, 30,715 higher-density units (or 18.9 percent of the total) were authorized for construction. For the pre-Metrorail period of 1970-1976, a total of 115,644 higher-density dwelling units were permitted in the region, 17 percent of the units permitted were located in envelope. During the post-Metrorail period of 1977-1980, more than 47,000 units were permitted, 23 percent of the units permitted were located in the station areas.

The majority of high-density units authorized in the District of Columbia, Arlington and Alexandria County were located near Metrorail stations. However, a very small share of new higher-density units in Fairfax, Montgomery and Prince George's Counties were in the station areas.

It was found that the majority of high-density units permitted in Metrorail station area were permitted to the operation of the respective stations. Since the majority of new housing continues to be located in Fairfax, Montgomery and Prince George's Counties, a small share of new housing is accessible to Metrorail on foot.

Nearly 500 commercial construction and rehabilitation projects, representing a private investment exceeding \$3 billion, have been started within the Metrorail envelope since Metrorail opened. It is expected to be more than \$5 billion when all 103 miles are finished. From 1981 to 1986, 40 percent of all office construction and 36 percent of all non-residential construction in the metropolitan region has occurred at Metrorail stations.[2]

5.5 INTERACTION OF RAPID TRANSIT AND URBAN ECONOMY

Recent major rapid transit improvements have been important inducements to downtown economic development near stations, but only when supported by other powerful forces.

The Beijing and Vancouver studies concluded that the rapid transit improvements there were significant forces in the extent and nature of the intensive high-rise commercial office development in downtown. In Beijing, in particular, the new subways provided a much-needed increase in the accessibility of the downtown area and thus assisted its growth.

FIGURE 5-4: REGIONAL HOUSING PERMIT ACTIVITY 1970-1980

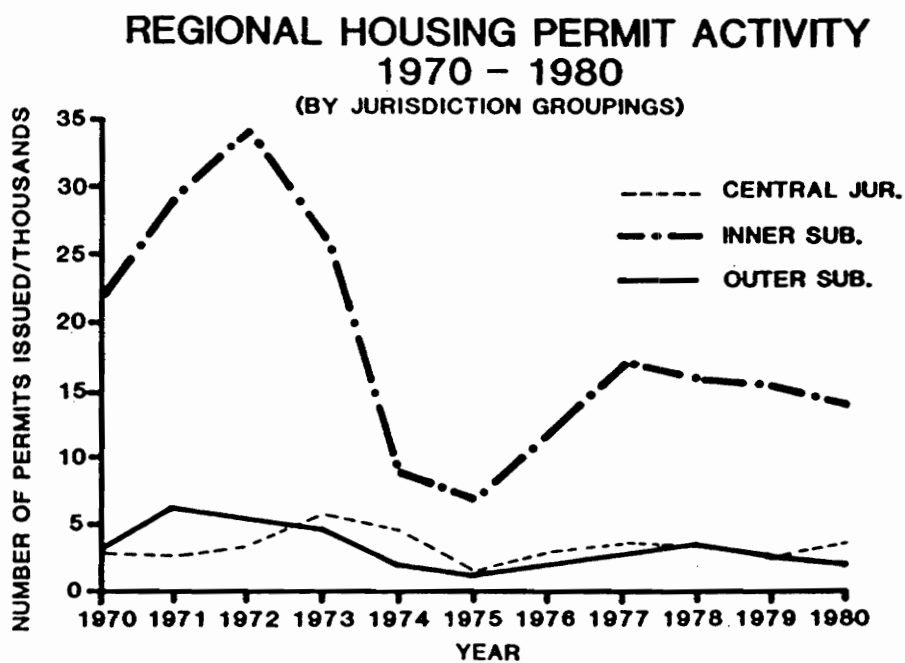


TABLE 5-1
DISTRIBUTION OF HIGH-DENSITY HOUSING PRE AND POST-METRO

LOCATION	PRE-METRO 1970-76		POST-METRO 1977-80	
	UNITS	PERCENT	UNITS	PERCENT
IN STATIONS AREAS	19,939	17	10,776	23
OUTSIDE AREAS	93,182	81	35,790	76
UNDETERMINED *	2,523	2	467	1

Note: * Lack of site-specific data.

In such cases, where inadequate prior access was actually a recognized constraint on downtown growth, the evidence indicates that rapid transit has been a virtual necessity for intensification of development to occur. As in Beijing and Vancouver, Metrorail of Washington, also enhanced the downtown's accessibility by providing additional commuting capacity in some major congested radial corridors. However, in all three cases, other factors were also essential in this downtown development.

In subsidiary centers as well as town centers outside the downtown, recent rapid transit improvements have so far had relatively mixed effects. Largely rapid transit-induced commercial development has occurred in several such centers, nota-

bly in Metrotown and New Westminster along the SkyTrain system as well as Guchan Road station at the Main Line of Subway Beijing.

The primary factor behind such impacts has been the existence of a strong and effective demand for new office and retail space. This appears to have been determined by social and economic forces of regional and national scale. A related factor present in all instances was an already healthy and active downtown area, which encouraged both consumers and developers. If town centers and subsidiary business centers throughout a metropolitan area are stagnating, there is little reason to expect that rapid transit service to one of them will generate development. In a period of slow or no economic growth, little impact can be expected under the best of circumstances.

5.5.1 TIMING

Timing of such new development appears to have been determined largely by these same economic forces, such that new development in downtown and elsewhere cannot not be predicted to occur within a short time after the rapid transit system is announced or built, although so many cases confirmed that is true. In Vancouver, the SkyTrain was opened in 1986, but intensive redevelopment began at about the same time (1982-86), in while the development began seven years later after the opening of the Main Line of subway in Beijing. Consequently, decision-makers should not expect similar development to occur just after a rapid transit improvement.

5.5.2 AVAILABLE LAND

The availability of land for development has also been a major factor. This refers not only to nearby open or underutilized parcels but also to the feasibility of their assembly into a site large enough for economically viable development. In many instances in this study it was observed that fragmented or clouded ownership of otherwise highly attractive sites absolutely prevented development that otherwise would have occurred. This suggests that this factor should be a consideration in the early stages of transit planning, particularly in the location of stations.

5.5.3 PLACEMENT OF THE STATION

Another similar factor is the placement of the station with respect to the business district. At Beijing's Chongwenmen Station, the downtown is actually three blocks away. In contrast, SkyTrain and Metrorail stations are located in the center of Vancouver and Washington, D.C. shopping and office areas respectively, where related development has occurred.

5.5.4 PUBLIC INVESTMENTS

Other public investments coordinated with the transit improvement also appear to have been influential in encouraging transit-oriented development, although in many instances their effect has been overshadowed to date by opposing forces such as the lack of consumer demand. Typical of public investments are the British

Columbia government's large office complex now being completed at Vancouver's New Westminster station, and the convention center built near the Metro Center Station in downtown Washington, D.C..

5.5.5 FORMAL URBAN RENEWAL

The formal urban renewal activities coordinated with rapid transit development have been an important aspect of this public investment in several cases. Even without the construction of public facilities the simplification of land assembly for private developers has in some instances led to redevelopment. In others, the combination of publicly-assembled land and the presence of new public buildings has proven attractive to private developers. This is especially significant since the area involved was otherwise deteriorated and without significant development for many years.

Similar efforts at public-private renewal activity around rapid transit stations have been attempted elsewhere, notably Washington, D.C.. Although development appears inevitable, a variety of forces including lack of economic demand and the general unattractiveness of the specific areas involved have restrained action by developers.

5.5.6 OTHER FACTORS

Travel (cost) time has no significance in the choice of retail location. The basic attractiveness of the retail location was the prime determinant. Attractiveness com-

ponents indicate what increase in retail activity must occur to effect the downtown share of the regional market, and what levels of growth on non-downtown markets will dampen the impact of downtown development. Local zoning ordinance has a greater effect on economic development than transit access. Other complementary factors, such as attractive surroundings, an expansionist business climate, and competitive advantages such as increased density allowances, are essential.

5.6 ENVIRONMENTAL IMPACTS

The physical impacts relating to the rapid transit planning process are environmental design, aesthetics and historic values, aquatic ecosystems, air quality, noise and vibration. The primary elements of the external terminal environment are land use, the efficiency and configuration of the terminal's access systems, its aesthetic and socio-economic impact on the community, and its effects on the health, tranquility and natural ecology of the surrounding area. Internal environmental design elements are comprised of both objective and subjective factors including service standards, traffic characteristics, visual design, patron services, comfort and maintainability.

5.6.1 NOISE AND CROWDING

Environmental impacts have been negligible for the transportation disadvantaged. Two negative environmental impacts are station area traffic and increased noise levels. Negative impacts are more intense in suburban non-minority areas.

Noise from trains is perceived as a problem. Elevated trackways tend to generate the greatest sound problems. Most interviewed persons react indifferently to environmental impacts. Residential neighborhoods around SkyTrain stations have experienced negative impacts due to increased traffic. Comfort and other qualitative aspects of service are apparently not an important consideration in most rider's choice between rapid rail and bus or car.

The rapid rail transit station activities, traffic, and trains have not noticeably increased sound levels. The quietness of stopping trains has reduced station-related noise. Metrorail related peak period noise showed no significant increase in ambient noise levels. Area with heavy automobile access did not adverse noise effects. Metrorail and SkyTrain sound on above ground lines is bother to some nearby residents. However, Subway Beijing do not bother any residents by its train noise due to its underground operations in whole routes.

SkyTrain riders were somewhat less positive concerning noise levels and vehicle crowding on the system. Only 36.1 percent disagreed or strongly disagreed with the statement "SkyTrain is quiet" and 32.8 percent disagreed or strongly disagreed that SkyTrain were not crowded.

Metrorail is a quiet space for transition from the work world to home. It appears to stimulate travel dependent household. Subway Beijing is regarded a crowding

system due to its over-capacity ridership. However, it is less crowded than bus or trolley service in Beijing.

5.6.2 AIR POLLUTION

The extents that rapid rail transit system can contribute to pollution control are this system reduces the air pollution generated by vehicles, and it does not generate new pollution in the region.

The electric-powered rapid rail transit offers a way to reduce concentrations of auto-originated pollutants. Direct measurements of the carbon monoxide levels around rapid transit stations show little difference between present levels and those prior to the system operations. However, there is a little difference in major traffic corridors. The reason that rapid transit has no significant effect on regional air quality improvement is that the system's usage resulted reduction in vehicle-miles is in a small percentage in the region.

With the increase of service length of rapid rail transit, some conceivable amount of diversion from auto to rapid transit would make much of a dent in the air pollution problem, taking into account the limited circumstance under which rapid transit is cheaper than private auto, carpools or vanpools. Dust and dirt during construction of rapid rail transit systems was the most mentioned item in the survey of people in nearby areas.

5.6.3 ENERGY AND POWER DEMAND

The viability and efficiency of a transit system is highly dependent on both the type of city and the service being offered. Rapid transit is generally regarded as energy efficient, yet it can not meet all needs for all urban travel. It also saves more energy than auto, carpools, and vanpools do.

Actions to shift persons from auto to rapid transit can save a small but significant amount of energy. New development has substantially increased downtown demands for water, gas, and electricity. This is largely a transfer of demand rather than an absolute increase in the metropolitan resources requirements.

5.6.4 AESTHETICS AND PSYCHOLOGICAL EFFECTS

Aesthetic is more than "looks". It includes the enjoyment and stimulation that people receive from their experience. Because of many transport facilities are attractive, the integrated design of aesthetic quality in rapid rail transit system is important for creating attractive environments for the people using rapid transit facilities and for those in the surround communities.

Urban design professionals judged the Metrorail components to be compatible in scale with the surrounding areas except the scale of parking lots in suburban residential areas. However, most residents found the station architecture to be an asset for community. Most stations built near existing large structures were judged to complement the existing structure.

It was found that shadow effects of station structure and elevated parts of rapid rail were insignificant. Both professionals and residents agreed that landscaping is

very important in softening the visual impact of the rapid transit segments at grade. By placing SkyTrain facilities within and adjacent to other transportation right-of-way, SkyTrain was able to minimize visual appearing of the train and environmental disruption. The only visible environmental impacts on Metrorail and SkyTrain station areas is the high level of on-street parking.

Lighting of some stations was viewed as a potential problem by the professionals. However, the residents were indifferent to lighting. Many residents felt that the lighting would be helpful in reducing crime and accidents.

Transportation facilities, community character and land use placing that are attractive to both user and non-user enhance the prestige and satisfactions of living in a community. Community goals relative to their visual character and image represent both economic and social values to residents. A program of orderly urban growth and land use will help solve long range environmental problems.

It should be remembered that people tend to adapt to their environment; once a new development has been in place, people grow accustomed to it.

5.6.5 OTHERS

Beijing Subway's overall environmental effects are neutral due to its underground operations. Neither the building nor the operation of rapid rail transit have caused significant damage to the natural environment. No significant ecological systems or components are known to have been damaged or disturbed.

5.7 SAFETY AND CRIME

The three systems' security and travel comfort are far superior to most other rapid rail transit systems. Security is usually not a concern for patrons leaving their cars. However, automobile-related crime, such as breaking and thefts, are more frequent and increasing in core D.C.. Accidents in stations concourses are rare. Crime in stations is rare also.

Metrorail's effects on crime around its stations appear to be minimal. Theft and burglary of automobiles were found to occur on the streets around some downtown stations with parking lots and overflow parking. Metrorail patrons were the most frequent victims, and nearby residents did not perceive a threat to themselves.

Urban area officials expressed concern about increased crime during night service. However, there has been only a slight increase in arrests, mostly related to intoxication and drug. Violent crime rates remained at a low level.

Large numbers of teenager visitors were attracted to the commercial district. Some negative effects including loitering, vandalism, and shoplifting were reported.

Crime exists throughout cities and rapid transit systems because the social ills of property, lack of opportunity and despair are ambiguous in present day society. There is no easy solution nor quick cure to the dilemma.

SkyTrain riders are generally positive regarding the safety of SkyTrain. A total of 66.9 percent agreed or strongly agreed with the statement "I feel safe onboard SkyTrain".

5.8 ECONOMIC BURDEN

Metro debt burden and tax rate did not influence local tax rate or bonding decisions. Metro had a favorable impact in local government finances by providing new sources of financing for public improvement projects.

Up to \$2 billion in private funds invested in downtown Washington between 1982 and 1985. This investment alone generated \$50 million a year in new revenue for the District of Columbia.[3]

The impacts of rapid transit expenditures on economic development will increase in direct proportion to the amount spent. A transit-related economic development strategy should include provisions for offsetting the likely economic disadvantages that will result in some areas. Rapid rail transit development will most likely reduce financial resources for transit services.

Rapid transit beneficiaries frequently extend beyond direct users to neighboring property owners and business served by transit and the general public. Therefore the groups should share in the cost of transit. Innovative financing techniques could realize a higher return on public investment, with benefits beyond urban transportation, e.g. energy conservation, urban redevelopment, economic growth.

Both revenues and expenditures from detached housing have been above the level of older housing. Garden apartments frequently create a surplus because of the low number of school-age children compared to those in detached housing. Commercial development create a fiscal surplus since they are unlikely to attract many new immigrants. However, new shopping centers frequently reflect a shift of existing retail activity -- not all new retail sales. Office building are likely to provide more re-

venues than cost of service consumed. Industrial development are found to have a mixed effect when secondary impacts, particularly immigration, are considered.

5.9 PROPERTY VALUE

SkyTrain's influence on price increases was most pronounced for homes within 1500 feet of a station, diminishing rapidly as distance increased. Property price gains attributable to Metro have been negligible. Study findings in Washington refute the theory that a rapid transit system is likely to cause large price increases for property near Metrorail stations which could be taxed to help by pay for the system. Increases in property prices were most prevalent during the planning and construction phase of SkyTrain, tapering off after that. Residential rents are less likely than property prices to be sensitive to anticipation of long-term benefits from planned transit services. Office rents were affected more consistently by SkyTrain than residential rents.

The procedure of such studies is (a) to record the values of pertinent variables, such as land value, construction value, travel volumes, and speeds, for a period of time prior to the introduction of the facility; (b) to record the value of the same variables for a comparable time period following the introduction of the facility; and (c) to compare the 2 sets of values.

Land values are greatly affected by area accessibility, growth potential, development stage, existing land use, and land use control in regards to highway improvement projects. Proximity to selected Metrorail stations revealed small but significant increases in the prices of single family dwellings. Small but noticeable ef-

fects were also detected for increases in office rents near stations. Initial positive effects on property prices have largely disappeared.

Access to SkyTrain has become an added component defining residential location desirability. While property values can be independently evaluated of employment, income, and housing, it is preferable to include these analyses as part of a broader economic impact study. All station areas have experienced housing sale price increases. Some land value appreciate was noted.

5.10 *DISADVANTAGED MOBILITY*

The special needs of transportation disadvantaged persons were not prominent matters of concern during Metrorail's planning period. Metrorail and SkyTrain has aided minority and low-income residents of inner cities by encouraging firms to remain centrally located.

Metro is the mode of travel chosen by minorities roughly in proportions to their incidence in the population of the greater Metrorail service area, but the rate of Metrorail use appears to be lower for Blacks and Spanish-Americans in the smaller area close to Metrorail station. Metrorail and SkyTrain are accessible to disabled persons, including persons in wheelchairs.

The impact of rapid rail transit on the mobility of disadvantaged has been small. The minimal effect of rapid transit on improved travel accessibility for lower income groups results from the inability of rapid transit to compete with bus and trolley relative to out-of-pocket cost and significant travel time savings.

REFERENCE

1. Census of Retail Trade, *Major Retail Centers in SMSA, District of Columbia*, U.S. Department of Commerce, Bureau of the Census, op. cit., 1970-1985

CHAPTER 6: COMMENTS AND CRITIQUES

6.1 *EUROPEAN EXPERIENCES*

Not alike the United States, Canada preserves more European heritages in both individual opinions and governmental policies. Thus, it is necessary to compare the difference between West European and United States.

Most European countries have a longer traditions of planning than is the case with most North American cities. Sweden differs most from the United States and Canada because of its public ownership of urban land and strong implementation control as well as China. However, it is erroneous to dismiss European practices and experiences in urban planning simply because their "conditions are different", including factors such as attitudes toward planning, governmental powers, densities of cities, taxation policy and auto ownership. The fact is that most of these conditions are far less dissimilar than usually believed. With the exception of Sweden, most West European countries have governmental structures not greatly different from American. Problems of fragmented governmental bodies within metropolitan areas

exist in most countries and cities. Difficulties in reconciling community interests with those of private developers or owners are similar to those found in American cities. Population densities are higher than those in western U.S. cities, such as Houston and Phoenix, but they are comparable to and often lower than those typical for older U.S. cities, such as Baltimore or Boston.

One highly significant difference which appears to be the most important factor in achieving different rapid transit planning and construction results despite similar basic conditions: attitudes toward public transportation, toward all public services and toward cities in general are different in European cities from those typical for their U.S. counterparts. Europeans are used to having a high quality, reliable transit service and they do not tolerate serious interruptions in it; it is inconceivable in Switzerland, Germany or The Netherlands, for example, that a transit system in a major city would be on strike for more than a day or so. While U.S. citizens take such phenomena nearly a way of life, similar cities in Europe would have a public uproar and tremendous pressure would be exerted for immediate restoration of service. Similarly, lack of transit in a major part of a city is also considered intolerable. Aware of these expectations of the public, European city governments are very sensitive to transit's importance and take a very active role in all matters concerning operations and planning of transit system.

This general consensus among the public, governments at all levels, employers and businesses that adequate transit service (which in medium and large cities refers primarily to rail rapid transit) must be provided is a major factor in overcoming the major difficulties and obstacles in achieving this goal. Actually, the public often demands a higher level of transit service than is financially or physically feasible under many conditions. This awareness about transit is very much different from the atti-

tudes found in many of U.S. cities, where a generation of people has already grown up without modern transit service.

Finally, attempts to collect information on the impact which European rapid transit has on land use, in terms of such quantitative measures as increases in land value or the number of households or jobs which have been attracted to transit-served locations, have not been successful since that question is not considered meaningful by the city and transit planners in those countries. Land use and transit are typically planned together, rather than separately. Thus the "impacts" of rapid transit on land use is so obvious, in both qualitative and quantitative terms, that it is not the subject of conjecture or argument.

The questions of what impact rapid transit would have on land development is seldom discussed by European engineers and planners for two reasons. First, there are few if any places where conditions approach an open market in urban form and land use pattern: too many other influences, both supporting and opposing development, are always involved.

Second, building a rapid transit system and leaving it separated from desired land uses is considered to be a failure apparently which automatically leads to underutilization of the potential such a rapid transit system has for improving efficiency of urban transportation. Consequently, most discussions on this subject in European cities concentrate not on maximizing "impact" but rather on how to improve the existing planning procedures and implementation methods to insure that the investments in rapid transit are properly utilized through their coordination with land use planning. The most potentially useful lesson, then, which can be drawn from the European experience seems to be that public attitudes are a key factor in assuring successful coordination of rapid transit and land use. Differences in approaches to coordination are apparent between the European and American norms. However,

these differences, are largely the manifestations of differences in the expectations and demands of the European and American public. Certainly historical traditions of government and social structure are also influential. Still, the European experience suggests that if the attitudes of the American public would become more favorable toward the use of transit, then substantial improvements in land use-rapid transit coordination might become possible. This might be encouraged, for example, by federally sponsored demonstrations of such coordination on the model of the German or Dutch transit-oriented suburban residential developments.

6.2 *POLICY OPTIONS FOR RAPID TRANSIT*

Since rapid transit investment decisions are largely determined by government, They may prove to be a powerful implementation tool to be used by the public to guide growth into locations that serve the public interest more satisfactorily.

6.2.1 DO-NOTHING OPTIONS

The argument for the do-nothing option can be based on the philosophy that transportation plans should be designed to serve, not shape, whatever urban form the market produces. Using this argument, one must assume that a satisfactory transit system can be designed that will fit the travel requirements of any urban forms.

Without some powerful incentives and disincentives to do otherwise, the urban land market will probably continue to produce small clusters of retail, office and in-

dustrial activity on scattered sites, taking full advantage of the extensive urban freeway systems that exist in most urban areas. As autos become smaller and much fuel-efficient, these auto-dependent locations are likely to remain visible. If alternative fuels become available that are economical and environmentally acceptable, the further decline of the average density of our urban regions may continue. Vast areas of our urban regions are already zoned for commercial use and there is plenty of land available in the outer city to accommodate the expected growth and than come.

Current practice in the transit planning field utilizes this philosophy to a very great extent. If Urban Mass Transit Authority of U.S. continues to support the do-nothing approach to rapid transit planning, we can expect to see more and more automobile, like transit services in the outer city and they will probably be quite expensive and carry only a very small proportion of the total trips in the regions.

6.2.2 DO-SOMETHING OPTIONS

The philosophical approach for do-something option here is that the transportation engineers and planners ought to design transit systems that will shape urban growth patterns in ways that will maximized their utility. The other major concept involved in that rapid transit works best when it has high density areas to serve. This implies that an urban form that has several dense and diverse centers can be more easily and economically served with an area-wide rapid transit system than an urban form that has no significant centers. As noted previously, this assertion has yet to be proved conclusively an it may not even be possible to do so. It is, however, intuitively appealing and widely believed.

Most people regard rapid rail transit, a part of mass transit, as some kind of public welfare program. It is fact that almost all countries subsidize their rapid transit systems. Some of the systems become a financial burden of its government, while some of them do not. One reason which is usually quoted for the phenomenon is lack of good management and efficient productivity for those systems. Some other reasons are that the fare is too low to support the system, and reduced government subsidies. However, these views neglect the most important thing -- the public attitude toward the mass transit, as noted previously. Most decision-making and policy-making are based on public attitudes and opinions.

Although the United States has a strong European background in political, economic, cultural, social, educational, linguistic, ideologic, religious fields, there is a big gap between the United States and West European countries (including Canada). That is the difference in character of nation. The United States known as "pot", the role of individual has been strengthened from colony age, the development toward the West to modern time.

Most Americans take a indifferent attitude towards the existance of mass transit, especially the middle class which is the majority of total American population. The trend is strengthened by the widespread accepted viewpoint about individual right. Individual interest dominates in this society, however, both West Europeans and Canadians pay more attention on the public interest because the individual is only a member of public in society.

Under this circumstance in the United States, decision-makers make a pro-auto transit policy to fit the indifferent ever negative attitudes of public. This policy forms a negative circulation: more and more people live scarcely, it is impossible to provide transit in those regions; therefore, more and more people drive their cars causing the small percentage of public transit in modal split.

6.3 METHODOLOGY OF ANALYSIS

As noted previously, several factors, including rapid rail transit improvement, affect urban development. We cannot employ a simple method to forecast the future influence of this transit improvement on urban development. A actual relation between this improvement and development cannot be expressed by mathematical formulas.

Under this circumstance, we could employ a set of models as methodology to forecast possible development induced by proposed rapid transit improvement. Three major factors are being considered in modeling the process: population, land use, and economy.

6.3.1 POPULATION

There is no evidence to verify the viewpoint that rapid rail transit improvements have led to net population growth in metropolitan areas according to the analysis previously. In European countries, Canada, and China, this transit improvement tends to condense population density and to increase households in the transit influence envelopes, due to the pro-public transit policy of those governments. Rapid rail transit is an ideal transport tool for those residents. However, most people in U.S. are not transit-dependent riders. It is not an important consideration for those riders to live within the transit envelopes when they choose their living locations in U.S..

Besides these factors mentioned above, there are several other factors influencing population change: central city revival, rehabilitation of old downtown, hous-

ing renovation, suburbanization. Obviously, population change in the rapid transit influencing envelops is the result of redistribution of population within a metropolitan area.

There are a variety of simple population forecasting models, which are for most part descriptive models.[1] The simplest of these methods use historic trends of population change to extrapolate future trends. These methods include linear and exponential models and comparative and ratio methods. The later two also use historic population data from a reference area other than that requiring the projection. These model, though simple to use, have a number of deficiencies. First, they do not break down population change into its components: births, deaths, and migration, Second, they cannot explain the forces behind the predicted change, and there is no theory underlying their primarily mechanistic results. Third, these models often fall short, because more than simple population totals are usually needed. They do not usually provide and clues to changes in population characteristics such as age, sex, income, or ethnicity. Despite these disadvantages, some simple mechanical models are the best predictors in certain situations.

A more helpful method is the cohort-survival technique. It does break up the phenomenon of population change into its three component parts. Change for each component is described and predicted separately. Three components are then combined and applied to cohorts, or groups of people aggregated by one or more characteristics, and projections are made for a future time period.

There are more complex methods of predicting population change. Migration has been the subject of numerous studies and multiple regression, a statistical technique that relates a variety of factors (in this case, employment and income factors relating to the origin and destination of migration), has been used to predict migration within the U.S..

Migration is heavily influenced by employment and availability of job opportunities. It is therefore important to coordinate population forecasts with forecasts of future economic conditions and employment. Historical migration rates should not be automatically assumed to continue, and future migration forecasts should be based on anticipated rates of job creation and employment opportunities.

We could get the forecasting result of population by these methods. In order to estimate the future impacts on population change of a proposed rapid transit system better, we could employ the technique of public participation. A survey could be taken by asking people questions, either by telephone or by questionnaires, including the possibility of moving their residence in order to perceive the accessibility advantages of the proposed system. In order to ensure accuracy of survey, we choose sample size of survey as follows:

- Taking 2 - 5% for the region with 300,000 -- 500,000 population;
- Taking 1.5 - 4% for the region with 500,000 -- 1,000,000 population;
- Taking 1 - 3% for the region with more than one million.

6.3.2 ECONOMY

In most studies, there is a need to identify the local economy's present strengths and weaknesses and future potential and needs for growth. The primary factors to be considered include employment, characteristics of the labor force, income, and retail market opportunities. The local economy is the driving force behind population growth because it is growth in the local economy that creates jobs and affects migration rates.

The basic unit of study for economic projections is the Standard Metropolitan Statistical Area (SMSA), as defined by the U.S. Federal government. An SMSA is more suitable for economic studies and projections than a smaller area because the SMSA is relatively self-contained from an economic standpoint. Projections of employment, income, and other factors are often broken down into classifications according to the Standard Industrial Classification Codes.

The organization principle of most regional analysis is first to assess what changes will take place in those industries whose goods or services are largely exported out of the region, and then to estimate the effect that those changes will have on the rest of the economy. The entire process is sometimes called a community economic base study.

A variety of techniques are used to project changes in the area's exporting economy. Each method usually involves first identifying those local industries (in broad sense of the term) that are the chief exporters. This can be done by comparing the activity level of the local industry (in employment, dollar sales, or production volume) to the national level. Two methods for measuring the activity level are the location quotient and the minimum requirements approach.

There are two sets of methods commonly used for projecting what will happen to the exporting activities. The first, the ratio method, projects changes in a region's share of a certain economic export activity. Changes in share are called shifts. In the process of shift/share analysis, we can assume a constant share, a constant rate of shift, or a changing shift.

Another technique for projecting the future of exporting activity uses econometric methods. These multiequation models were initially used to test economic theories, but they have also been applied with some success to descriptions of regional economies. The idea is to relate a large number of theoretical explanatory

variables to regional output by using statistical tools. These relationships can be complex, nonlinear, and often time-lagged. The models constructed can be used to predict the impact on the regional economy of various policies, such as rapid transit improvement, aimed at regional development.

Once changes in this basic or export sector have been assessed, it is possible to use certain techniques to estimate the effects these initial changes will have on the rest of the regional economy. Two associated methodologies involve the multiplier concept and the input-output study. The multiplier measures the effect of changes in the sector based on the premise that increases in export sales from the region will directly increase the regional income. This income will then be used for saving, investment, and consumption. This investment and consumption, depending on where it is spent, can also increase the level of local economic activity. The multiplier is an attempt to measure all of these waves of economic effects.

Input-output studies are more sophisticated versions of multiplier analysis. The exporting sector is not treated as a large undifferentiated mass, but is broken up into a number of subsectors. Having decided on the number and types of subsectors to be included, the analyst runs a survey to estimate the level of inputs and outputs among all subsectors. The results of the survey are displayed in an input-output table, and mathematical analysis of the data enables the us to judge the impact on other sectors and on the overall regional economy of a change in any one sector. However, input-output studies tend to be quite expensive, and these techniques are more often used for learning about regional and local economies than for problem solving.

Four sectors could be chosen to determining the impacts of rapid rail transit improvement qualitatively on economic development: retail sales, tax, employment, and construction activities. The initial level of the sectors could be determined according to specific situation of each metropolis; the changing rate should be deter-

mined by regression of data collected before and after a rapid transit improvement in those cities where the rapid rail transit system was done. With combining this empirical model of other rapid transit systems, the future development in the metropolitan area with a proposed rapid transit system could be projected by these techniques noted previously.

6.3.3 LAND USE FORECASTS

An important aspect that a rapid rail transit improvement influences urban forms is the change of land use in the metropolitan area. Forecasts of future land-conversion needs are usually based on population and employment forecasts. Population is commonly used as a basis for projecting needs for all land-use classifications for areas that are relatively self-contained from an economic standpoint. Where employment projections are available, they may be used to forecast land needs for commercial and industrial land. In cases where both population forecasts and employment forecasts are available, both methods should be used and compared with each other. Land-use data and projections are usually broken down into classifications. These classifications are often based on the Standard Land-Use Coding Manual, but they vary from community to community. Common classifications of land use include residential; manufacturing; transportation, communications, and utilities; wholesale and retail trade; cultural, entertainment, and recreational services; resource production and extraction; and undeveloped land and water areas. It is useful to use a land-use classification system that is compatible with other state, regional, and community agencies working in the area.

When making forecasts of future land-conversion needs induced by the rapid transit improvement, it is advisable to base density figures on existing land-use patterns and local conditions. For new development, it is preferable to develop figures reflecting recent typical development densities. Use of total figures that include older development may not reflect future development densities or types. Development densities should be examined and compared with figures from other typical metropolises where have the transit improvement to get representative values. Once representative values for the present densities of various land uses have been determined, it is possible to develop density standards for future development, based on historical data and trends as modified by anticipated future changes or plan policies. It is possible for a community in a metropolis to encourage higher or lower densities of development than have been historically experienced by adopting planning policies and taking actions to encourage changes in density.

The amount of land that will be needed in the future is forecast by looking at population and employment projections and their associated land needs. Rates of land use for different categories developed from present land development patterns and discussions with advisory committees. These rates might specify different types of residential density, commercial land use, parks and institutional uses for every additional 1,000 persons. These rates of land use can then be applied to the forecasted growth to determine the types of land that will be needed in the future. It is sometimes desirable to prepare more than one forecast to reflect different policies of urban growth.

The forecast of land use demand does not include a forecast where the development will take place. To allocate land use demand, there must be a determination of the available unused land. This would include lands that are outside flood plains, contain soils suitable for urban development, and are not designated for other use.

Then an allocation can be determined by considering previous land use plans and zoning regulations. The prediction may be based upon past development trends or upon modified trends. Another method of allocation of land use demand uses mathematical modeling. Growth indices are developed for each parcel of land to relate it to location, rapid rail system, utilities, public services, and nearby development. Future growth is then allocated to each analysis zone based upon its growth relative to other analysis zones. Other mathematical procedures that simulate land development decisions, competitive aspects of land use, or optimization procedures might be used.

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CONCLUSION

Metrorail, Subway Beijing and SkyTrain are all well planned systems. They are not like some early developed systems in New York and Chicago in the beginning of this century. The three systems reflect three major styles in the world -- American, European and Chinese. They are existing respectively in different societies where dominate individual in United States, mixture of public and individual interests in Canada and public interests in China.

The decisions to build a rapid rail transit system in the metropolitan region were made for many reasons, but they can be grouped under three principal goals:

- Relieve traffic congestion, especially downtown areas;
- Provide a transit alternative to the automobile drivers; and
- Support a compact pattern of regional town centers along corridors radiating out from a over-developed downtown.

The ridership changes of rapid rail transit usually follow the three phase pattern -- rapid upward climb phase in initial times; slow growth phase; and stable growth

phase with the expansion of service. This pattern corresponds to the psychology of riders, the customers of rapid rail transit, -- trial, comparison and determination.

The rapid rail transit are found to serve a majority of riders going to and from work. About 20 to 30 percent riders who appear to have been diverted from the private auto is a very significant and probably indicative of the comparably high level of service offered by rapid rail transit service. People will opt for rapid transit as long as the system compare favorably with the automobile in terms of speed and reliability. Rapid transit system attracts not only former auto drivers but also new riders from other modes due to the fact that the system is a time and cost-saving transportation tool for people. The improvement enhanced the downtown's accessibility by providing additional commuting capacity in some congested radial corridors. The role that rapid rail transit played in transportation system cannot be replaced by any other transportation mode.

Most transportation problems arise out of the nature of urban life itself; choices among solutions must be based on available alternatives and the values held by city residents. Three basic problems define the kinds of alternatives available, the advantages and disadvantages of different modes of transportation for varying needs, and the way in which transportation problems meld with other urban problems.

The most visible problem in urban transportation is that caused by the desire of large numbers of people to move at the same times to the same places. This problem also occurs in the case of weekend recreational travel and trips to special events. It is an illustration of the function of the city in bringing people together to do what they could not do separately. Much of the attractiveness of the city consists of those activities which require support from large numbers of people. Improvement of rapid transit is an important means to solve the problem.

Since proximity among activities is the major reason for being of city, the most valuable resource is space. A good transportation system uses as little space as possible for moving people in order to reserve as large an amount as possible for the activities to which people want access. Some modes of transportation require more space than others proportional to their capacity to move people. Automobiles have very high space consumption per person trip. Rapid rail transit has very low requirements in relation to capacity.

Urban populations are diverse in their cultures, types of work, life styles and values. If such diversity is to be maintained, the transportation system must provide for the needs of all the population. The elderly and youth, the poor and the handicapped have special needs. For most residents in United States, the automobile has made possible greater access to opportunities. On the other hand, where private transportation is relied on, those who need public transportation are deprived of the same opportunities, because mass transit can only reasonably be provided if it is used by many. The gap between the two modes could be reduced by the rapid rail transit, because it not only provides an alternative for the auto drivers, but also increase the mobility of the people who have to use mass transit.

On the other hand, urban transportation problems can best be approached through the coordination between an efficient transportation system and polycentric city pattern. Historically, the nature of transportation technology and organization has had a tremendous influence on patterns of urban development. The viewpoint is confirmed by this study that the polycentric urban pattern is the best form which would develop with the least damages on the metropolis, and could be served by rapid rail transit system. In reverse, this urban pattern will also strengthen the system's impacts on social and economic development in the region. The polycentric pattern is the best urban form for metropolitan regions. New mixed-use town centers

in metropolis are sprouting upwards on the fringes of central cities in metropolitan region, partly in hopes of creating viable rapid rail transit environments.

Rapid transit offers savings over automobiles. Residents near their lines view these impacts as favorable. These rapid transit systems operations are relatively energy efficient and pollution-free. Commuters have experienced only minor life style impacts. Children and young people have increased mobility, as well as elderly and handicapped have some increased mobility.

Rapid rail transit improvements influence public policy making, especially land use policy. This improvement can influence land use significantly when supported by other essential factors including land use control (zoning), availability of developable land, attractiveness of surroundings, public facilities, and regional demand, but should not be relied on solely or even primarily for such purposes. Accompany with other factors, rapid transit system changes land use, reduces deterioration of downtown, induce public and private development around it. It acts as an engine of economic development. While rapid rail transit improvement cannot and would not claim responsibility for all development within its region or envelope, it acts as a major catalyst in assisting economic and social development. There is also a common belief that rapid transit should precede and guide growth, reflected in the decision of several communities to extend expensive new rapid rail lines in advance of demand. It is a tool to help government implementing its policy.

There is no direct relation between rapid rail transit improvement and regional population growth, but it influence the population redistribution. It is apparent that rapid rail transit attracts new employment to its envelope and influence areas from other parts of the metropolitan region.

As an advantaged mass transit means, rapid rail transit influences urban and regional society positively. It is apparent from the extensive research conducted on

the study that substantial impacts attributable to the rapid transit system have occurred in these metropolises. The most important of these is an apparently substantial increase in residential property values in areas served by these transit lines, most notably in those areas most distant from downtown.

A good transportation system in metropolitan region should satisfy the variety of needs for mobility engendered by a very heterogeneous population. A system which mainly depends on automobiles cannot meet the needs. An efficient mass transit system could compensate the insufficiency of automobile. The rapid rail transit system would enhance the productivity of mass transit system efficiently and effectively to compete with auto in both speed and costs. As a critical part which is not replaceable in urban transportation system, rapid rail transit plays an increasingly important role.

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