

**Coordinated Transportation and Land Use Planning in the Developing
World – The Case of Mexico City**

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Submitted to the Department of Urban Studies and Planning
in partial fulfillment of the requirements for the degrees of

Master in City Planning

and

Master of Science in Transportation

at the

Massachusetts Institute of Technology

June 2002

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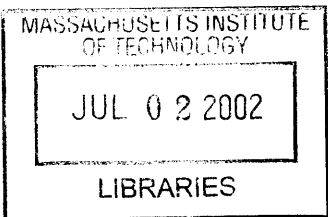
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FOOTNOTES

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Abstract

Transportation, land use and the environment are inextricably linked. In recent decades there have been efforts, primarily in the developed world, to coordinate transportation and land use planning so as to use land resources more efficiently and promote the use of transit and non-motorized transport (walking and biking) at the expense of the automobile. This is done in order to reduce congestion and pollution and to provide more equitable access to jobs.

This thesis examines the applicability of coordinated transportation and land use planning methods such as transit-oriented development (TOD) in the developing world, and more specifically, in the Mexico City Metropolitan Area (MCMA). TOD is a policy that promotes dense, mixed land uses near transit stations. Essential to its success are an extensive transit system, government incentives to developers and zoning regulations, and a strong real estate market.

In the developing world, where cities are growing fast and most people still do not own cars, TOD provides an opportunity to design the urban form of the growing cities to be transit-oriented. Low-income people can thus be served by cheaper high capacity transit, and can thus spend less of their meager income on transportation and have better access to jobs. They will make fewer and shorter trips by low capacity transit such as informal modes, reducing congestion and pollution. In the long term, TOD may slow down motorization and mitigate its effects.

Mexico City faces a crisis of mobility, environment and equity. It needs coordinated transportation and land use planning to curb further sprawl, which would worsen these problems. It has many of the prerequisites for TOD. It has the densities, an extensive Metro system (although not extensive enough), and embryonic (and still weak) metropolitan planning organizations. Opportunities for coordinated transportation and land use planning there include station area development, downtown redevelopment, real estate development along the proposed suburban rail line, and a policy of building new affordable housing within walking distance of high capacity transit. The greater the geographical scope of each option, the more government involvement it requires, and the larger its potential positive impact is.

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Acknowledgments

I would like to begin by expressing my gratitude to my teacher, research advisor and thesis advisor, Professor Joe Sussman for his guidance and patience. I admire his systems approach to problems and his ability to see the “big picture”. I learned from him that transportation planning is much more than just quantitative modeling. I also want to thank my academic advisor from DUSP, Professor Joe Ferreira, for his advice over the years, for reading and commenting on my thesis, and for teaching me GIS. I would also like to thank other faculty members I have had the honor of studying with, particularly Mike Shiffer, Fred Salvucci, Nigel Wilson, John Miller, George Kocur, Joe Coughlin, Ralph Gakenheimer, and Amedeo Odoni.

I would like to acknowledge financial support from the Integrated Program on Urban, Regional and Global Air Pollution with funds provided by the Fideicomiso Ambiental del Valle de Mexico, MIT-AGS and the U.S. National Science Foundation. I would like to thank Mario and Luisa Molina for the great opportunity to work on such an important project. I admire their noble effort to improve the lives of the people of Mexico City. I would also like to thank Steve Connors for teaching me how to do scenario analysis, and how to work in a data-poor environment. I also want to thank the students on the project for their moral support, particularly Chiz Aoki, Rebecca Dodder, and Ali Mostashari.

Big thanks to Alejandro Villegas for his tremendous help in providing me with data for my research and thesis. I would not have been able to do it without his extensive knowledge of transportation in Mexico City and his helpful advice.

I would like to thank the friends I made at MIT for their moral support and for the company and conversation they provided me. In particular I would like to thank Georges Darido, Vladimir Ivanov, Emmanuel Carrier, Sheldon Lyn, George Proakis, and Angela Moore.

I would like to thank my family in the States for their support and for inviting me to their homes on the holidays. Thank you Aunt Joan, Fred, Aunt Diana, Bob, and Cathy.

I want to thank my brother Jacob and sister Roni in Israel for their support. Most of all, I want to thank my parents for their tremendous moral and material support. I would not have been able to get this far without them. This thesis is dedicated to them.

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Chapter 1: Introduction to the Transportation – Land Use – Environment Connection

1.1 Introduction and Motivation

In recent years, planners in many American cities have become increasingly interested in coordinated transportation and land use planning as a means of combating suburban sprawl and the resulting environmental deterioration. They seek to use land resources more efficiently, revitalize long-neglected urban cores, improve public transportation, reduce automobile use, and promote walkable, transit-accessible communities. They hope to improve mobility, accessibility, and social equity, and to improve the environmental situation.

Transit-oriented development (TOD) is one method of accomplishing these goals. It involves concentrating high-density residential and commercial land use near transit stations in the hope of increasing transit ridership and reducing auto use and trip length.

In the US, there is a debate over the effectiveness of TOD in the American setting. However, the debate over TOD has largely taken place within the context of the developed world, where most people own cars, and specifically within the context of the United States, where the massive dispersion of urban population and jobs to the suburbs has already occurred. There is little research about TOD in the context of the developing world, where transportation and land use patterns are very different. The aim of this thesis is to examine the effects TOD could have in the context of the fast-growing and fast-changing cities of the developing world.

Mexico City, which is one of the world's largest cities, faces profound environmental, transportation and socio-economic problems. This thesis aims to explore the ways in which coordinated transportation and land use planning might be used to alleviate these problems.

The MIT Integrated Program on Urban, Regional and Global Air Pollution is conducting a study of air pollution in Mexico City, and is seeking to develop a comprehensive and robust set of pollution-reducing policy options that address a wide variety of emission sources. This thesis sprung from a study of Mexico City's extensive Metro system intended to find ways of improving ridership on this relatively clean mode of transportation. The thesis seeks to explore the possible role that the Metro and other high-capacity modes such as suburban rail might have as a backbone for TOD in Mexico City.

1.2 The Transportation – Land Use – Environment Connection

Transportation, land use and the environment are inextricably linked. Vehicles generate air pollution. Most types of urban land use generate air pollution, as well as solid and liquid waste. Transportation investments facilitate economic development and cause changes in land use, which in turn generate more activity (trips) on the transportation system. Economic development usually produces negative environmental impacts. The following section looks at some of these relationships.

1.2.1 The Environmental Effects of Transportation and Land Use

Human activities have many detrimental effects on the environment, damaging ecosystems, sickening and even killing humans, and polluting the air, water and soil for decades and even centuries (even more in the case of nuclear waste). There are several kinds of pollution:

- Air pollution – pollutants emitted by vehicles, factories, power stations and even household appliances cause illness, damage the ozone layer and contribute to global warming.
- Water pollution – Raw sewage and industrial waste, including highly toxic materials, often end up in rivers, lakes and oceans, killing wildlife and posing a health risk to humans.

- Soil pollution – Toxic materials often contaminate the soil in the industrial areas of cities and around mines, and seep into aquifers underground, contaminating the water supplies of millions of people. Vehicles also contribute to aquifer pollution. They leak oils and other residues onto the road, and then the rain carries these materials off the road and onto the open ground, where the pollutants can percolate into the aquifers underneath the road.
- Noise pollution – Loud noises, particularly in urban areas (e.g. airplane noise near airports), can cause hearing impairment in humans and significantly reduce the quality of life. Animals are also affected by noise pollution. Diesel engines on ships produce loud noises that disorient whales and dolphins.
- Visual pollution – While this kind of pollution does not have direct health effects on humans, it is still a problem. Some types of air pollutants create visible air pollution, or smog, that can significantly reduce visibility. There are other more minor kinds of visual pollution as well. City lights obscure the stars at night. Some would argue that billboards on buildings and along roads are also a form of visual pollution.

Pollution has detrimental health effects on humans, and can cause serious illnesses, reduce the quality of life, and reduce life expectancy. Since the focus of this thesis is on transportation-related pollution, and since transportation causes primarily air pollution, the following section will focus primarily on air pollutants emitted directly (primary pollutants) and produced indirectly (secondary pollutants) by vehicles, and will describe their nature, origin and health effects.

- Ozone (O₃) – This gas occurs naturally in the upper atmosphere, where it has the beneficial effect of protecting life on Earth from harmful ultraviolet radiation. However, human activity also leads to the creation of ozone at low altitudes, where this strong oxidant poses a serious health risk, causing “chest pain, eye irritation, headaches, lung function losses, and asthma attacks.”¹ Ozone is a secondary pollutant. Its main precursors are NO_x and VOCs, described next.

¹ Molina & Molina (2002).

- Nitrogen Oxides (NO_x) – This family of gases includes several important pollutants, including NO and NO₂. The latter is an important ozone precursor, and also causes respiratory problems. Power plants and vehicles are the main sources of NO_x.²
- Volatile Organic Compounds (VOCs) – This group of gases, such as hydrocarbons (HC) includes several toxic compounds. It is an ozone precursor, and can cause cancer and respiratory illnesses. Vehicles are a source of VOCs through incomplete combustion of fuel.³
- Suspended Particulate Matter (PM) – These are tiny particles that float in the air. They are emitted by vehicles, particularly those powered by diesel fuel. Dust is a form of particulate matter that is carried in the wind both naturally (dust storms) and by human action (dust blown by vehicles traveling on unpaved roads). Power plants are also a source of PM. PM can cause reduced visibility (visual pollution). PM also carries health risks. The larger particles are expelled from the human body before they can reach the lungs, but particles smaller than 10 microns in diameter (PM₁₀) are respirable, and can cause respiratory disease. Even finer particles, 2.5 microns in diameter or less (PM_{2.5}), are now thought to be even more hazardous to health.⁴ Some particulate matter, like asbestos, can cause cancer.
- Carbon Monoxide (CO) – This toxic gas is caused by incomplete combustion of fuel, although catalytic converters have reduced its emissions. It has cardiovascular and neurobehavioral effects.⁵
- Sulfur Dioxide (SO₂) – This gas is produced from the burning of coal and other fossil fuels that contain sulfur. It causes respiratory diseases and is a precursor of acid rain.⁶
- Lead – This element used to be added to fuel before the advent of unleaded gasoline. Where leaded fuel is still used, it can pose a serious health hazard. It can cause kidney and brain, neurological damage, and learning disabilities.⁷

² Ibid.

³ Darido (2001).

⁴ Molina & Molina (2002).

⁵ Ibid.

⁶ Ibid.

⁷ Ibid.

1.2.2 Land Use, Transportation, and the Interactions Between Them

Land uses are the spatial organization of human activities. Urban land uses include industry, residences, commerce, open spaces (parks), and transportation infrastructure (roads, rail tracks, ports, airports). There is a great variety in the way land uses are organized and mixed. In some parts of the world, particularly developing countries and older city centers in the developed world, there is a great mix of land uses, whereas in many American cities there tends to be a clear-cut separation between different land uses (residential, commercial, industrial, etc.).

The transportation system is the blood system of the economy, without which it cannot function. A wide variety of modes carry people and goods to every inhabited corner of the earth. In cities around the world, people travel to work, shopping, school, or leisure on foot, by bicycle, by public transportation, or by private automobile. Public transportation ranges from low capacity modes such as taxis, through jitneys and buses, to high capacity modes such as light rail and heavy rail metro.

Before the advent of modern public transportation, cities had a compact form with high population density and mixed land uses. In the 19th century, horse-drawn streetcars, followed by electric streetcars, started a process of rapid urban growth in the form of “fingers” along the corridors formed by the new transit lines. Middle and high-income people, who could afford to regularly pay the transit fare, settled in the new suburbs. The first zoning laws were promulgated, as people grew less tolerant of land uses like laundries and factories, which were intrusive when placed in residential neighborhoods.

The mass production of automobiles in the early 20th century and their increasing affordability enabled more and more people to live away from transit corridors. In the United States, the postwar construction of the Interstate Highway System with federal funding, and the availability of cheap mortgages, caused a large migration from the inner cities to new sprawling suburbs. Cities lost a lot of tax revenue and began to decline. The perception of the inner city as unsafe and decaying, further increased the flight to the

suburbs. The construction of ring roads, such as the Boston area's routes 128 and 495 worsened the situation by making it attractive for businesses to relocate to the suburbs because of lower transportation costs and cheap land. In fact, most Americans no longer commute to work in the central city, although it is still the largest single concentration of jobs. The dispersed, low-density character of suburban sprawl makes the suburbs difficult to serve with high capacity public transportation, and the mode share of transit in most American metropolitan areas is very low, usually less than 10% of trips. This has negative implications for equity, since low-income people without cars, who live predominantly in the inner city and the older, inner suburbs, cannot afford to commute to jobs in the suburbs. Sprawl has also generated considerable congestion and pollution. Some cities have tried to solve the congestion problem by building more and more highways, but this only increased sprawl, and did not solve the problems of congestion and pollution.⁸

In Europe and in many Canadian cities there was less government funding for highways than in the US, and more investment in transit. In Europe there are also higher gasoline taxes, which discourage auto use, and the age of the cities, with their old, narrow streets, also affects urban form and modal choice. The result is that transit mode shares tend to be higher in European and Canadian cities than they are in the US. In addition, national governments in Europe and provincial governments in Canada tend to have a lot more planning and taxation power than the federal government, or even state governments, have in the US. The Netherlands, for example, has a national Ministry of Land Use. Thus, in Europe and Canada there is a greater ability to control the growth of cities and suburban sprawl. However, motorization is also occurring there, and congestion problems there are increasing as a result.⁹

⁸ There is a large volume of literature about sprawl. Some sources used here were TRB (2001), and Don Pickrell, "Transportation and Land Use", in Gómez-Ibáñez et al. (1999).

⁹ TRB (2001).

1.3 Anti-Sprawl Policies in the US

Several US policies aim to control sprawl and use the existing land resources more efficiently. Through new legislation, such as the Intermodal Surface Transportation Efficiency Act (ISTEA) and the Transportation Efficiency Act For the 21st Century (Tea-21), the federal government gave the states and local authorities more flexibility in using federal transportation funds, encouraged coordinated transportation and land use planning, and encouraged planning at the metropolitan level through MPOs (Metropolitan Planning Organizations).

One policy is an Urban Growth Boundary, which sets a geographic limit to the expansion of the metropolitan area, in order to encourage infill development (i.e. the development of vacant or underutilized lots within the metropolitan area instead of “greenfield” sites on the outskirts), and densification of the area within the boundary. The most well known example is Portland, Oregon, although Miami has a similar policy. Portland has had to expand its UGB several times, and there is criticism over the increased cost of new buildings because land is more expensive. However, the higher land values encourage denser construction.

Many cities pursue a policy of urban core revitalization in order to entice middle class and upper middle class people, as well as businesses, to remain in the city or to relocate to it from the suburbs. City governments try to achieve this through economic incentives, improvements to the physical appearance of the city (streets, parks, old buildings) and the transportation system, and a crackdown on crime. The assumption is that if the central parts of the city no longer seem intimidating to middle class people, many of them, especially single people and young couples, would prefer to live in the center, which is more pedestrian-friendly and has more cultural life. One criticism of urban core revitalization is that it often results in gentrification, which is the displacement of low-income people, who can no longer afford the higher rents that result from increased demand by middle and upper middle class people. Some revitalization programs try to

address this problem by offering affordable housing or protection from rent increases to low-income people in these areas.

New Urbanism is an ideological movement more than a policy, but it seeks to create neo-traditional villages with denser, more mixed land uses that encourage non-motorized transportation (walking and biking) and less car use. These environments have the additional advantage of being transit-oriented.

Smart Growth is an anti-sprawl initiative that seeks to promote efficient use of land resources through infill development, brownfields redevelopment (i.e. recycling abandoned industrial sites), denser, mixed land uses, walkable communities, and transit-oriented development. While the actual development is done at the local, metropolitan and state levels, it is supported by the federal government, particularly the Environmental Protection Agency (EPA), which promotes the environmental benefits of reduced auto travel.

Transit-Oriented Development (TOD) is a form of Smart Growth that focuses on improving transit ridership by creating a transit-oriented urban form. The next section goes into greater detail on TOD.

The efficacy of these policies varies by state. In some states, like Massachusetts, all zoning and property tax collection are in the hands of individual municipalities. This makes coordination more difficult. Each town wants to attract development, sometimes at the expense of the transportation and land use interests of the region as a whole. Some US cities do not even have a formal zoning system. On the other hand, in some states like Virginia and Maryland zoning and property tax collection are concentrated at the county level. This has made smart growth and transit-oriented development in metropolitan Washington, D.C. a lot easier to implement.

1.4 Transit-Oriented Development (TOD)

As mentioned above, TOD seeks to improve transit ridership by creating a transit-supportive urban form. The three traditional ingredients of TOD are density, diversity and design, also known as the 3 D's:

- Density – Land use densification around transit stations in order to concentrate people, residences and jobs near transit stations and thus encourage people to commute by transit.
- Diversity – Mixed land-use around transit stations in order to reduce trip chaining (or rather the use of the automobile in the daily trip chain) by providing a mix of residential and commercial uses near transit stations. This allows most commuters to do their shopping, go to the bank or post office, etc. near the station, instead of having to drive to all those places, and allows some of them to live near the station as well. This also creates a walkable community for people who live in the station area.
- Design – Urban design elements that are meant to make the station area friendlier and more accessible to pedestrians and bicyclists. This could include pedestrian bridges or tunnels where necessary, bicycle lanes near the stations, bicycle racks at the stations, traffic calming in residential neighborhoods near stations, parking restrictions, aesthetic improvements like lighting and street furniture.

TOD is usually designed around a heavy rail (e.g. Washington, D.C.), light rail (Portland) or commuter rail system (San Francisco Bay Area). However, as will be discussed in chapter 2, it can also be done with a bus rapid transit (BRT) system, as was done in Curitiba, Brazil.

TOD has several positive environmental effects. It reduces the need to use the automobile. Air pollution is thereby reduced through fewer trips and less congestion. TOD promotes more efficient use of land resources near transit stations, resulting in the conservation of open spaces elsewhere. The increase in walking and biking trips improves personal health.

TOD is good for equity, since it makes jobs more accessible for low-income people. It also reduces the transportation costs of low-income people and allows them to save more of their income or spend it on other needs.

1.5 Policies That Support TOD

There are several ways a government can support TOD:

- Economic incentives, such as tax breaks for people who build high-density mixed-use developments near transit. These can include an exemption from betterment taxes and other taxes associated with construction, or even a total exemption from all taxes for several years. Sometimes developers are allowed a higher floor-area ratio (i.e. the ratio of the total permitted floor area of a building to the size of the lot on which it is built). Occasionally the government will participate in the actual costs of development. That could be the case if the development site is polluted. In exchange for all that, developers agree to build their project to TOD specifications, including (in addition to its obvious location near a transit station) pedestrian amenities, a certain agreed upon mixture of uses, etc.
- Zoning is an important tool. There can be regulations mandating high densities and mixed land-uses, and regulations requiring developers who build near transit lines to provide convenient pedestrian access to the transit stations. Similarly, there could be regulations prohibiting people from building shopping malls anywhere other than areas served by transit.
- The government can make a TOD site attractive for the private sector by assembling parcels for private developers. This saves the developers time and money and eliminates a lot of bureaucratic red tape. The developers can start out with one large, unified parcel instead of having to negotiate with several different owners.¹⁰

¹⁰ Halcrow Fox (2000). Also TCRP (1997).

One recent innovation is the Location-Efficient Mortgage, or LEM. This program was developed by a non-profit organization called the Center for Neighborhood Technology, together with the National Resource Defense Council and the Surface Transportation Policy Project. It is currently available in Chicago, Los Angeles, the San Francisco Bay Area, and Seattle, and is supported by the EPA and by the Fannie Mae Foundation, which is underwriting a \$100 million LEM experiment market test.¹¹ The assumption behind this program is that people who live in neighborhoods that are walkable and have good transit access will have lower transportation expenses, and can thus afford to have a worse debt-to-income ratio (i.e. they can afford to have more debt). This enables people with less income to get mortgages, and enables other people to qualify for larger mortgages than they could otherwise.

TOD has the advantage of requiring little direct public investment, since most of the actual development expenditures are borne by the private sector, unless the government specifically agrees to participate in the development costs. Tax breaks and zoning regulations (but not parcel assembly) do not cost the government much if the private sector does not participate, so the government has little to lose by offering them. For the government, TOD is more of an institutional effort than a financial expenditure. The government guides the private sector and provides it with incentives. Politically, it is usually easier for politicians to grant tax breaks than it is to make direct infrastructure investments, especially during times when the public is concerned about government spending.

1.6 Conditions For the Success of TOD

Whether building a Metro, light rail, or bus rapid transit will attract TOD depends on several factors, including the state of the real estate market, government support and incentives, and the extent of the transit system.

¹¹ www.cnt.org ; www.locationefficiency.com

In addition to the three D's mentioned above (density, diversity and design), transit is effectively the fourth element of TOD. The transit system has to be extensive. A small Metro system will not be conducive to TOD unless it is well integrated with the rest of the transit system.¹² If people are to use transit, the entire trip has to be convenient for them. If the transit system does not take them where they want to go at a reasonable time, they will not use it, even if they live in a walkable community with a transit station in the middle. Furthermore, TOD has to be done across the transit system if it is to have a significant effect on the citywide modal split. Of course, individual projects that have positive localized effects are good, but planners should be aiming at a greater effect.

Government support is essential for TOD to succeed. Developers will build where it is the most profitable for them. The various incentives mentioned above are necessary to entice developers to build near transit. As was previously mentioned, different countries, and different states within the US, have different planning cultures, some of which support TOD and some of which hinder it.

The two most crucial factors are the state of the economy and specifically the real estate market. These two have boom and bust cycles, and are often unpredictable. One can build a perfect Metro system, the government can assemble parcels in the most lucrative areas served by the Metro and give tax breaks for developers, and still no TOD will happen, because the economy is bad or the real estate market is down.¹³ The housing and job markets have to be strong enough to attract developers' interest in large projects.

1.7 The TOD Controversy in the United States

TOD is a controversial topic in the United States. Critics claim that while transportation projects have affected land-use patterns in the past, this effect has diminished with suburbanization, and that land-use planning does not have a significant effect on people's transportation choices such as whether to buy an automobile and when to use it.

¹² Halcrow Fox (2000).

¹³ Ibid.; TCRP (1997)

One of the main arguments against TOD is that it conflicts with the suburban lifestyle preferred by most Americans. Workplaces are more likely to be clustered near transit (e.g. the Central Business District of a city), than residential areas. Critics argue that in order for TOD to work, the residential densities required to have any effect on automobile use would have to be higher than most Americans would be willing to tolerate, i.e. densities of more than five or six dwelling units per acre (and pronounced reductions in automobile ridership only at 12-15 dwelling units per acre) according to one study,¹⁴ and “7 to 12 units per acre and 50 or more employees per acre” within a half mile of a transit station according to another.¹⁵ Furthermore, they claim that many of the successes attributed to mixed-use planning are actually due to parking policy¹⁶, and traffic calming.¹⁷ Some critics claim that mixed-use neighborhoods, by clustering different land uses in one location, reduce the travel costs for all modes, including the automobile, and that the grid street pattern, favored by New Urbanists, is actually convenient for automobiles, unless traffic calming and parking restrictions are implemented.¹⁸

Randal O’Toole of Portland, Oregon is a critic of government regulation, in this case Portland’s urban growth boundary, and Smart Growth and TOD policies. He says that urban growth boundaries have increased land values and made single-family housing unaffordable, and that people have been coerced into living in higher densities than they would like. He also claims that developers are not interested in high-density development. On the transportation side he complains that traffic calming, parking restrictions and a policy of blocking new investments in road infrastructure in favor of public transportation all amount to harassment of automobile users. All these policies have not resulted in a significant increase in the mode share of transit. He says that

¹⁴ Don Pickrell, “Transportation and Land Use”, in Gómez-Ibáñez et al. (1999).

¹⁵ TCRP (1997). This study supports TOD.

¹⁶ Pickrell, in Gómez-Ibáñez et al. (1999).

¹⁷ Boarnet and Crane (2001).

¹⁸ Ibid.

people have moved across the Columbia River to Washington State to escape these policies.¹⁹

1.8 Does TOD work? Examples from the United States and Europe

In the United States, the effects of TOD, where it has occurred, have been limited mostly to the area around transit stations. TOD has had little effect on the overall modal split in US cities. In most metropolitan areas, including those in which TOD has been done, the mode share of the automobile is still far higher than that of transit. Most people already own cars and live in auto-oriented suburbs, and the automobile culture is entrenched.

Metropolitan Washington, DC offers some examples of successful TOD at the station-area level. In the surrounding states of Maryland and Virginia, zoning and property tax collection are done at the county level, and some of the counties around Washington, particularly Arlington County, Virginia and Montgomery County, Maryland, have shown an interest in developing the areas around Metro stations. In addition, the regional transit agency, WMATA, has aggressively pursued joint real estate development with the private sector near Metro stations.

Ballston, Virginia is a case in point. Arlington County government designated the area near Ballston Metro station as a coordinated mixed-use development district, permitted high-density construction within it, and allowed a near doubling of the floor-area ratio of commercial buildings there if they devoted more than half of their floor space to residential uses. WMATA owned some land near the station and entered a joint venture to build high-rise housing on it. The federal government had a policy of locating offices near Metro stations, and some new federal buildings were built near Ballston station. When developers were considering whether to build a large new shopping mall, Ballston Common, the county agreed to participate in the costs of a large parking lot for the mall, which could also serve as a park-and-ride for the Metro station. The mall was built, and created a positive climate for real estate development, which led to the construction of

¹⁹ O'Toole (2001).

many more commercial and residential developments in the station area. A suburb was thus transformed into a transit-oriented community with about 2,500 dwelling units and 3.7 million square feet of development. Ballston attracts affluent professionals, and rents are relatively high. A survey done in one of the apartment complexes there showed that 69% of those polled commuted by Metro, and of those who worked in DC, 88% chose the Metro.²⁰

Figure 1-1 and Figure 1-2 show Ballston before and after TOD.



Figure 1-1: Ballston, 1970

Source: Cervero (1997)

²⁰ Cervero (1997).

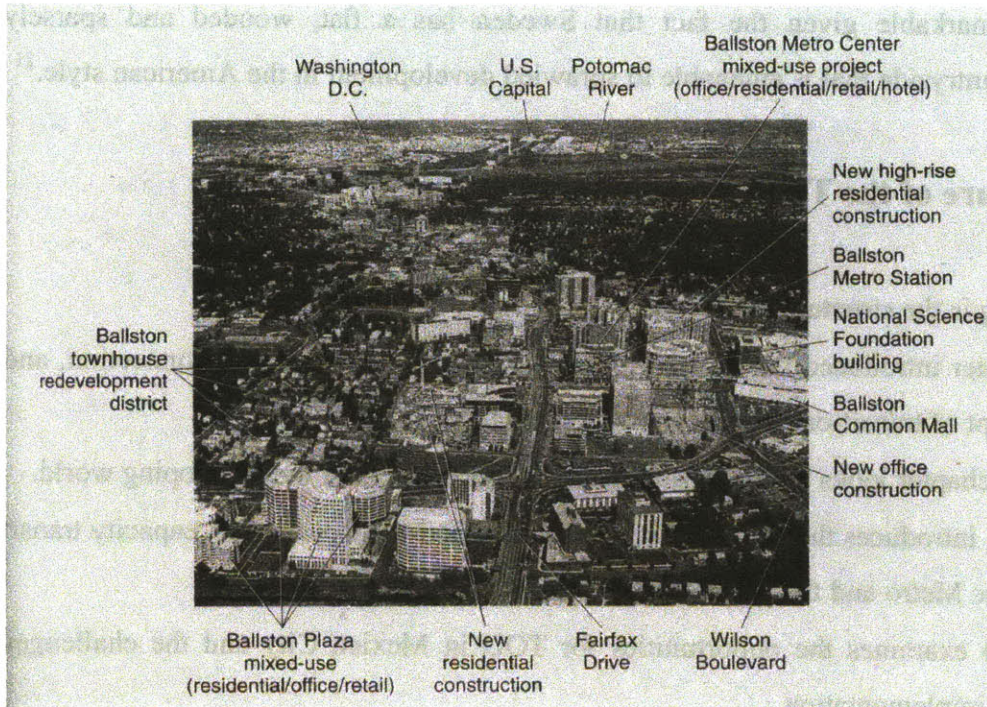


Figure 1-2: Ballston, 1995

Source: Cervero (1997)

In Europe, where the power of national governments is typically stronger, TOD has been pursued on a larger scale, of which Stockholm is perhaps the prime example. In the postwar era there was a shortage of housing in Stockholm. Planners developed a plan to build a series of new towns around commuter rail stations. The rail stations became the heart of these communities, and commercial land uses were concentrated around them. Residential densities are higher around the stations. The communities are pedestrian and bicycle-friendly. The new towns were not planned as dormitory cities. While many of their residents do commute to central Stockholm, the new towns also have concentrations of jobs that attract commuters from elsewhere in the metropolitan area. The result is that 30-40% of the residents of the new towns commute to work by transit, while more than 50% of the employees who commute to work in the new towns use transit. Walking and biking also have relatively high shares, especially among residents. This is despite the fact that Stockholm has one of Europe's highest auto ownership rates. Stockholm has managed to create an urban form that is polycentric but still transit-oriented. This is all

the more remarkable given the fact that Sweden has a flat, wooded and sparsely populated countryside that is amenable to sprawled development in the American style.²¹

1.9 Structure of the Thesis

The following is the structure of this thesis:

- This chapter introduced the transportation – land use – environment connection, and the concept of transit-oriented development (TOD).
- The next chapter looks at these issues from the perspective of the developing world.
- Chapter 3 introduces the Mexico City case study, and focuses on high capacity transit such as the Metro and the planned suburban rail system.
- Chapter 4 examines the opportunities for TOD in Mexico City and the challenges facing its implementation.
- Chapter 5 presents the conclusions of this study.

²¹ Cervero (1998).

Chapter 2: Transportation, Land Use and the Environment in the Developing World

This chapter focuses on conditions in the larger cities of the developing world, contrasts them with the developed world, and presents the case for transit-oriented development in the developing world.

2.1 Urban Land Use and the Problems of Planning in the Developing World

Nearly all of the world's fastest growing cities are located in the developing world, as are most of the world's megacities, or cities of more than 10 million people.

Cities in the developing world are generally characterized by higher densities than cities in the developed world, both in terms of dwelling units per given area and in terms of population per given area. This is despite the fact that high-rise buildings are rare in most developing countries. In the poorer neighborhoods, large families (family size in the developing world is usually larger than in the developed world) live in small houses packed tightly with few open spaces between the buildings.

The urban form of cities in the developing world is usually quite different from that of cities in the developed world. A lot of the growth of these cities is due to migration from the countryside. The migrants often settle on the outskirts of the cities in shantytowns that lack even the most basic infrastructure. In addition, the natural growth of the pre-existing population of the cities means that some poor people are forced out of the center and into the shantytowns due to the lack of affordable housing in the center. Over time, the shantytowns are often legalized and are incorporated into neighborhoods or separate towns as part of the metropolitan area, and infrastructure is slowly provided.

In general, though, cities in the developing world experience a lot less flight to the suburbs than cities in the developed world. To be sure, there is often a migration of middle and high-income people to the suburbs (often American-style suburbs, sometimes gated communities) due to concerns about crime and the availability of cheap land. However, middle and high-income people are still the minority of the population in most of the developing world. The result is a more densely populated and a more vibrant (and chaotic) central city with mixed land uses. These include residential uses (mostly low-income), small-scale commerce both formal (shops) and informal (street vendors), small-scale light industry (e.g. small textile or furniture factories), and government services.

Many cities have master plans and zoning codes, but their implementation is often poor. The cities are usually unable to prevent the establishment of illegal settlements (often referred to as “land invasions”) and are often unwilling to evict squatters. Powerful local and foreign economic interests often have their way in determining the location of new industries and big projects, sometimes at the expense of proper planning, and to the detriment of the environment and the population. The result is uncontrolled growth and sprawl of the cities.

Efforts to control transportation, land use and the environment in the developing world through government planning are hampered by poor institutional capacity. This can manifest itself in several ways:²²

- Lack of sufficient planning legislation and planning organizations.
- Inexperienced planners.
- Corruption.
- Too many posts filled by political appointees rather than career civil servants. This contributes to low institutional memory and too much political meddling in the planning process.
- Lack of resources to collect the extensive data needed to inform the planning process.
- Insufficient interdisciplinary cooperation between urban planners, transportation planners, economists and environmental experts.

²² More information on this issue can be found in Vasconcellos (2001).

- Little or no public participation or input in the planning process. In countries where most people are poor, all planning decisions are made by professionals who come from a middle class or upper class background, and are sometimes out of touch with the realities of life of the majority of the population.
- In metropolitan areas, particularly (but not only) those that stretch across several political jurisdictions, there is often a lack of coordinated metropolitan planning.

2.2 Urban Transportation in the Developing World

Unlike the developed world, the automobile does still not dominate travel in the developing world, although that is rapidly changing in many countries.

Most people still cannot afford to own a car, and auto mode shares are still lower than 50% (usually a lot lower) throughout the developing world.²³ Transit and non-motorized transportation (NMT) satisfy the population's transportation needs. NMT includes walking, biking, and human-powered public transportation (bicycle-taxis).

However, rising incomes and the prestige of the automobile are causing rapid motorization in developing countries, although it is still much lower than in the developed world. This is particularly evident in countries like China, where biking used to be the near-universal mode of transportation, but now the roads are becoming less and less friendly to bicyclists, and more and more freeways (illegal for bicyclists) are being built. According to Table 2-1, there is a large variation in motorization rates among different countries in the developing world, although Latin America is motorizing faster than other regions.

Road infrastructure is still poor in most of the cities of the developing world (not to mention the countryside). The percentage of city space devoted to roads is usually smaller than in the developed world, especially in Asian cities (Bangkok is notorious for having large neighborhoods, or "superblocks" with few internal roads), but also in Latin

²³ WBCSD (2001), p. 4-5, Figure 4-2.

America. Many countries cannot afford the massive infrastructure investments needed to support an increasing automobile fleet.

Upper Middle Income	Motorization (vehicles/thousand inhabitants)	Lower Income	Motorization (vehicles/thousand inhabitants)
Argentina	176	Egypt	30
Brazil	77	Honduras	37
Hungary	268	India	7
Libya	209	Indonesia	22
Malaysia	172	Kenya	14
Mexico	144	Mozambique	1
Averages	174		18.5

Table 2-1: Motorization rates in developing nations, 1998

Source: WBCSD (2001), p. 4-6, based on World Bank figures.

Transit exists in many forms, formal and informal, privately operated and publicly operated. Most large cities have extensive formal public transportation systems, operated either by the government or by one or more private operators. In some places, like Brazil, there are government subsidies that make public transportation more affordable to the population. Some of the larger cities have rail-based public transportation. Some cities, like Mexico City and São Paulo, have extensive subway systems. Bus Rapid Transit systems, pioneered in Curitiba, Brazil, exist today in Quito and Bogotá as well.

Informal transit fills in the gap left by formal transit systems, which are either not extensive enough or provide poor service. Low to medium-capacity vehicles, such as sedans, vans, converted jeeps (in the Philippines), and minibuses, which are owned by their drivers, offer flexible routes at high frequencies, albeit at a higher cost than formal transit. The owner-drivers make their living from their single vehicle. Informal transit is often the only public transportation that serves the shantytowns, particularly the more remote ones. Government regulation in different cities ranges from strict to nonexistent.

The fares on informal transit usually vary by distance. In the developed world this is not a problem, because most suburbanites are middle class or high-income, and those of them who use transit (e.g. commuter rail in New York) do so by choice and can afford the high fares. Many transit systems in the developed world use multiple fare zones to cross-subsidize some of their other routes and services. Unfortunately, in the developing world the poorest people live on the outskirts of the cities. For them, the variable fares of informal transit are regressive. Since the owner-drivers need to make a living from their single vehicle, and since the vehicles have relatively low capacity, the owner-drivers have no choice but to charge high fares to the outskirts of the cities in order to operate profitably. This is very bad for the poor, who have to spend a large proportion of their meager income on transportation, and also need to spend a large amount of time traveling. This diminishes their economic opportunities and perpetuates their poverty, marginalization, and socio-economic isolation.

2.3 The Environmental Problems of Cities in the Developing World

In general, environmental standards are lower in the developing world. In China, many houses are still heated by burning coal. Power stations and heavy industry are dirtier than in the developed world. Vehicles are usually older and more polluting. Motorcycles with two-stroke engines are still common in India and other developing countries. The use of unleaded gasoline is still not universal. The diesel used by buses and trucks usually contains high levels of sulfur, and the vehicles themselves are usually old. Inspection and maintenance standards for vehicles are lax. All this contributes to severe air pollution in many cities like Mexico City. In New Delhi, the Indian Supreme Court issued a ruling forcing the government to shut down polluting factories and vehicles to fight the severe pollution problem in that city.

Many large cities suffer from water shortages. Shantytowns, which often lack sewage systems, contribute to aquifer contamination. Poorly regulated factories also contribute to

water and soil pollution. The people hardest hit by air, water, and soil pollution are the poorest people, who often lack access to adequate health care.

2.4 Transit-Oriented Development in the Developing World

Against this background, this thesis presents the argument that TOD (as well as other forms of coordinated transportation and land use planning) is not only necessary in the developing world, but also has a lot more potential there than in the developed world, despite the fact that it is generally more difficult to implement than in the developed world due to institutional weakness.

The fact that the automobile does not yet have a dominant mode share in the developing world makes TOD more likely to succeed than in the developed world. In addition, the densities cited in the US as thresholds for TOD (7-12 or 12-15 dwelling units per acre) are considered normal, or even low, in most of the developing world. A single 4-story building, with 3 apartments on each floor, contains 12 dwelling units, and more than one such building can fit in one acre, particularly in the center of a city. Additionally, households in the developing world tend to be larger than those in the developed world, so each dwelling unit contains more people.

Many cities in the developing world are growing rapidly. In addition, a lot of their housing stock is of poor quality and will eventually have to be replaced. These are often considered to be serious problems. However, they also present a great opportunity. With proper planning and a certain amount of vision, cities in the developing world can design their evolving urban form to be transit-oriented. In the developed world this is much more difficult to do, because many cities are already built up and are not expanding much further. There, TOD is more applicable on a project-by-project basis than as a citywide policy. It is likely to create a few pleasant, livable communities in the metropolitan area, and provide some of their residents with an easy commute (like the Ballston example in chapter 1), but it is unlikely to have a major effect on the overall metropolitan modal split or on the travel habits of the metropolitan population. In the developing world, TOD can

have an effect on an entire metropolitan area if it is adapted as a policy while it is still growing.

This is not to say that TOD in the developing world will take place entirely on newly developed land. Infill development (developing underutilized urban land instead of developing previously non-urban land on the outskirts) is a large part of TOD no matter where in the world it is implemented. Here too, cities in the developing world present many opportunities. As mentioned previously, low-quality housing stock in existing low-income neighborhoods will have to be replaced eventually. Downtown development and densification is also a goal of TOD, because a relatively monocentric urban form is easier to serve with a dense network of high capacity transit. It will be necessary, however, to guarantee that new housing built in poor neighborhoods will remain affordable to the majority of the population, so as not to displace the poor.

High-capacity public transportation, which has a lower operating cost per seat and can charge lower fares, could be expanded to low-income outlying areas if nodes of high density (and almost guaranteed high ridership) could be established there.

While TOD will not prevent motorization, it could reduce its negative impacts, like sprawl, congestion and pollution. For example, by coordinating transportation and land use planning during the stage of rapid urban expansion and before mass motorization, cities can establish early control over the supply of parking spaces.

TOD is more equitable than building an extensive highway infrastructure to accommodate automobile users, because the vast majority of the population cannot afford a car and will not be able to afford one in the near future, and because highways are often built through poor neighborhoods, causing a disproportionately negative impact on those who cannot afford cars. In Bogotá, Colombia, the Peñalosa administration used this argument to justify investments in pedestrian roads, bicycle lanes, bus rapid transit

(instead of a more expensive Metro), and sidewalk construction (which eliminated many parking spaces).²⁴

In summary, coordinated transportation and land use planning in the developing world should aim to control sprawl by:

- Concentrating low-income people at nodes of high density and along corridors of high density that will justify investment in high-capacity transit that has lower costs per seat and can charge lower fares.
- Preserving the attractiveness and affordability of the city center and its immediate surroundings, which are easier to serve with a dense network of high-capacity transit, and preserving as much as possible their importance as the main travel destination in the metropolitan area.
- Making the best use of the land around transit stations by promoting high density, mixed use and improved pedestrian access in cities that already have high capacity transit systems.
- Providing as many people as possible with access to downtown via transit or walking without needing an intermodal transfer.
- More generally, making transit and walking attractive alternatives to driving, in the hope of slowing down motorization, and even attracting choice riders who already own cars but would prefer to commute by other modes and use their cars mainly for nonwork trips.

Institutionally, TOD is difficult to implement in the developing world because it requires a concerted interdisciplinary effort, coordination at the metropolitan level, and enforcement of TOD policies. The institutional weaknesses mentioned above make these things difficult. However, they are still possible if there is determined political leadership and a professional team of planners.

²⁴ Presentation by Enrique Peñalosa, former mayor of Bogotá, at the MIT Sustainable Mobility Conference, May 3, 2002.

It is primarily due to the institutional difficulties that there are very few examples of successful TOD in the developing world. As in the developed world, TOD requires government involvement in the form of zoning (rarely enforced effectively), financial incentives, and parcel assembly (critical in the developing world, where parcels are often very fragmented and land ownership is often unclear). As in the developed world, having a Metro system does not guarantee that TOD will happen. In Shanghai, the Metro went hand in hand with the new development in the Pudong area. In Guangzhou, development was expected near the Metro, but the real estate market collapsed and the development did not materialize, underscoring the importance of market forces. In São Paulo, the government built some public housing on land it owned near Metro stations.²⁵

As in the developed world, the high-capacity transit system has to be extensive and to reach enough people and destinations. However, most developing-world cities cannot afford an extensive rail-based transit system. In Bangkok, a large investment was made in a single rail line, the Skytrain, but ridership was lower than expected because the line did not cover enough of the city, and also because fares were expensive for most people (the line was privately constructed and run). Busways are a potential solution to that problem, providing that governments can establish sufficient control over the often-chaotic roadways. Curitiba and Bogotá are examples of successful busway systems.

2.5 Curitiba – TOD on a Citywide Scale

Curitiba, capital of Paraná state in southern Brazil, is a highly successful example of coordinated transportation and land use planning on a citywide level. It is so successful that even cities in the developed world seek to emulate its success. This city of 1.5 million people (2.3 million in the metropolitan area) has Brazil's second highest auto ownership rate, but a 75% transit mode share of commute trips, compared with 57% in Rio de Janeiro and 45% in São Paulo.²⁶ Between 1966 and 1996, its population almost

²⁵ Halcrow Fox (2000).

²⁶ Cervero (1998), p. 267.

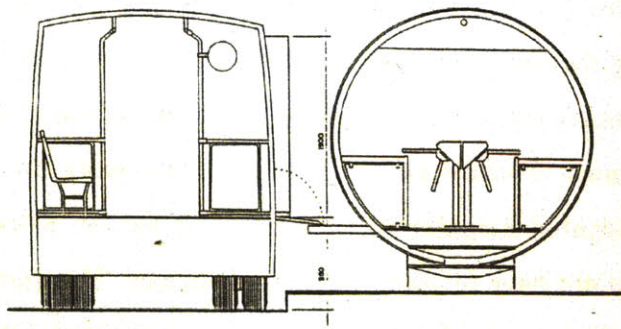
quadrupled from 400,000 to 1.5 million, but the city took advantage of this growth to design a transit-oriented urban form.

Much has been written about the bus system of Curitiba. It is one of the world's first Bus Rapid Transit (BRT) systems. It has bi-articulated buses (Figure 2-1), with a capacity of 270 passengers running along exclusive rights-of-way on avenues, radiating from the historic center, as well as smaller direct buses running on parallel streets and making fewer stops, interdistrict buses that follow circumferential routes at various distances from the historic center, and feeder buses feeding into this system. Tube-shaped stations (Figure 2-2, Figure 2-3) allow level boarding through all doors. The fare is paid at the station, and doors are extra-wide. Transfers are free, and are done at large transfer stations, that also offer commercial services. In effect, this creates a Metro system for the price of a bus system. The buses are run by private companies, which are heavily regulated by the city and are reimbursed by VKT. They all cover their costs out of the farebox. The fleet is very new.



Figure 2-1: A bi-articulated bus in Curitiba

Source: URBS



Source: URBS (1993)

Figure 2-2: Diagram of a tube station



Figure 2-3: A Tube Station

Source: Cervero (1995)

However, our main concern here is with Curitiba's contribution to TOD, namely the combination of strict zoning regulations with the BRT system. The system of coordinated transportation and land use planning is called the "trinary system" (Figure 2-4). The radial avenues along which the bi-articulated buses run are called "structural axes". The trinary system is based on dense land-use along the axes, with density gradually decreasing with distance from them. High-rises are concentrated along the axes, with retail-commercial uses on the ground and second floors, and residential and/or office space on the upper floors. One block away from the axes are eight-to-twelve-story residential buildings, and density keeps decreasing with distance because of the zoning ordinances in place.²⁷ The streets that run parallel to the axes are one-way and allow the movement into and out of downtown of cars and direct buses, which make fewer stops. Parking in downtown Curitiba is scarce. Off-street parking spaces are privately owned and expensive.

Construction bonuses in the form of additional floors are given to mixed-use development along the axes. Large-scale shopping centers are only permitted along the axes, thus concentrating trips along the axes and increasing bus ridership. People live, work and shop along the axes. The city blocked the construction of American-style

²⁷ *Ibid.*, pp. 273-274.

shopping malls on the periphery of the city. An industrial area was established on the outskirts of town. Only non-polluting factories can be built there. There are over 400 companies there, including Volvo, which produces the buses, some other automobile assembly plants, and hi-tech companies. Twenty percent of Curitiba's workforce is employed at the industrial area. Residential neighborhoods were built for the workers near the industrial city, so that they do not have to commute long distances. This further reduced congestion in the city. In addition, the historic center was converted into a pedestrian zone.

Out of concern for equity, the city built housing for 17,000 low-income people on land it owned along the structural axes.²⁸ Developers who were building within walking distance of the axes were allowed to add two extra floors if they contributed to a low-income housing fund.

All of this has created a linear city that is evolving along the structural axes.²⁹ The term "linear" refers to the fact that the city's growth was channeled along the lines of the axes, rather than allowing the downtown to spread amorphously in all directions. Visitors to Curitiba are often impressed when they see how visible the land-use policy is. One can see the highest buildings along the axes, and then somewhat lower buildings further away from the axes, then lower buildings, then even lower buildings, with density gradually tapering down. Figure 2-4 is not a simplified abstraction used to explain the principles behind the land-use system. Curitiba actually looks like that.

²⁸ Rabinovitch (1995), p. 8.

²⁹ Cervero (1998), pp. 282-286.

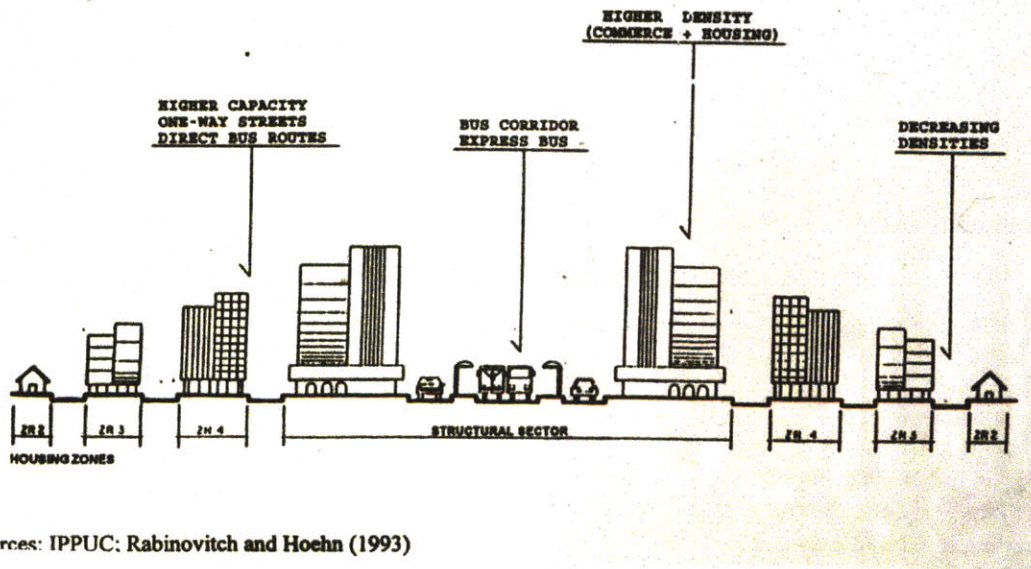


Figure 2-4: Cross-section of Curitiba's system of transportation and land use
 Source: Cervero (1995)



Figure 2-5: Curitiba's zoning system in practice
 Source: Cervero (1998)



Figure 2-6: A structural axis in Curitiba

Source: Cervero (1998)

All this was done during the twenty years, from the mid-seventies to the mid-nineties, when Curitiba was dominated by Jaime Lerner, who was mayor for three terms and ran the city's planning body, IPPUC, during the entire period, even under opposition mayors. He is currently governor of Paraná state. Lerner was trained as an architect, and his team included architects and planners. They had a vision for the city, and they implemented it. They were able to cut corners and take unorthodox steps, like converting a downtown street into a pedestrian mall literally overnight and then waiting to see what residents would think of it.

The attention Curitiba's planners gave to equity issues in the planning process is often lacking in other cities. Brasilia, the planned, auto-oriented capital of Brazil, illustrates the dire consequences of ignoring equity issues in the planning process. The planners of Brasilia did not build nearly enough housing for the working class, and the result is that

most low-income people have to commute to work in Brasilia by bus from remote satellite cities whose distance from Brasilia is between 15 and 60 km.

2.6 Is Curitiba Applicable Elsewhere?

No other city has tried to adapt the entire Curitiba strategy. Some critics have expressed skepticism about the possibility of adapting the Curitiba system to other cities. They ask whether the system is scalable, and whether it is applicable in cities that do not have a neat set of wide avenues radiating from a small center that can easily be turned into busways.

The BRT component has been copied in several places in recent years. Systems have been installed in Quito, Ecuador, in Los Angeles (the Metro Rapid system), and in Bogotá, Colombia (the Transmilenio system). Bogotá has 7 million people and has implemented a system of trunk lines and feeder lines. Daily ridership on the trunk lines of the system is about 600,000 passengers, not far from the best-performing lines of the Mexico City Metro.³⁰

The zoning regulations are a different issue. In Curitiba they were implemented while the city was growing, and before it could sprawl. They would probably not produce such dramatic effects if applied in a city that has already experienced sprawl. Curitiba's trinary system cannot be recreated elsewhere unless another city has a similar urban form. However, Curitiba's zoning regulations can be used to concentrate demand along corridors with high-capacity transit. The equity provisions are important, since they help keep the transit corridors affordable to low-income people while allowing the private sector to build more residential and retail space.

Another problem with the zoning regulations is that most of Curitiba's metropolitan population lives in the city, whereas in other metropolitan areas, a larger part of the population might live in other jurisdictions. With competing interests of different

³⁰ <http://www.transmilenio.gov.co:8080/transmilenio/Transmilenio.htm>

municipalities, it is doubtful whether zoning can be planned and enforced without a strong metropolitan government.

Another source of criticism of Curitiba, typically heard in Mexico, is Lerner's alleged "authoritarian" ways. Critics like to point out that Lerner was initially appointed by the military regime that ruled Brazil at the time, and that is how he was able to get his program implemented. However, the critics neglect to mention that he was subsequently reelected twice in democratic elections, and was later elected state governor. In addition, his plan was not implemented all at once. Rather, it was implemented over many years through trial and error, particularly the bus system.

The next chapter introduces the case study, Mexico City, paying particular attention to the Metro system as a possible backbone for TOD.

Chapter 3: Transportation, Land Use and the Environment in Mexico City

This chapter describes the transportation, land use and environmental situation in Mexico City, with a particular emphasis on the Metro system and other high capacity modes, which can serve as a backbone for a transit-oriented urban form.

3.1 Introduction to Mexico City

Mexico City, the capital of Mexico, is one of the world's largest cities. It is situated in a valley at an altitude of 2,200 meters amidst the volcanic mountains of central Mexico.

The size of the Mexico City Metropolitan Area (MCMA) is 5,294.42 km², of which 1,483.23 km² are in the Federal District (Distrito Federal – DF), and 3,811.19 km² are in the surrounding State of Mexico (Estado de Mexico – EM). In 1995, the population of the MCMA was 16,920,332, of which 8,489,007 lived in the DF, and 8,431,325 in the EM. The MCMA houses about 10% of the population of Mexico.³¹

Administratively, the MCMA includes the 16 *delegaciones* (boroughs) of the DF, 28 *municipios* (towns, municipalities) in the EM, and 1 municipio in the State of Hidalgo. These represent the contiguously urbanized metropolitan area. A larger area, the Metropolitan Zone of the Valley of Mexico (ZMVM) includes 26 additional municipios in the EM. An even larger region, called the Megalopolis, comprises all or parts of the following neighboring states: Mexico, Hidalgo, Morelos, Tlaxcala, Puebla, and Querétaro. Their capitals, respectively, are Toluca, Pachuca, Cuernavaca, Tlaxcala, Puebla, and Querétaro, and they are known as the *corona*, or “crown” of cities surrounding Mexico City. Several of these cities, particularly Puebla, are large metropolises in their own right.

³¹ Garza (2000), p. 243.

Figure 3-1 and Figure 3-2 show the ZMVM and the megalopolis.

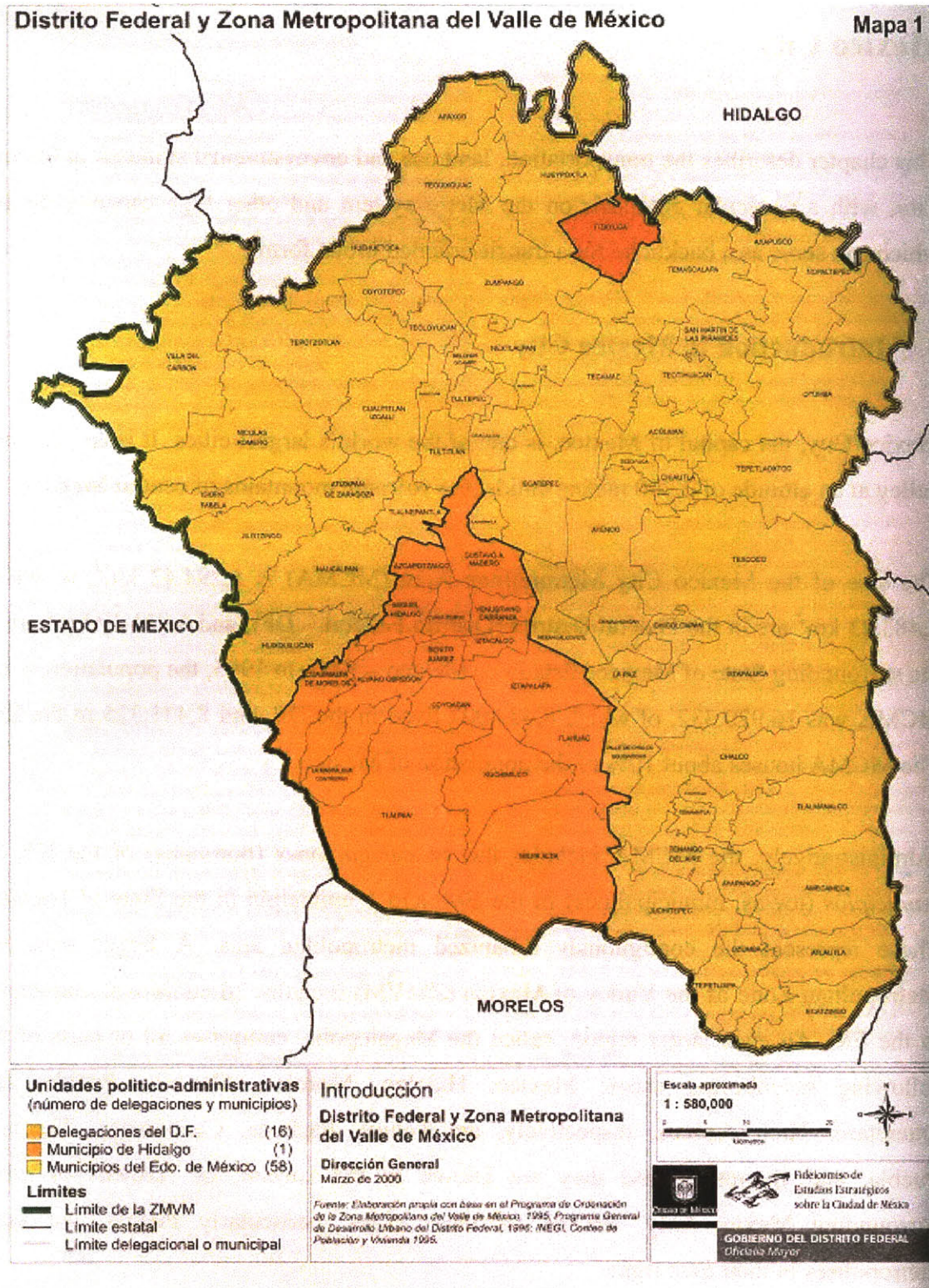


Figure 3-1: The ZMVM

Source: GDF (2000)

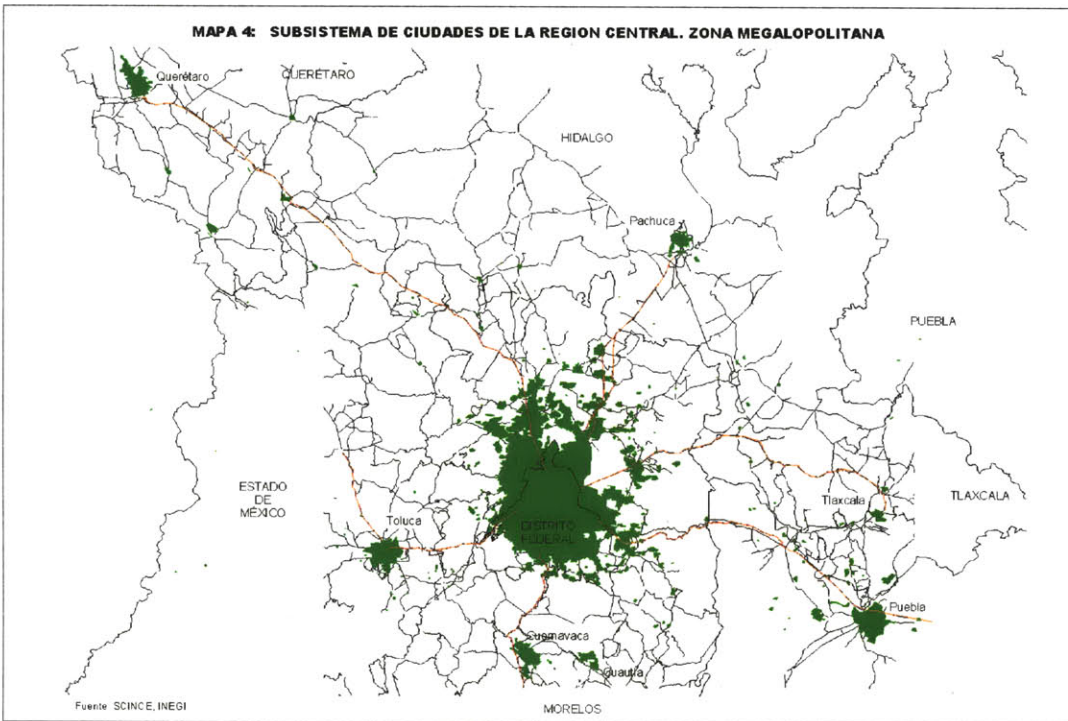


Figure 3-2: The Megalopolis and “Corona”

Source: Colegio de México

Between 1928 and 1997, the mayors of Mexico City were appointed directly by the president of Mexico, and often served one six-year term concurrent with that of the president who appointed them. The DF administration was considered a department of the federal government, and was called the *Departamento del Distrito Federal* (DDF). Thus there was a strong link between national and municipal politics in Mexico City. This was particularly evident during the dispute over the construction of the Metro, which will be discussed later.

In 1997, the all-powerful Institutional Revolution Party (Partido Revolucionario Institucional – PRI), which had ruled Mexico since 1929, was losing its grip on power amid public discontent with its corrupt ways. The constitution was changed so that the

DF was detached from the federal government and became, in effect, a state. In the first democratic mayoral elections, which were held that year, the left wing Party of Democratic Revolution (Partido de la Revolución Democrática – PRD) won control over the city, and is still in charge at present (2002). The 2000 general elections were won by Mexico’s third major party, the right wing National Action Party (Partido Acción Nacional – PAN). At present, the EM is still ruled by the PRI.

3.2 Land-Use Patterns in Mexico City and Their Evolution

Mexico City is densely populated, despite the relative lack of the high rise buildings that people in the developed world often associate with high densities. There is little variation in density between the DF and the urbanized EM. The average density in the DF is 11,953 people/km², while the average density in the urbanized EM is 11,239 people/km². The average density of the MCMA is 11,587 people/km².³² The highest density in the MCMA is in the low-income eastern EM suburb of Nezahualcóyotl, which has a population of 1,233,868 people and a density of 18,887 people/km². The highest density in the DF is in the central *delegación* of Gustavo A. Madero, which has a population of 1,256,913 people and a density of 18,280 people/km².

Table 3-1 compares densities of several cities and metropolitan areas around the world and highlights the peculiarity of Mexico City’s uniformly distributed density. However, one should exercise caution when comparing these figures, because methods of calculating density can vary. In Mexico City, for example, densities were calculated by dividing population by urbanized area (including urban parks), whereas some other cities may have simply divided population by total area. In some cities, like New York, this does not make a big difference, because the five boroughs are mostly built-up. However, in the MCMA only 27.58% of the area is urbanized, and even in the DF only 47.88% of the land is urbanized (the rest is mountains and a ‘protected ecological zone’). Thus, if

³² *Ibid.*

we use total area, the density of the DF is 5,723 people/km², as opposed to 11,953 people/km² when only the urbanized area is taken into account.³³

City / Metropolitan Area	Area (km ²)	Population	Density (people/km ²)
MCMA (total area)	5,294.42	16,920,332	3,196
MCMA (urbanized area)	1,460.34	16,920,332	11,587
New York City	776.47*	8,008,278	10,313
- Manhattan	58.77*	1,537,195	26,156
- Brooklyn	180.76*	2,465,326	13,638
- Metropolitan Area (NY, NJ, PA, CT)	26,751.64*	21,199,865	792
Los Angeles City	1,200.82*	3,694,820	3,077
Seoul	605.52	10,373,234	17,131
Tokyo (23-ku area)	621	~ 8,130,000	13,084
- Tokyo Prefecture	2,187	~ 12,059,000	5,515
Bangkok	1,568.7	6,320,174	4,029
Greater London	1,699	6,967,400	4,101
- Inner London	306	2,434,400	7,955
São Paulo	1,509	10,405,867	6,896
- Metropolitan Area	8,051	17,834,664	2,215

Table 3-1: Comparison of densities around the world

Sources: Garza (2000), www.census.gov (for US cities), english.metro.seoul.kr (for Seoul), www.chijihonbu.metro.tokyo.jp/cityprofile/index.html (for Tokyo), www.nso.go.th (for Bangkok), www.eb.com (for London), http://www.prefeitura.sp.gov.br/guia_de_informacoes/sp_em_numeros/sp_em_numeros.a_sp (for São Paulo).

* For American cities, the census provides land area, water area, and total area. Densities were calculated both here and in the census based on land area.

³³ *Ibid.*

As seen in Table 3-2, density has remained constant and has even decreased during the twentieth century, since both population and area increased at about the same rate.

Year	Urbanized Area (Square Kilometers)	Total Population	Density (People/Km²)
1900	27.14	344,721	12,700
1950	229.89	2,952,199	12,800
1960	470.70	5,125,447	10,900
1970	682.60	8,623,157	12,600
1980	1,079.73	12,994,450	12,000
1990	1,305.49	15,274,256	11,700
1995	1,460.34	16,920,332	11,600
2000	1,547.10	17,946,313	11,600

Table 3-2: Population density in the MCMA over time

Source: Garza (2000), p. 242.

Most of the growth of the MCMA has occurred since the 1940s due to natural growth and migration from the countryside. Figure 3-3 shows the territorial growth of the MCMA over time.

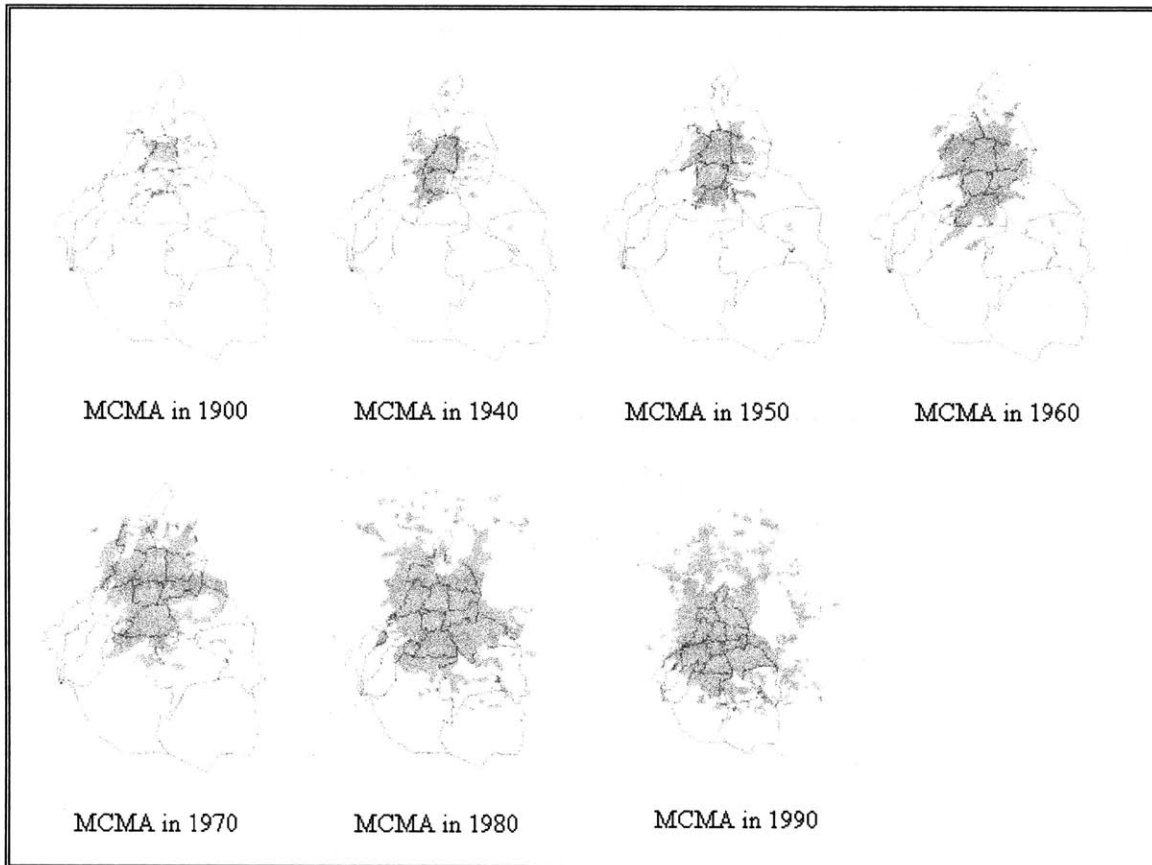


Figure 3-3: Growth of the MCMA during the 20th century

Source: Lemus (1998)

As shown in Figure 3-4, industry is concentrated in the north, particularly in the EM. About 3 million people live in the low-income suburbs of the semiarid eastern EM, whereas many of the more affluent people live in the mountainous west. Even there, though, there are many poor people. The poor are spread out throughout the MCMA, whereas the middle and upper classes live in specific areas. The southern part of the DF is relatively sparsely populated, and is officially a protected ecological zone, although there are some informal settlements there. Heavy industry has been slowly leaving the MCMA, while the importance of the service sector has grown. Land in the industrial areas is often underutilized, while the service sector has located primarily in the parts of the downtown that are west of the historical center, and in the western and southwestern DF.

In the 1950s and 1960s, DF mayor Ernesto Uruchurtu opposed migration from the countryside, fearing that it would ruin the character of the city and overwhelm its resources. He even evicted squatters forcibly on several occasions. He was also opposed to big industry. This helps to explain why so many migrants and industry ended up in the EM. Uruchurtu and his policies will be covered in greater detail in the history of transportation section below.

Some of the urban growth of the urbanized EM has occurred in the form of American-style suburbanization, with middle and high-income people leaving the central city for the real and perceived safety and comfort of the suburbs. However, most urban growth in the EM started out as informal squatter settlements that were established through what is called “land invasions” by poor migrants from the countryside, or by local inhabitants who could not afford to buy or rent a house. In the beginning, these settlements lack any kind of infrastructure save electricity, which the inhabitants illegally “borrow” from the main grid. The few roads that exist are often unpaved. Many of the informal settlements are located in areas prone to flooding, leading to much loss of life and property when floods strike. Slowly a process of legalization begins. Water and sewerage are gradually provided to many of the inhabitants, and the settlements are incorporated into towns. Roads get paved, thereby eliminating a source of PM. This is how many of the current EM suburbs were formed, and this process is still continuing on the fringes of the MCMA. In the past, the provision of infrastructure was sometimes linked to politics and vote buying.

The 1985 earthquake, which damaged primarily the historical center, accelerated the depopulation of the downtown area, as people left the four central delegaciones, particularly Benito Juárez, and moved to the EM or other parts of the DF. The fastest-growing areas nowadays are on the metropolitan fringe in the northern and eastern EM and southern DF.³⁴

³⁴ Ibid., and GDF (2000).

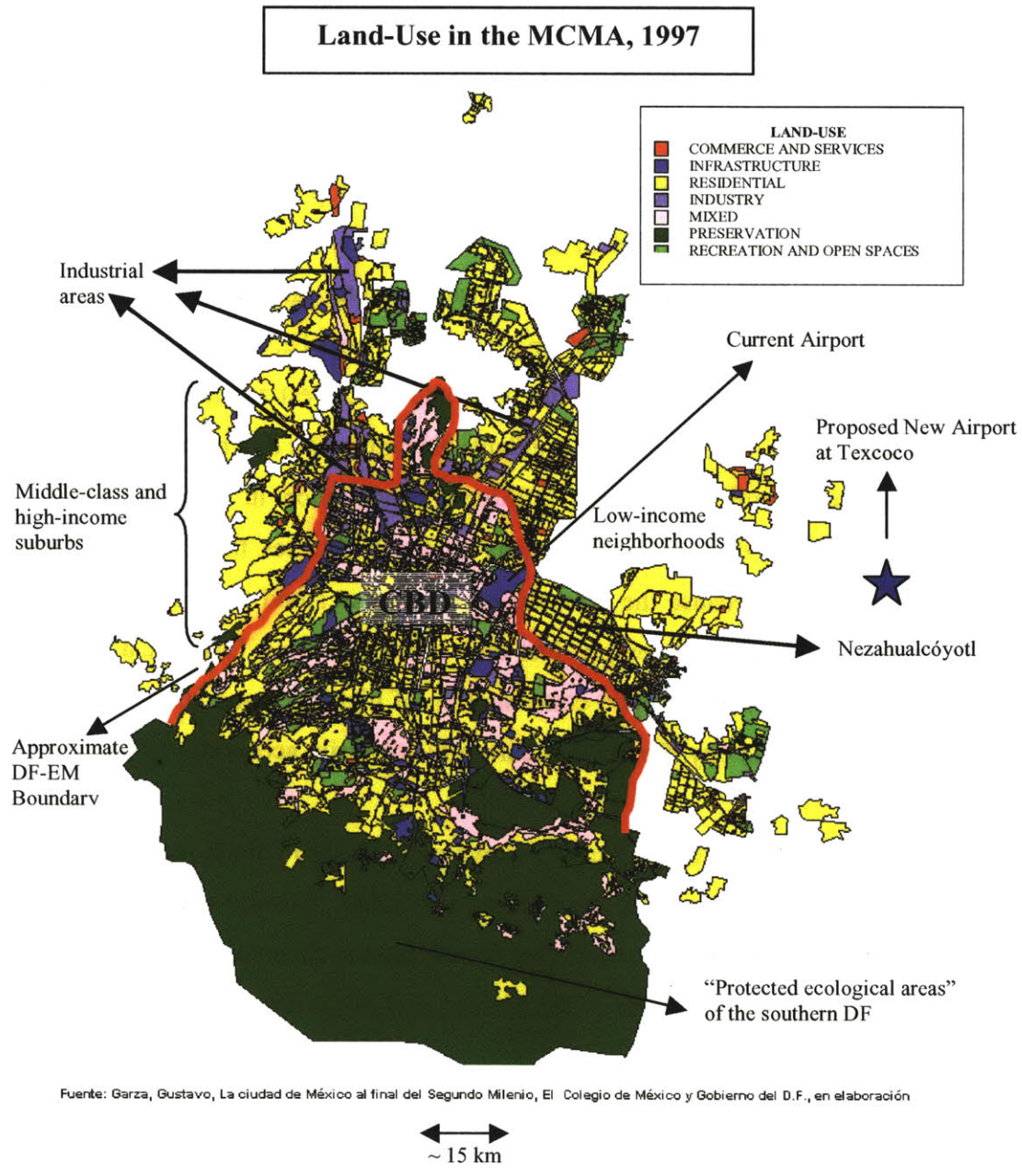


Figure 3-4: Land-Use in the MCMA, 1997
 Source: Garza (2000)

Despite its high density, Mexico City is still primarily a low-rise city. This is due to several reasons. The first reason is geological: large parts of the center and east of the city are built over a dry lake bed. In addition, the area is seismically active. This makes tall buildings more expensive to build. The second reason is that there was little demand for high-rise buildings until recently. A weak economy and the availability of land in the EM discouraged such investments. The downtown did not develop as densely as some of the proponents of the Metro had hoped in the 1960s. Most office development occurred either along Reforma Avenue, just west of the historic center (and thus west of the heart of the Metro system), or in the southwest (in places like Santa Fe, on the road to Toluca). Suburban shopping malls were built in the west and southwest to cater to middle and high-income people (e.g. Perisur mall or the Santa Fe mall). The downtown retained a lot of old colonial architecture. There was little new construction in the downtown area before the devastating 1985 earthquake. Many of the high rises that were built there recently were built only because the previous buildings that stood there collapsed in the 1985 earthquake. One still sees empty lots and surface parking lots just a block off Reforma Avenue, which has the main concentration of high-rises and some of the most expensive real estate in the city. Reforma is currently not easily accessible by the Metro.

Despite the sprawl, and despite the fact that downtown Mexico City is not as developed as it could be, it still attracts most of the trips in the MCMA, because many people work there and because there are services there that do not exist in the poorer EM. It is still the commercial and administrative center of the MCMA and of the entire country.

In the longer term, the focus of development will shift more and more towards the EM. The EM government has an ambitious transportation infrastructure plan, which includes interstate roads linking the Atlantic and Pacific coasts of Mexico through the EM just north of the DF, as well as ring roads bypassing the DF. In addition, the federal government has decided that the new airport will be located in Texcoco, in the

northeastern EM suburbs.³⁵ This will undoubtedly have a profound effect on the urban form of the MCMA. Similar to what happened in the United States in the 1960s, firms may choose to relocate near the new roads, where land is cheaper and where it is easier to ship products to the rest of the country. The airport will also create industrial activity around it. This may greatly accelerate the process of decentralization in the MCMA, and lead to the evolution of a more polycentric urban form. This, in turn, will accelerate motorization.

3.3 A Brief History of Transportation and Urban Form in Mexico City in Recent Times

Since the 1940s Mexico City has undergone a process of rapid urbanization, which greatly increased its population and its built-up area, strained its resources and its transportation system, and turned it into the megalopolis that it is today. Mexico City's mayor from 1952 to 1966 was the charismatic Ernesto Uruchurtu, the only mayor of Mexico City in the 20th century who served more than one full six-year term in office.³⁶ Uruchurtu was very popular because he was able to resolve the city's financial crisis and balance its budget. A nationalist, he nationalized the foreign-owned trolley company (Compañía de Tranvías) that had been providing Mexico City with its first modern transit system since the turn of the century. He also restructured the bus service in the city in a way that improved level of service for the users, kept the bus fares low, and gave considerable political power to his allies at the Alianza de Camioneros, a powerful organization of bus operators.³⁷

Uruchurtu was concerned about the changing character of the city. Most of his political support came from the middle and lower middle classes, i.e. small industry, small commerce, and artisans, who all supported the status quo and felt threatened by the

³⁵ Presentation by Francisco Covarrubias from the EM government at the Fifth Workshop on Mexico Air Quality, January 21-24, 2002, Ixtapan de la Sal, EM, organized by the MIT Integrated Program on Urban, Regional and Global Air Pollution.

³⁶ Typically, the mayors, who were appointed by the president since 1928, served until the end of the term of the president who appointed them. Uruchurtu served under three different presidents.

³⁷ Davis (1994), pp. 137-173.

growing population of poor migrants and the rise of big industry. They objected to massive development and densification of the downtown, because they feared that rising land values would drive them out. Uruchurtu was their champion. He resented the migration from the countryside that brought hundreds of thousands of poor, uneducated people into the city, and fought against squatter settlements in the DF, thereby pushing some of the poor migrants into the EM. He objected to the construction of new industry in the DF, which would have competed with the businesses of his core political supporters. This is one of the reasons that nowadays much of the industry in the MCMA is located in the EM, north of the DF boundary. Middle class anxiety about changes in the urban character of the city was so great that two different plans drafted in the 1950s for widening the avenues to better accommodate traffic encountered fierce opposition and were abandoned. Conservationists also objected. Uruchurtu could not get either plan through, even though the second plan was very modest, and involved only two avenues.³⁸

The idea of building a Metro system in Mexico City first came up in 1952, but was abandoned as unfeasible. In 1958, ICA (Ingenieros Civiles Asociados – Associated Civil Engineers), a professionally and politically powerful engineering firm that built many of Mexico’s public buildings during that era, presented a new plan for a Metro system, which it deemed feasible. The plan, which slowly gained supporters over time, caused much controversy and can be seen as a battle over the character of Mexico City. The Metro was supported by ICA, land developers, large commerce and industry, and the rising banking and tourism sectors, which all had an interest in developing and densifying the downtown area, and in expanding the city outward. ICA, for example, was not just an engineering firm. It also dealt in real estate, and had an interest in raising land values, as did the financial sector. The traditional middle and lower middle classes naturally opposed the Metro project, fearing that it would destroy the city they knew and that rising land values would force them out of the center. The big bus operators in the Alianza de Camioneros profited from running short high-ridership routes through downtown and feared competition. In contrast, the smaller bus operators welcomed the Metro as an opportunity to provide feeder service.

³⁸ Ibid.

As for Uruchurtu, he objected for several reasons. First, he was concerned about costs, having barely managed to balance the budget of Mexico City. He did not want to get the city into debt. Second, he was concerned about the character of the city, and worried that the Metro would cause explosive growth. Third, he did not want to lose his middle and lower middle class base of political support.³⁹

Gustavo Díaz-Ordaz, who became president of Mexico in 1964, was a strong supporter of the Metro. Díaz-Ordaz had connections with ICA and with large industry and commerce, and also had a political stake in the success of the Mexico City Olympics of 1968. The Metro was a good project for an Olympic city to show off to the world. Conflict soon broke out between him and Uruchurtu. When bus drivers went on strike in 1965 to protest low wages and the bad labor practices of the Alianza, their strike was uncharacteristically tolerated by the federal government, and got support from PRI-affiliated unions. Uruchurtu and the Alianza refused to budge, and the strike went on for a long time, causing chaos in the transportation system, and eroding public support for the once-popular Uruchurtu. In September 1966 Uruchurtu was forced to resign, and President Díaz-Ordaz appointed one of his allies, Alfonso Corona del Rosal as mayor. The new mayor quickly pledged his support for the Metro. The STC (Servicio de Transporte Colectivo) was created to run the Metro system. Construction began in 1967 with French technical and financial assistance, and the first stretch of line 1 opened in 1969.⁴⁰ By the end of 1970, three lines were in operation, with a combined length of 40 kilometers. Construction was mostly cut-and-cover, and proceeded at the rapid pace of one kilometer a month.

The Metro facilitated the expansion of Mexico City, since it made the center of town more accessible from the periphery. However, the anticipated development and densification of downtown Mexico City did not occur. The Metro system went through the historical center, but the central business district evolved further west, along the

³⁹ Ibid.

⁴⁰ Ibid.

Reforma axis, where the Metro did not go. The Metro was used mostly by low-income people coming into the center of town from the outskirts. Operation and maintenance costs of a world-class Metro system, while typical for a system of this type, were very high for a relatively poor developing-world city. The system deteriorated. Middle class people avoided it. The system was considered wasteful and construction of further lines was halted between 1970 and 1977. In the late 1970s the country experienced an economic boom due to increased oil revenues resulting from the oil crisis. Under pressure from pro-growth forces, construction started again on a massive grid of lines. However, the boom ended by the early 1980s, the federal government, which paid for the construction, ran into heavy debt, and construction was halted in the early 1980s before the grid could be completed. This is one of the reasons for the low ridership of some lines. Construction of Metro vehicles was “Mexicanized”, i.e. it was moved from France to Mexico. However, French technical assistance was still necessary, and many components still had to be imported. Some claim that it would have been cheaper to import the vehicles than to manufacture them in Mexico.⁴¹

The 1985 earthquake, which devastated the historic center of the city, left the Metro largely unscathed. The tunnels survived the tremor despite the poor soil, and the trains were back in operation within four hours.⁴² This improved the prestige of the Metro and ICA.⁴³

In the 1970s, the city was expanding. Once Uruchurtu was forced to resign because of his opposition to the Metro, the government implemented a plan to build “road axes”, or *eyes viales*. Basically, the government demolished many buildings to widen the main thoroughfares and create a series of east-west and north-south arteries. The expropriation of property and the demolition of buildings created a lot of anger and resentment among the population of affected areas. This project did, however, improve the traffic situation, at least in the short run.

⁴¹ Ibid., p. 229.

⁴² Interview at the STC, January 24, 2002.

⁴³ Diane Davis at a talk at MIT, March 2002.

Mexico City used to have an excellent bus system, which gradually replaced the trolleys. However, during the economic crisis of the 1980s, the neo-liberal government disinvested in public transportation, and gave licenses to operators of colectivos, a form of jitney service or informal transit. The colectivos had higher fares, but had higher frequencies, and more flexible routes and stops than the buses. With their superior level of service, they quickly destroyed the bus system, as illustrated dramatically in Figure 3-5. Meanwhile, the bus company, Ruta-100, which was badly managed, went bankrupt. Recently, the city formed a new bus company called RTP (Public Transportation Network).

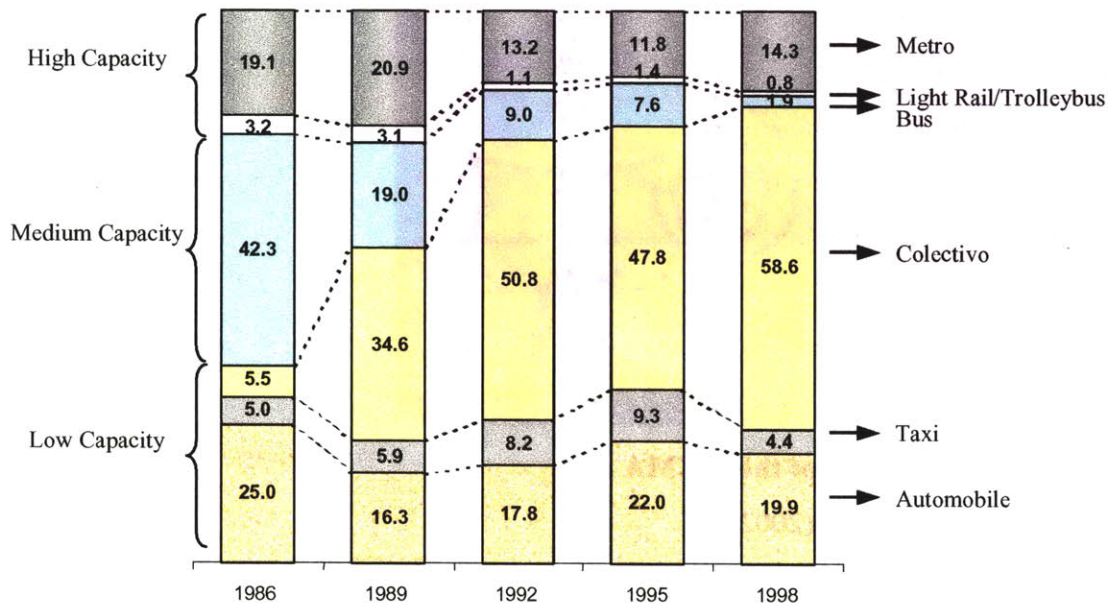


Figure 3-5: The evolution of mode share in the DF, 1986-1998

Source: SETRAVI (1999), quoting: 1986, CGT y COVITUR, DDF; 1989 - 1998 Poder Ejecutivo Federal, 3er Informe de Gobierno.

3.4 The Environmental Problems of Mexico City

Mexico City’s altitude, location and land use patterns combine to create a severe air pollution problem. As previously mentioned, Mexico City is situated at an altitude of 2,200 meters above sea level. At high altitudes, fuel combustion is less efficient, resulting in more air pollution. Mexico City is located in a bowl, surrounded by high mountains

from three directions, trapping the pollution inside the valley. Unfortunately, the fourth side (north of downtown) is where the heavy industry is located, further exacerbating an already bad situation. Figure 3-6 illustrates the topographical constraints in the MCMA.

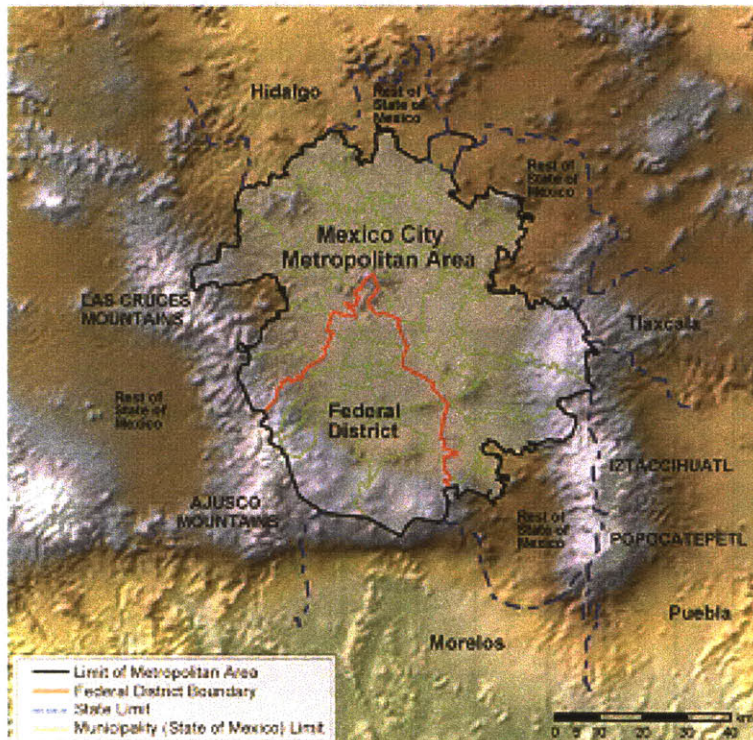


Figure 3-6: Topography of the MCMA

Source: Molina & Molina (2002)

As can be seen from Table 3-3, transportation contributes 81% of Mexico City's NO_x, an ozone precursor, as well as 98% of CO, 21% of SO₂, 36% of PM₁₀, and 40% of HC. Transportation also contributes 40% of VOCs in the MCMA, but it is now believed that the ozone in Mexico City is formed primarily by NO_x,⁴⁴ as opposed to cities like Los Angeles, where VOCs are mostly responsible for the formation of ozone. Ozone pollution is felt most severely in the mountainous western part of the MCMA, whereas PM₁₀ pollution is usually concentrated in the arid east, where dry lake beds generate a lot of dust.

⁴⁴ Molina & Molina (2002), p. 252.

Vehicle Type	NO _x	CO	SO ₂	PM ₁₀	HC
Private autos	23.0	46.5	8.9	3.5	17.2
Taxis	5.4	7.4	2.5	1.0	3.2
Combis (colectivos)	0.5	1.2	0.1	0.1	0.4
Microbuses (colectivos)	4.6	12.3	0.7	0.3	4.2
Pick up	9.2	14.4	2.3	0.9	5.2
Heavy-duty gasoline trucks	7.4	12.3	1.1	0.4	3.9
Diesel vehicles < 3 tonnes	0.1	0.0	0.1	0.7	0.0
Diesel tractor trailers	11.0	0.9	1.6	10.0	1.6
Diesel buses	5.7	0.5	1.0	5.9	0.8
Diesel vehicles > 3 tonnes	13.4	1.2	2.1	12.9	1.9
Heavy-duty LPG trucks	0.1	0.0	0.1	0.1	0.0
Motorcycles	0.1	1.3	0.3	0.1	1.0
Total Mobile Sources	80.5	98.0	20.8	35.9	39.5

Table 3-3: Transport contribution to total 1998 emissions in the MCMA (in percent)

Source: Molina & Molina (2002), p. 253, based on CAM (2001)

PM₁₀ comes primarily from diesel vehicles like buses and trucks, whereas NO_x and CO come primarily from gasoline-powered vehicles, such as automobiles, taxis and colectivos.

Table 3-4 shows the emissions inventory of each vehicle category. As Table 3-5 illustrates, on a per-vehicle basis it is clear that diesel trucks and colectivos contribute a disproportionately large share of emissions, and that the automobile is a lot cleaner. However, as Table 3-4 shows, automobiles lead in absolute emissions per mode because of their sheer number. It is also useful to remember that currently the mode share of the automobile is only in the twenties. The implications of rapid motorization on pollution cannot be overstated. In addition, poor road infrastructure means that cars will spend more and more time in traffic jams, and idle engines burn fuel less efficiently.

Vehicle Type	Number of Vehicles	NOx	CO	SO ₂	PM ₁₀	HC
Private autos	2,341,731	47,380	822,477	2,000	701	81,705
Taxis	109,407	11,093	131,453	567	199	15,310
Combis (colectivos)	5,499	930	20,448	28	10	1,945
Microbuses (colectivos)	32,029	9,524	216,740	166	59	19,761
Pick up	336,080	18,961	255,503	522	183	24,599
Heavy-duty gasoline trucks	154,513	15,297	216,865	240	84	18,683
Diesel vehicles < 3 tonnes	4,733	150	249	24	133	168
Diesel tractor trailers	70,676	22,678	16,675	363	1,990	7,587
Diesel buses	12,505	11,640	9,270	214	1,174	3,853
Diesel vehicles > 3 tonnes	90,940	27,662	20,956	468	2,562	9,205
Heavy-duty LPG trucks	30,102	308	298	15	16	215
Motorcycles	72,704	215	22,729	63	22	4,742
Total Mobile Sources	3,260,919	165,838	1,733,663	4,670	7,133	187,773

Table 3-4: 1998 Emissions inventory from mobile sources in the MCMA (metric tons/year)

Source: Molina & Molina (2002), p. 254, based on CAM (2001)

Vehicle Type	Number of Vehicles	NOx	CO	SO ₂	PM ₁₀	HC
Private autos	2,341,731	20,233	351,226	854	299	34,891
Taxis	109,407	101,392	1,201,504	5,182	1,819	139,936
Combis (colectivos)	5,499	169,122	3,718,494	5,092	1,819	353,701
Microbuses (colectivos)	32,029	297,356	6,766,992	5,183	1,842	616,972
Pick up	336,080	56,418	760,245	1,553	545	73,194
Heavy-duty gasoline trucks	154,513	99,001	1,403,539	1,553	544	120,915
Diesel vehicles < 3 tonnes	4,733	31,692	52,609	5,071	28,101	35,495
Diesel tractor trailers	70,676	320,873	235,936	5,136	28,157	107,349
Diesel buses	12,505	930,828	741,303	17,113	93,882	308,117
Diesel vehicles > 3 tonnes	90,940	304,179	230,438	5,146	28,172	101,221
Heavy-duty LPG trucks	30,102	10,232	9,900	498	532	7,142
Motorcycles	72,704	2,957	312,624	867	303	65,223
Total Mobile Sources	3,260,919	50,856	531,649	1,432	2,187	57,583

Table 3-5: Emissions per vehicle in grams/year/vehicle

Source: Based on Molina & Molina (2002)

Missing here are emissions from the Metro system. The Metro is electrically powered, so its emissions are part of emissions from power stations. However, only part of Mexico City's electricity is produced in plants within the valley of Mexico, so it is difficult to know which part of the Metro's emissions contributes directly to air pollution in the MCMA.

Mexico City uses an index called IMECA (Metropolitan Air Quality Index) to measure the overall air pollution and the level of risk to the population. A level above 200 is considered dangerous, and a smog alert is issued to the public. During smog alerts the use of cars is curtailed, some industrial activities cease, and sometimes people are asked to stay at home.

Another environmental problem is the scarcity of water, particularly in the poorer eastern side of the valley, which is arid. Illegal settlements, which lack basic sanitation, contribute to this problem through the contamination of underground aquifers with untreated waste.

3.5 The Automobile

The automobile is increasing its presence in the MCMA. As noted above, it is not very dirty on a per-vehicle basis. The problem is that the number of automobiles is overwhelming. This problem is only likely to worsen in the future. In Mexico the automobile is an important status symbol. Most households with a combined monthly household income of more than 5-10 minimum salaries (the minimum salary in Mexico is about 4 USD per day) own a car.⁴⁵ People at this level of income are still a minority (36% of all households in the MCMA),⁴⁶ but they are a growing one.

⁴⁵ INEGI, 1994 Origin-Destination Survey, Table 28.

⁴⁶ *Ibid.*

Parking in Mexico City is underpriced, and attempts to introduce parking fees in places like suburban shopping centers are not well accepted by the population. One such attempt was quickly abandoned after politicians denounced it as “unegalitarian”.

In order to reduce emissions from older, more polluting cars, Mexico City has instituted a program called “Hoy no circula”, under which cars whose license plate ends with certain number are forbidden to drive one day of the week. Cars that are particularly old and polluting are banned two days of the week. The problem is that some people simply buy a cheap second car whose license plate ends with a different number. These cars are often very old and pollute a lot more than their owner’s primary car.

Mexico City has a large network of inspection and maintenance centers, whose role is to test residents’ automobiles on a regular basis for compliance with emissions standards. Vehicles that exceed the regulations need to be repaired or they will be taken off the road. This program suffers from a problem of corruption, with some drivers bribing the testers in order to obtain a clean bill of health for their dirty cars.

Mexico City plans to adapt American emission standards for automobiles. The EPA’s Tier I emission standards, which were adapted in the US in 1994, were adapted in Mexico in 1999, and the tougher Tier II standards, which will be adapted in the US starting in 2004, will be adapted in Mexico as of 2006.

3.6 Taxis

Mexico City has at least “official” 100,000 taxis, although there are many more illegal ones. The old Volkswagen Beetle vehicles, most of which are painted green to signify that they have catalytic converters, are a conspicuous presence on Mexico City’s streets.⁴⁷

One of the problems with the taxis is the shortage of taxi stands. This means that most taxis wander the streets empty, looking for passengers, while producing a lot of

⁴⁷ Mexico is the only country in the world that still produces the old Beetles.

unnecessary emissions. The shortage of taxi stands also contributes to the lack of safety on the city's taxis. Tourists are often warned never to hail a taxi off the street because they risk being kidnapped by illegal taxis ("pirate" taxis) and robbed.

The city is trying to encourage taxi drivers to switch to bigger vehicles that have 4 doors and are sturdier than the old Beetles. The government will give a 10,000-15,000 peso down payment to taxi drivers, after which they will pay 600 pesos a week for 3.5 years. The taxi drivers must give their old taxis to the government to be scrapped before they can get their new taxi.⁴⁸

3.7 Road-Based Public Transportation: Colectivos and Buses

Colectivos now dominate passenger transportation in Mexico City. They have usurped the role of the bus and almost completely consumed its mode share, as Figure 3-5 above dramatically illustrates. This thesis does not dwell extensively on road-based public transportation, as this topic has already been dealt with extensively in other work by the MIT Integrated Program on Urban, Regional and Global Air Pollution.⁴⁹

Colectivos are a catch-all phrase for informal transit that includes sedans, vans called combis, and, predominantly, minibuses.

Colectivos provide a good service to passengers in that they come very frequently, have more flexible routes, and are more flexible with respect to stops. Essentially, they will stop almost anywhere. Even though they cost more than the Metro for longer trips, a lot of people are willing to ride them. Many of them are people who have no other choice because their neighborhoods are not served by high-capacity transit, but there are also many choice riders who do not like to take the Metro during rush hour, when trains and platforms on the busiest lines are packed and pick pocketing and even sexual molestation

⁴⁸ Presentation by Luz Elena González from the DF SMA at the at the Fifth Workshop on Mexico Air Quality, January 21-24, 2002, Ixtapan de la Sal, EM, organized by the MIT Integrated Program on Urban, Regional and Global Air Pollution.

⁴⁹ A deeper analysis of road-based public transportation in Mexico City is offered in Georges Darido's excellent thesis from 2001.

are common. Faced with the poor level of service on the Metro, they choose the colectivo instead.

Of course, colectivos are not without problems. They have a relatively high breakdown rate for several reasons. First, no new vehicles have been produced since 1994. Second, colectivo microbuses were built on an ambulance chassis, which was not designed to carry tens of people (during rush hour one sometimes sees vehicles that are so packed that people are hanging out the door). Crime exists on colectivos as well, and some people claim that organized crime is involved in their operation (a similar claim is also made about illegal taxis). Another problem is underage colectivo drivers. Colectivos are often driven dangerously and aggressively and contribute to congestion and pollution.

Colectivos are often owned by their drivers, and provide a source of livelihood to many families. Sometimes, the owner drives the vehicle part of the day, and leases it to another driver for the rest of the day.⁵⁰

Colectivos in the DF are relatively regulated. They are organized into route associations. Each association has its own garages, and its member drivers keep non-member colectivos off their route. The colectivos in each route associations roughly follow the same route, with some variations (e.g. route 2 roughly follows Reforma Avenue). The government regulates the fare structure in the DF (for short distances, the fare is similar to that of the Metro), though the route associations are a powerful lobby. In the EM things are a lot less organized. The government is weaker, there are fewer alternative modes to compete with the colectivos, and so colectivo owners are a much stronger force there. Colectivo fares in the EM are higher than in the DF.

The DF government is trying to convince colectivo owners to switch to buses, as part of an attempt to regulate the colectivos. The plan is to replace 28,000 old units (both

⁵⁰ Cervero (1998), p. 389.

microbuses and old buses) with 12,000 new buses. Bus manufacturers are involved in this plan.⁵¹ The question remains: What will happen to all the other displaced drivers?

3.8 Trolleybuses and Light Rail

These modes are operated by the STE (Servicio de Transportes Electricos). This is a company that was formed when the government nationalized the tram lines in the 1950s (like many tram systems in Latin America, they used to be under foreign ownership). Over the years it has come to operate Mexico City's sole light rail line, which runs from the southern end of the Metro's line 2 to the picturesque southern delegación of Xochimilco. This line is not doing very well, carrying only 15.5 million passengers in 1997,⁵² compared to some of the Metro lines that carry almost a million passengers per day. The STE also operates the city's trolleybus lines, which provide clean bus service along major axes, and also operate on some counterflow lanes, but cannot compete in terms of headway and route flexibility with the colectivos. In 1997, 17 trolleybus routes carried 63.3 million passengers.⁵³ In comparison, the Metro carries 4.5 billion passengers per year, and the colectivos a lot more. In addition, following the collapse of the state-run bus company Ruta-100, the STE was given control over a fleet of articulated buses. In short, the STE operates an odd mixture of modes, none of which are doing very well, as can be seen in Figure 3-5. More light rail and trolleybus lines are planned, but that creates some conflicts that will be described later.

3.9 The Metro

The Mexico City Metro is one of the busiest Metro systems in the world. Yet it has a relatively small mode share despite the size of the system and despite its location in a developing country with low auto ownership and usage rates.

⁵¹ Presentation by Aarón Mastache of the Fondo de Fomento Económico del GDF at the at the Fifth Workshop on Mexico Air Quality, January 21-24, 2002, Ixtapan de la Sal, EM, organized by the MIT Integrated Program on Urban, Regional and Global Air Pollution.

⁵² SETRAVI (1999), p. 33.

⁵³ *Ibid.*

3.9.1 Overview of the Metro System

Mexico City's Metro is one of the heaviest-used in the world. It now has 11 lines and transports about 1.4 billion passengers annually.

The following figures provide a basic overview of the Metro system and its lines.

	1995	1996	1997	1998
Trains in service on weekdays	217	217	217	220
Total length of network (km)	177.7	177.7	177.7	177.7
Trips (thousands)	1,035.1	1,041.4	1,047.0	1,046.1
Vehicle-kilometers (thousands)	35,253.6	35,435.9	35,645.5	35,646.2
Change (%)		0.52	0.59	0.00
Daily Passengers transported (thousands)	1,473,969.3	1,425,467.3	1,361,546.2	1,344,036.4
Change (%)		-3.29	-4.48	-1.2

Table 3-6: General Metro Data

Source: SETRAVI (1999), quoting: Coordinación General de Transporte y Secretaría de Transportes y Vialidad, GDF.

	Line									
	1	2	3	4	5	6	7	8	9	A
Length (km)	16.65	20.71	21.28	9.36	14.43	11.43	17.01	17.72	13.04	14.65
Average distance between stations (km)	0.833	0.863	1.013	0.936	1.11	1.034	1.215	1.265	1.087	1.465
Minimum and maximum headways	1'55" 10'00"	2'10" 10'00"	2'05" 10'00"	5'50" 15'00"	4'10" 15'00"	5'50" 15'00"	4'15" 8'00"	3'15" 10'00"	2'30" 10'00"	2'50" 9'00"
Weekday capacity	763,470	670,140	665,550	279,990	327,320	275,400	373,320	410,040	480,420	335,580
Number of trains in operation	37	38	40	7	13	8	14	24	21	18
Operational velocity (km/hr)	32.1	33.6	33.4	36.2	38.6	37.1	40.6	36.6	36.6	42.6

Table 3-7: Comparison of metro lines, 1998

Source: SETRAVI (1999), quoting: STC-Metro.

Line	Average number of passengers per day				Passengers per line kilometer		Change (%) 1995 - 98
	1995	%	1998	%	1995	1998	
Lines with high ridership							
1	859,052	21.3	758,935	20.6	51,595	45,582	-11.7
2	919,671	22.8	824,296	22.4	44,407	39,802	-10.4
3	774,492	19.2	686,520	18.6	36,395	32,261	-11.4
Subtotal/ average	2,553,215	63.2	2,269,751	61.6	43,540	38,707	-11.1
Lines with medium ridership							
9	321,052	8.0	311,751	8.5	24,621	23,907	-2.9
Lines with low ridership							
8	255,694	6.3	282,945	7.7	14,430	15,968	10.7
7	221,024	5.5	221,058	6.0	12,994	12,996	0.0
5	223,364	5.5	208,141	5.7	15,479	14,424	-6.8
A	243,013	6.0	185,762	5.0	16,588	12,680	-23.6
6	128,825	3.2	118,554	3.2	11,271	10,372	-8.0
4	92,085	2.3	84,330	2.3	9,838	9,010	-8.4
Subtotal/ average	1,164,005	28.8	1,100,790	29.9	13,759	13,012	-5.4

Table 3-8: Metro ridership on individual lines in 1995 and 1998

Source: SETRAVI (1999)



Figure 3-7: Typical Metro vehicles

Source: Metro website: www.metro.df.gob.mx



Figure 3-8: Map of the Mexico City Metro system

Source: www.metropla.net

The numbers in Table 3-9 only tell part of the story, because many of the busiest stations are also busy intermodal terminals. Pantitlán, for example, is also a major bus and colectivo terminal. In total, 850,000 people pass through that station daily.

Line	Station	Weekday Ridership
3	Indios Verdes	156,318
2	Cuatro Caminos	147,989
9	Pantitlán	102,862
2	Tasqueña	99,367
2	Zocalo	82,998
3	Universidad	81,970
5	Pantitlán	80,834
1	Pantitlán	80,023
1	Chapultepec	79,066
A	Pantitlán	78,702
B	Constitución de 1917	70,834
1	Observatorio	66,552
1	Insurgentes	64,969
1	Merced	54,681
1	Zaragoza	52,818
9	Chilpancingo	52,129
3	La Raza	51,797
3	Zapata	51,364
2	Hidalgo	50,537

Table 3-9: Busiest stations in the system (number of Metro boardings)

Source: Metro website: www.metro.df.gob.mx

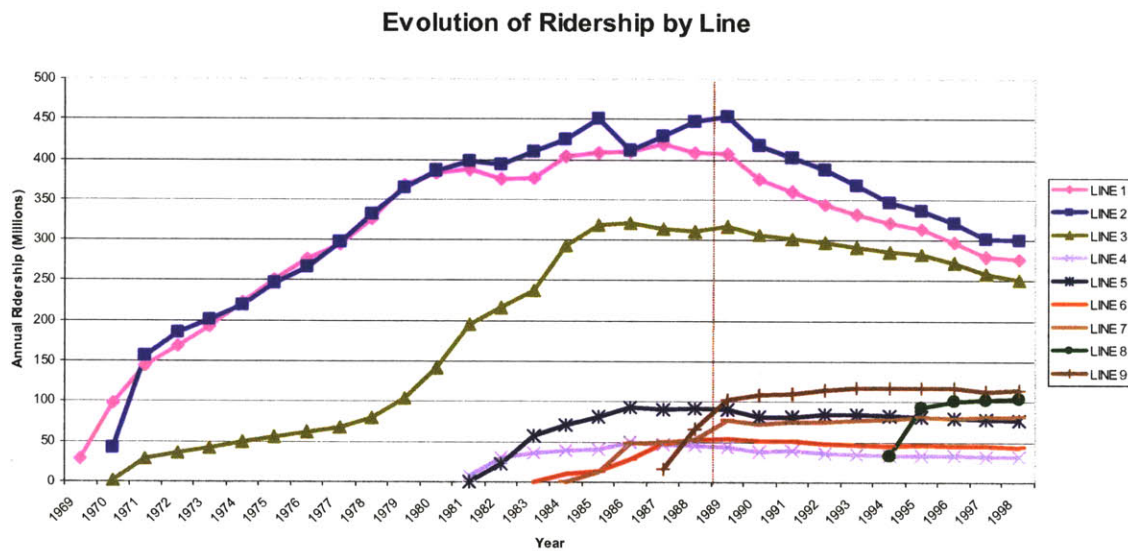


Figure 3-9: Ridership changes from inauguration in 1969 to 1998

Source: STC

Ridership increased continuously until the late 1980s, and then began to decline as lines 1, 2, 3 reached saturation, people left the downtown area (many following the 1985 earthquake), and as the colectivos began to compete directly with the Metro. However, some of the ridership declines in the top 3 lines might be attributed to the opening of new lines. Line 9 runs parallel line 1. Line 8 may have taken up some of the ridership lost by line 2.

3.9.2 Characteristics of Some of the Lines, and Issues Concerning Them

Most lines, except line A, run on rubber tires and get their electricity from a third rail. Rubber tires are a French technology. They have higher maintenance costs, but this technology makes it easier for trains to accelerate and slow down, so it is possible to have stations more closely spaced, and it is easier to negotiate sharp turns. The rubber tires also make for a smoother ride, and are somewhat better for the soft soil of Mexico City.

Lines 1, 2, 3 are the original lines of the system, and have by far the highest ridership. They all go through the downtown area. Their terminals on the DF-EM border (Pantitlán, Cuatro Caminos and Indios Verdes) are the busiest stations in the system.

Line 7, in the western DF, is the line of the system built furthest below ground. The western part of the DF is hilly, as opposed to the downtown and eastern areas, which are a dry lake bed with soft soil. Therefore line 7 was built by tunneling rather than the cut-and-cover method that was used in most other underground sections.

Line 5 was supposed to provide people coming from the eastern EM with a connection to the northern EM, bypassing the downtown area of the DF, but ridership on this line is very low, and did not meet the planners' expectations. Perhaps that is because construction was halted at the DF-EM boundary, about 6 kilometers short of its intended terminus, which is just beyond the boundary in the EM. The same reason was given by planners at the STC for the lower than expected ridership on many lines, including lines

4, 6, 7, 8, and 9. Planners at the STC say that if these lines were expanded just a few more kilometers, and the grid of lines completed as planned, ridership would go up considerably.⁵⁴ Another possible explanation is that the origin-destination projections gave incorrect predictions of ridership.

Ridership on line 8 was also low, but it is now slowly improving, probably because more people from southeastern neighborhoods of the DF are now going to work downtown.

Line 9 runs parallel to line 1, and is a reliever for it. This line is doing relatively well and handles some of the excess passengers that line 1 cannot carry.

Line A was built on existing rail right-of-way (Mexico City – Puebla line); Line A is steel-rail and gets its electricity from catenary wires, whereas the others use rubber tires and get their electricity from a third rail.

Line B has only recently been completed, with the DF stretch opening in 1999, and the EM stretch opening in November 2000. It goes right through Ecatepec, a low-income suburb with 1.457 million people. From preliminary reports, line B has a ridership of about 340,000 passengers per day, making it a medium ridership line on the order of line 9. However, the STC did not have enough money to purchase the planned number of trains, and the line is currently running only about half the trains it is supposed to run. The shortage of trains meant that some trains had to be transferred to line B from other lines. Currently there are 21 trains operating at 4-minute headways, and within a few years the STC hopes to have 38 trains operating at 2-minute headways, and STC planners expect ridership to rise to 600,000 passengers per day. The author observed that many stations along the DF portion of this line were full of passengers heading towards the EM during the evening rush hour.⁵⁵

⁵⁴ Interview at the STC, January 24, 2002.

⁵⁵ Ibid.

Additionally, there is evidence that the opening of line B actually eliminated some colectivo trips. Previously, Ecatepec residents wishing to go to downtown, often took a colectivo to one of three stations along line 1 in the eastern DF, and would then transfer to the Metro. Since the EM portion of line B opened, line 1 boardings at those three stations went down significantly, in one station going down by 47%. There was no such decrease anywhere else along line 1.⁵⁶ This suggests that some people chose line B over the colectivos. One potential problem for line B is that a new highway was built alongside it. This highway will no doubt be used by colectivos to the detriment of Metro ridership, and might complicate efforts blend the new line into the urban form of the surrounding area.⁵⁷

3.9.3 The Environmental Impact of the Metro

The Metro is considered to be a clean mode, since it is electrically powered. Moreover, at least some of the electric power comes from power plants outside the valley. However, some of the electric power used by the Metro is produced by power plants within the Valley of Mexico, which are powered by natural gas. The Metro is responsible for a nontrivial part of emissions from power plants. Still, on a per-passenger basis, the Metro is by far the cleanest mode of motorized travel.

3.9.4 The Metro Compared to Metro Systems in the World

The Mexico City Metro compares favorably with other world metros, with some of the highest ridership figures and the lowest costs of any system.

Table 3-10 shows compares basic data about several Metro systems from around the world.

⁵⁶ Ridership data provided by STC.

⁵⁷ *Metropolitano Línea B* (undated), a glossy booklet promoting line B, casually mentions (on page 17) that 19 kilometers along the route of line B were being transformed into a highway with five lanes in each direction, as part of the “complementary works”. In other words, the Metro paid money to create competition that will undoubtedly reduce its own ridership.

City	Opening Date	Metropolitan population (millions)	Number of lines	Number of stations	Length (km)	Number of cars	Annual Passengers (millions)
Moscow	1935	8.8	11	158	255.7	4,143	3,188
Tokyo	1927	11.8	8	155	269.3	2,401	2,090
Mexico	1969	16.2	11	167	201	2,583	1,344
Seoul	1974	10.2	4	114	131.6	1,602	1,338
New York	1904	13.2	25	468	371	5,081	1,093
Paris	1900	11.0	15	294	201.5	3,399	1,029
Osaka	1933	2.6	7	85	105.8	1,086	992
Hong Kong	1979	5.5	3	38	43.2	759	813
London	1863	6.3	12	261	392	3,922	784
São Paulo	1974	17.0	3	41	43.6	588	694

Table 3-10: Comparison of basic data across several major cities

Source: Metro website: www.metro.df.gov.mx; some of the numbers were updated

The Mexico City Metro is a member of the CoMET group. This group, administered by the Railway Technology Strategy Centre of the Imperial College in London, obtains data on key performance indicators from the member systems, and publishes a comparative report. The member systems are: Mexico City (abbreviation MC in the following figures), Berlin (BN), London (LN), São Paulo (SP), Paris Metro (PM), Paris RER (PR), New York (NY), Tokyo (TK), Hong Kong MTRC (HK), and Moscow (MW). The following figures from the 1997/8 report, present the Mexico City in a favorable light even compared to developed-world systems.

Figure 3-10 shows that despite the high costs of running the Mexico City Metro, the cost per VKT is much lower than those of developed-world metros. This is due to lower wages in the developing world. Note that the Mexico City Metro has a high proportion of passengers per route-kilometers. The New York subway system is twice as large and carries about the same number of passengers.

The numbers in Figure 3-11 suggests that the on-time performance of the Mexico City Metro is among the best.

According to Figure 3-12, the Asian Metros' performance is remarkably high, and is followed by that of the Latin American Metros.

According to Figure 3-13, the operating costs per car-km of the Mexico City Metro are the lowest in absolute terms, and the second lowest as a percentage of the city's daily GDP per capita. What is striking is the contrast with São Paulo, the other developing world Metro, which is apparently a lot more expensive to operate on a per-kilometer basis.

Figure 3-14 shows once again the contrast between Mexico City and São Paulo. The Mexican, Brazilian and French systems seem to be more labor-intensive than other systems. This is probably due to lower wages in the developing world and strong unions in France.

Figure 3-15 (maintenance costs and staff hours per car-km) shows that costs are lowest in Mexico, but there is little difference between the developed and developing worlds in terms of staff hours per car-kilometer.

Figure 3-16 demonstrates once again the safety of the Asian systems. Mexico City's performance is average.

Finally, Figure 3-17, the radar chart, shows that the Metro does as well as or better than other metros in all categories, and is the best in the cost category. According to the radar chart, the Mexico City Metro gets the highest score in the cost category, a better than average score in the service quality category (the best is Hong Kong), and average scores in safety (Tokyo is the best), reliability (Tokyo), efficiency (London) and asset utilization (Tokyo).

Graph 1a - B1m

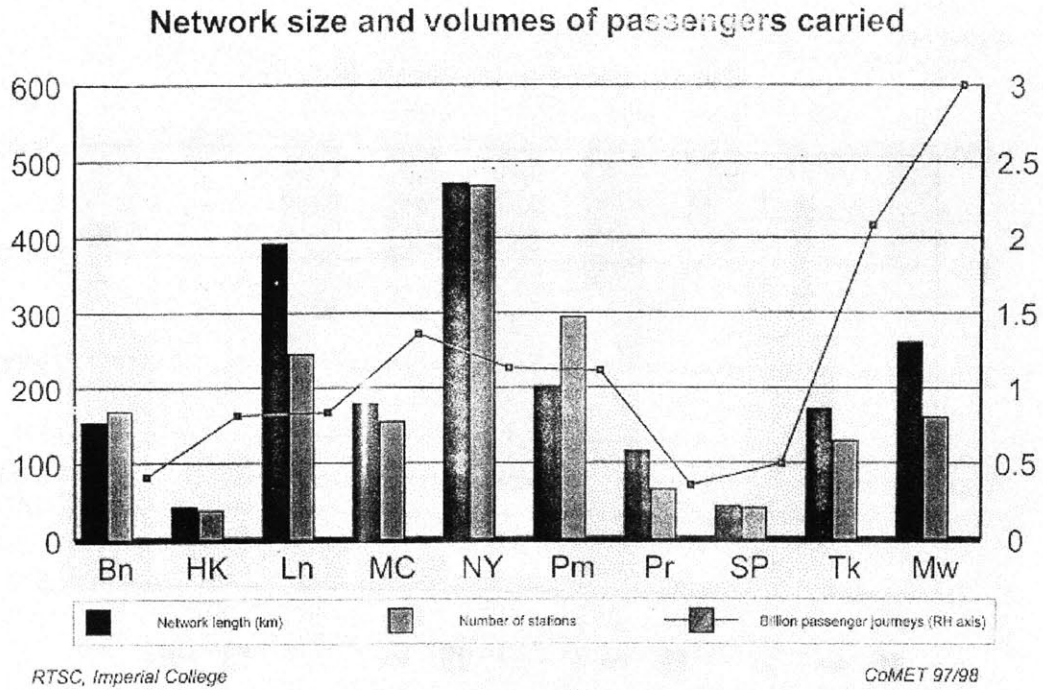


Figure 3-10: Network size and volumes of passengers carried

Source: RTSC (1998), provided by the STC

Graph 12 - r6

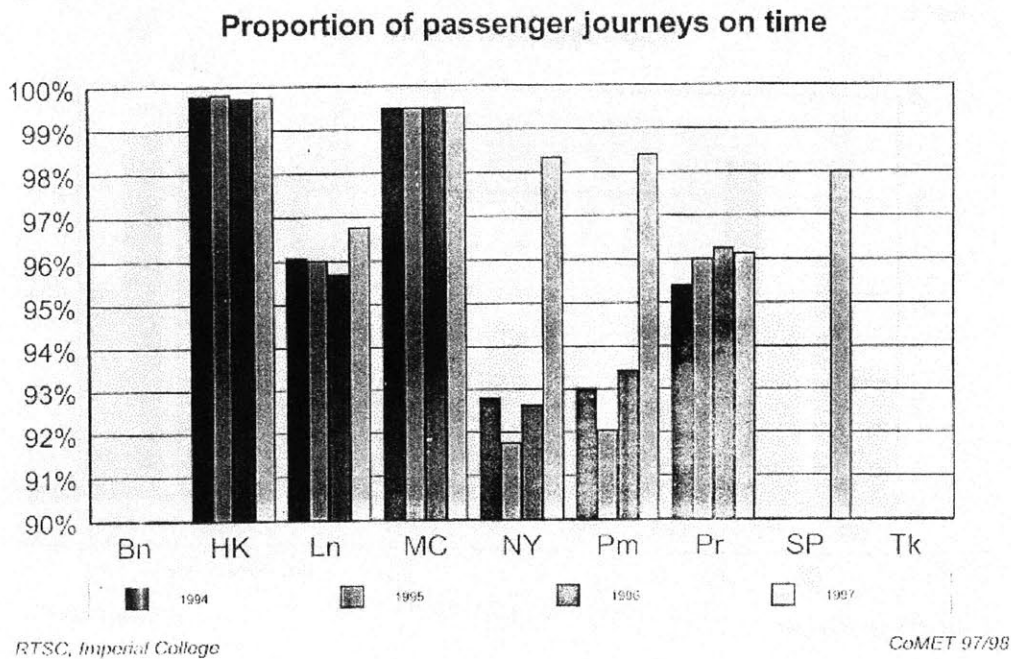
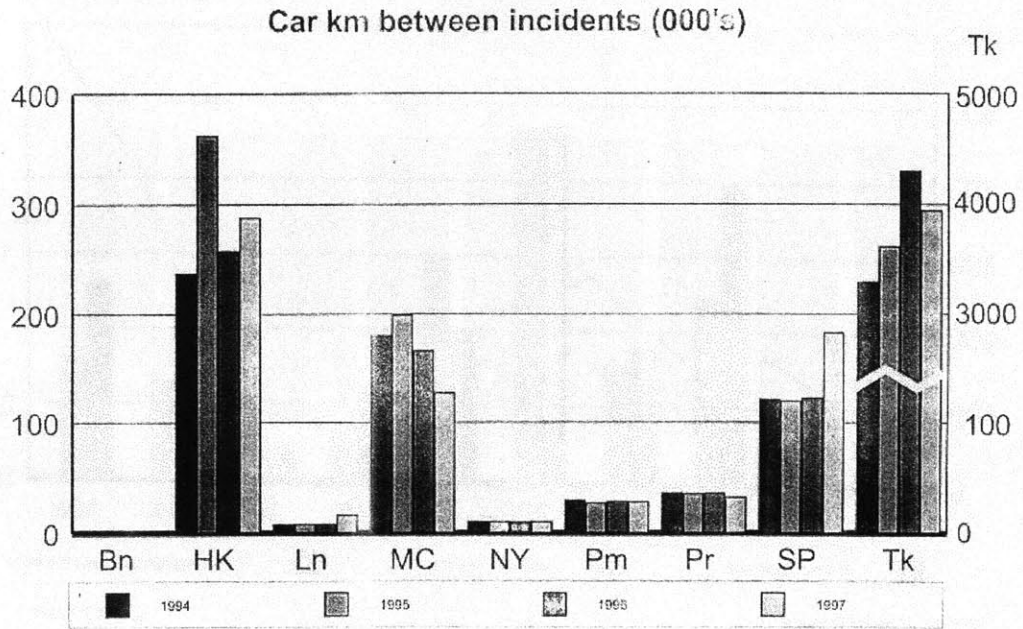


Figure 3-11: Proportion of passenger journeys on time

Source: RTSC (1998), provided by the STC

Graph 8 - R1



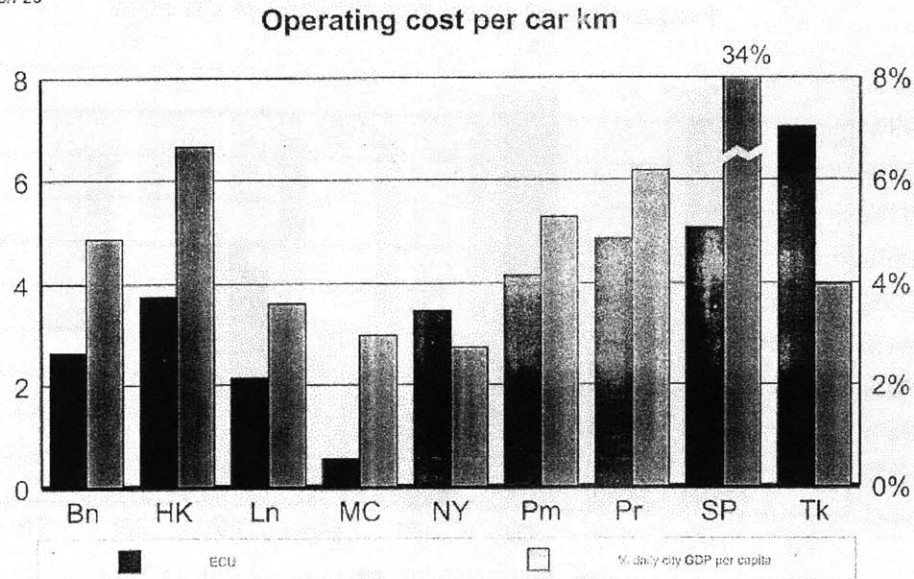
RTSC, Imperial College

CoMET 97/98

Figure 3-12: Car km traveled between incidents

Source: RTSC (1998), provided by the STC

Graph 20



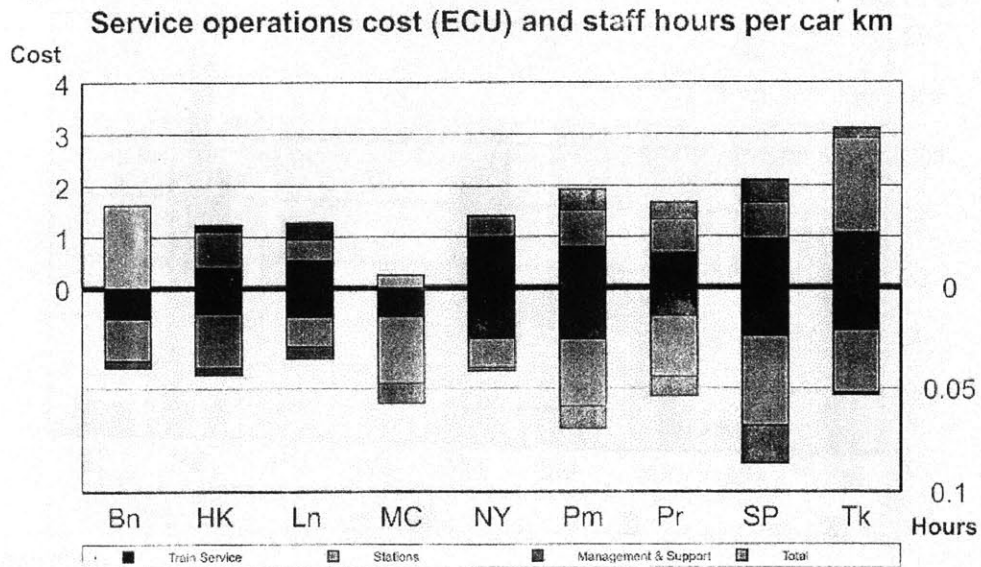
RTSC, Imperial College

CoMET 97/98

Figure 3-13: Operating cost per car km traveled in euros and as percentage of city GDP per capita

Source: RTSC (1998), provided by the STC

Graph 23 - F3



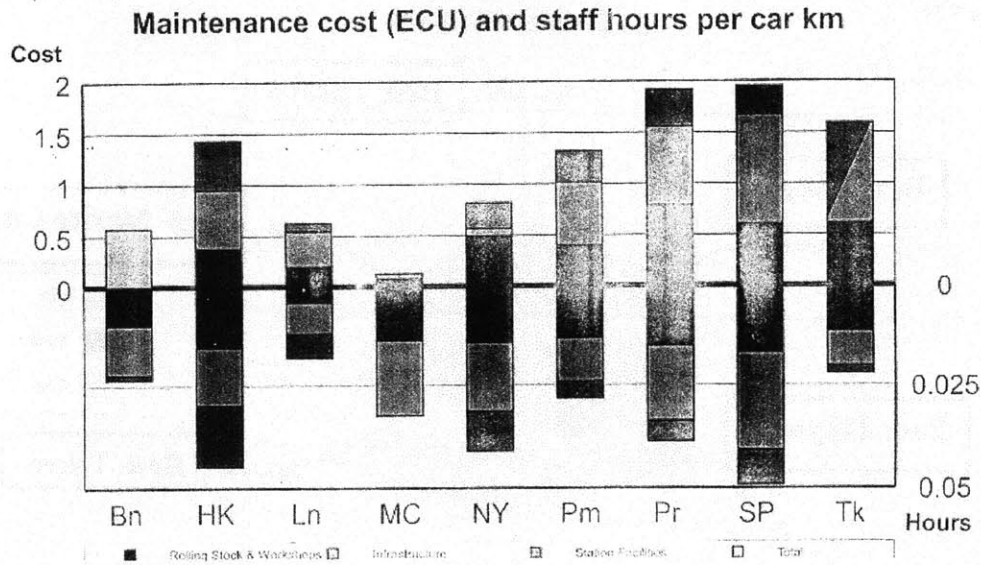
RTSC, Imperial College

CoMET 97/98

Figure 3-14: Operating cost (euros) and staff hours per car km traveled

Source: RTSC (1998), provided by the STC

Graph 24 - F4



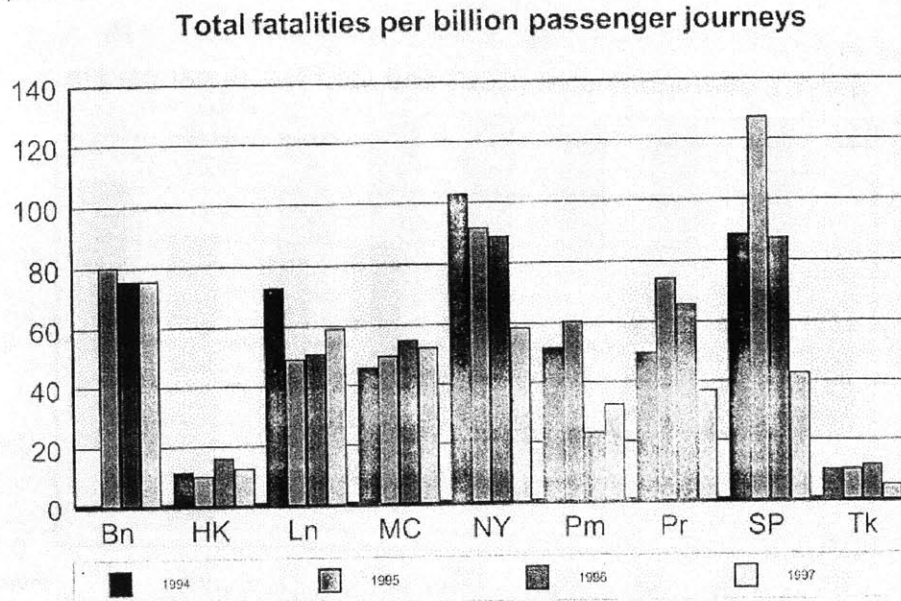
RTSC, Imperial College

CoMET 97/98

Figure 3-15: Maintenance cost (euros) and staff hours per car km traveled

Source: RTSC (1998), provided by the STC

Graph 29 - S1



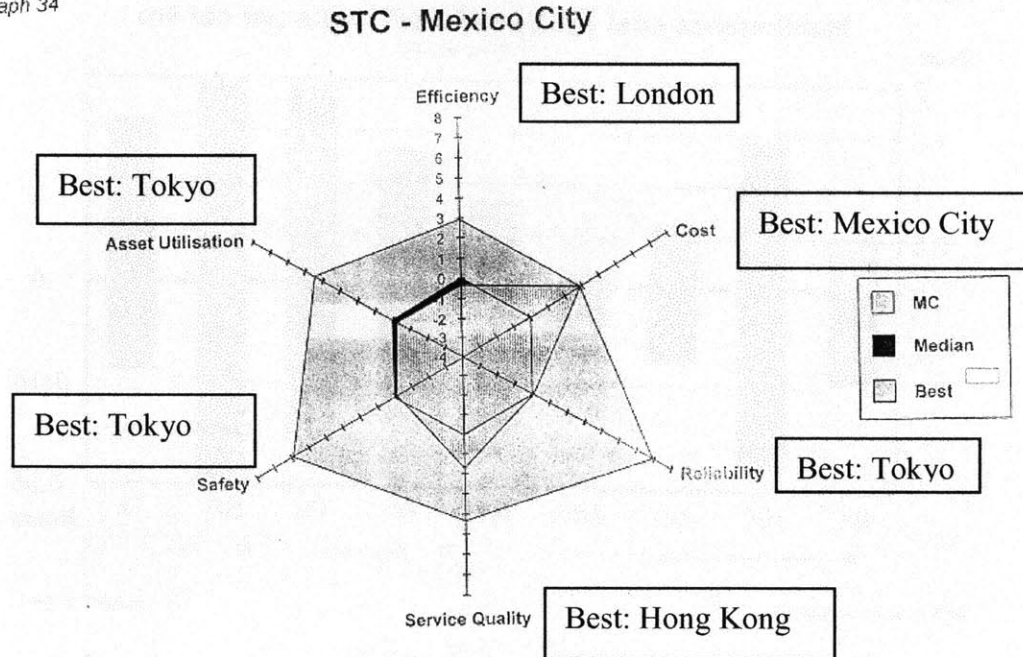
RTSC, Imperial College

CoMET 97/98

Figure 3-16: Total fatalities per billion passenger journeys (includes accidents, crime, suicide, and medical emergency)

Source: RTSC (1998), provided by the STC

Graph 34



RTSC, Imperial College

CoMET 97/98

Figure 3-17: Mexico City radar graph indicators

Source: RTSC (1998), provided by the STC

3.9.5 Ridership Problems of the Metro

As seen in Figure 3-9, the Metro system suffers from a ridership imbalance due to the way it was built and its state when construction ended. The three original lines – 1, 2, and 3 – are overcrowded. 62% of the Metro's riders take these lines. Their terminals, particularly Pantitlán (line 1), Cuatro Caminos (line 2) and Indios Verdes (line 3) are the most crowded stations in the system. The overcrowding greatly reduces level of service, causes extreme discomfort to passengers, and is a fertile ground for petty crime. The crowding problem is so bad that during rush hour the first three cars in each train are reserved exclusively for women and children. These problems drive away middle-class passengers and create a negative image for the Metro.

On the other hand, most of the subsequently built lines suffer from relatively low ridership. The Metro expansion of the 1970s and 1980s was supposed to create a grid of lines. However, construction of most of those lines stopped due to financial constraints before they could be completed, and the grid remained incomplete. The result is that many of these lines like lines 4, 5, 6, 7, and 8, which were supposed to end near the EM boundary or slightly beyond it, do not get there. In addition, most of these lines do not go through the downtown area, which is still the prime destination of trips in the MCMA according to the 1994 origin-destination survey. All of this makes for low ridership.

Another problem is that middle class people are afraid to use the Metro. There are several reasons for that. First, many of the stations are chaotic and unsafe. The entrances are jammed with colectivos and informal commerce. Second, there is the previously mentioned rush hour crowding and the associated discomfort and crime. People who look wealthier make a more attractive target for pickpockets. Third, with the exception of line 7, the Metro, currently reaches primarily poor neighborhoods, although that could change with the expansion of the Metro. Finally, Mexico is a developing country, and it has a high degree of social segregation. Most Metro riders are poor, and some middle class people may choose not to ride the Metro with them.

The fact that the middle-class passengers are deterred from using the Metro is unfortunate, since many middle-class people work downtown, and the Metro should be an attractive choice for them given the growing congestion in the streets and the easy access to downtown that the Metro system offers.

Thus, the Metro is used primarily by the poor, who are about half of the overall population, and by students. Many people who live in the EM need to go to downtown DF for services they do not have in the EM. Many low-income people use the Metro every day for at least part of their commute to low-paying jobs in the downtown area of the DF, or to jobs in the industrial area of the northern DF and the northern EM suburbs. According to the 1994 origin-destination survey, 44% of Metro trips were by EM.

The Metro's limited geographical reach has negative effects even on the low-income riders who use it. First, many of the riders are forced to transfer to colectivos for part of their trip, because the Metro does not reach their origin and/or destination. Many people do not even bother taking the Metro at all anymore. They simply take colectivos for the entire trip. The lack of fare integration between the Metro and colectivos means that these riders need to pay several fares, including the more expensive colectivo fares, in order to complete the trip. This makes transportation expenses a very big part of low-income people's budget, and makes their daily commute very long. In addition, few people would hire people who need to take two or three modes to work. They would never get to work on time.

The competition with the more flexible colectivos, the limited reach of the Metro system, and the lack of intermodal integration all lead to the Metro having a relatively small mode share, as evidenced in Figure 3-5 above.

3.9.6 Financial Situation of the Metro and Related Problems

The Metro is burdened with debt from previous construction efforts that were not only very expensive, but did not result in a big increase in ridership. In addition, federal government subsidies have been eliminated since the democratization of the DF and its detachment from the federal government. In particular, there are scarce funds for system expansion, and during 2001 and 2002 the expansion plan has been put on hold.

The total cost of running the STC has reached 4.4 billion pesos in 1998.⁵⁸ The total costs of running New York City Transit (NYCT) were about 10 times as much, at \$4.39 billion USD.⁵⁹ Figure 3-18 shows the breakdown of the total costs of the STC. The special expenses are mostly debt that was converted into federal bonds in order to protect the debt from inflation. Financial costs are interest paid on the debt.

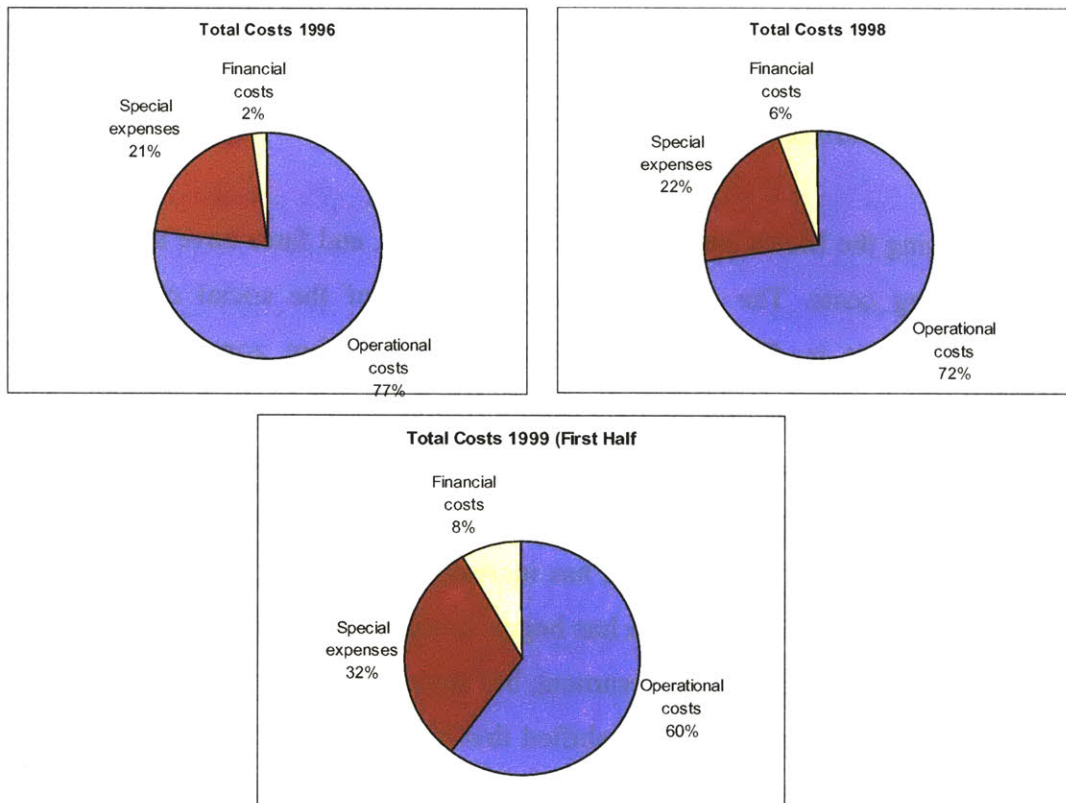


Figure 3-18: Total costs of the Metro

Source: STC (1999), *Plan de Empresa 2000-2006*

⁵⁸ *Plan de Empresa 2000-2006* (1999), p. 22.

⁵⁹ NYCT (2000), p. 24.

Figure 3-19 shows the breakdown of revenues. The reliance on loans has been decreasing as more subsidies were provided by the DF government.

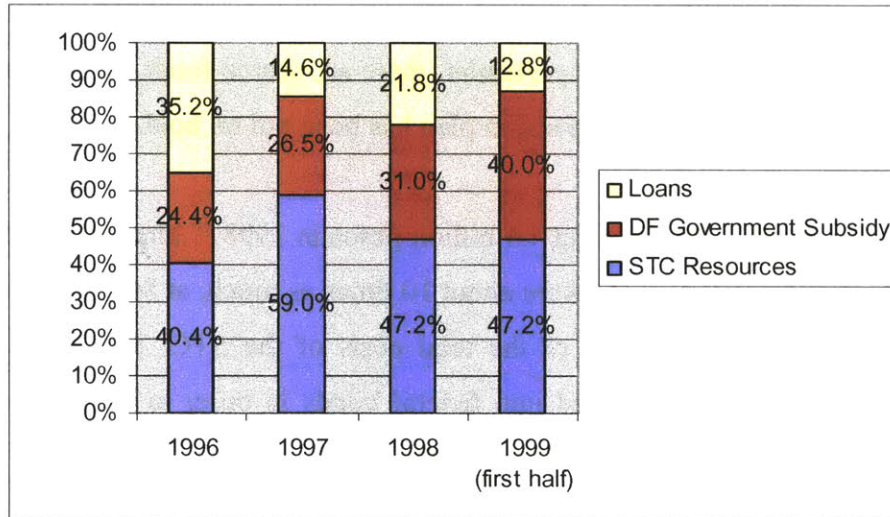


Figure 3-19: Breakdown of Metro revenue

Source: STC (1999), *Plan de Empresa 2000-2006*

The costs of running the Metro have escalated in the 1990s, and fares have not kept pace with the increasing costs. The geographical distribution of the social classes in the MCMA means that it is difficult to implement multiple fare zones like in some developed-world Metros, since the poorest people live in the EM suburbs and can least afford to pay increased fares. The price of a single one-way ticket has increased from 1 peso in 1995 to 1.5 pesos in 1997, while costs have increased from 2 to 4 pesos per passenger, as shown in Figure 3-20. This has increased the subsidy required to run the Metro, although the rate of cost increase has begun to level off recently. The subsidy has traditionally come from the federal government, but since the DF became democratic and autonomous, the federal government has shifted this burden to the DF government. The DF government has fewer resources than the federal government, and in January 2002 it increased the fare to 2 pesos. The Metro currently covers about 37% of its expenses out of the farebox from sales of single one-way tickets and 25-ticket packs (that currently cost 31 pesos). In addition, there are some revenues from concessions and rents from

STC-owned buildings. That explains why “STC resources” in Figure 3-19 is greater than the fare/cost ratio of 37%. In contrast, NYCT pays about 68% of its cost from the farebox.⁶⁰

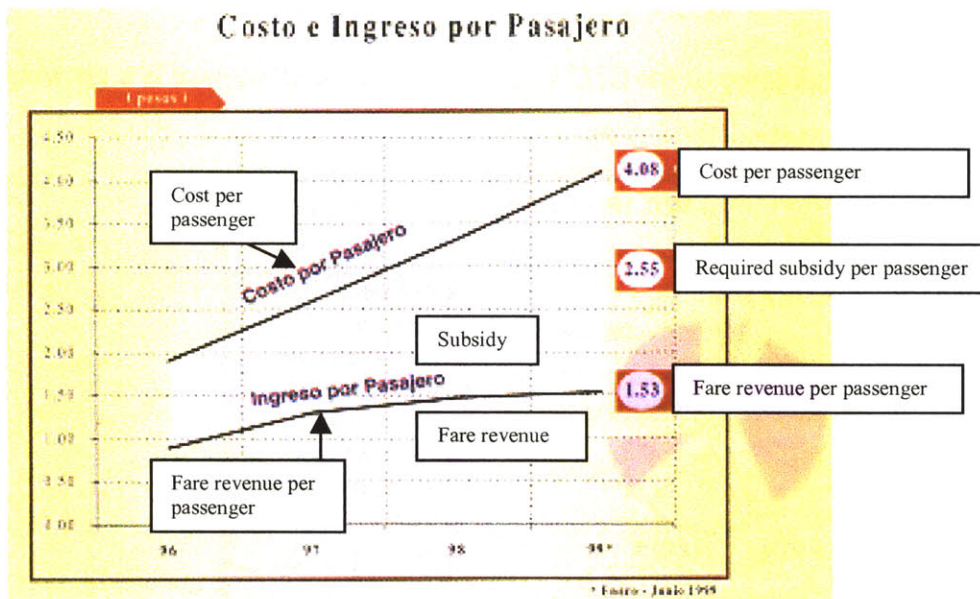


Figure 3-20: Cost escalation during the 1990s

Source: STC (1999), *Plan de Empresa 2000-2006*

One surprising problem in the Metro is the lack of commercial advertisement on trains and in stations, despite the high ridership that should theoretically make Metro stations lucrative for advertisers. STC officials claim that they are negotiating with several advertisers, and that the advertisers are demanding advertising monopolies on entire lines, including all vehicles and all stations.⁶¹ Normally, one would expect the advertisers to ask the transit agency if they could advertise in stations and vehicles, not the other way around, especially since the Metro carries so many people, including students, who are a valuable demographic for advertisers. NYCT earns about \$50-\$60 million USD every years from advertisement, out of which about 60% are from advertisement on the subway, and the rest from ads on the bus system.⁶²

⁶⁰ *Ibid.*

⁶¹ Interview with STC officials, January 24, 2002.

⁶² Telephone interview with Larry Hirsch, Unit Head, Revenue Analysis, Office of Management and Budget, New York City Transit, February 2002.

STC expenses in 1998 were as follows: 51.4% went to acquisition, modernization and maintenance of rolling stock. 29.7% went to operations, 9.3% to administration, and 8.1% to debt service.

Figure 3-21 shows the breakdown of the STC budget. Here too, debt service is a growing item.

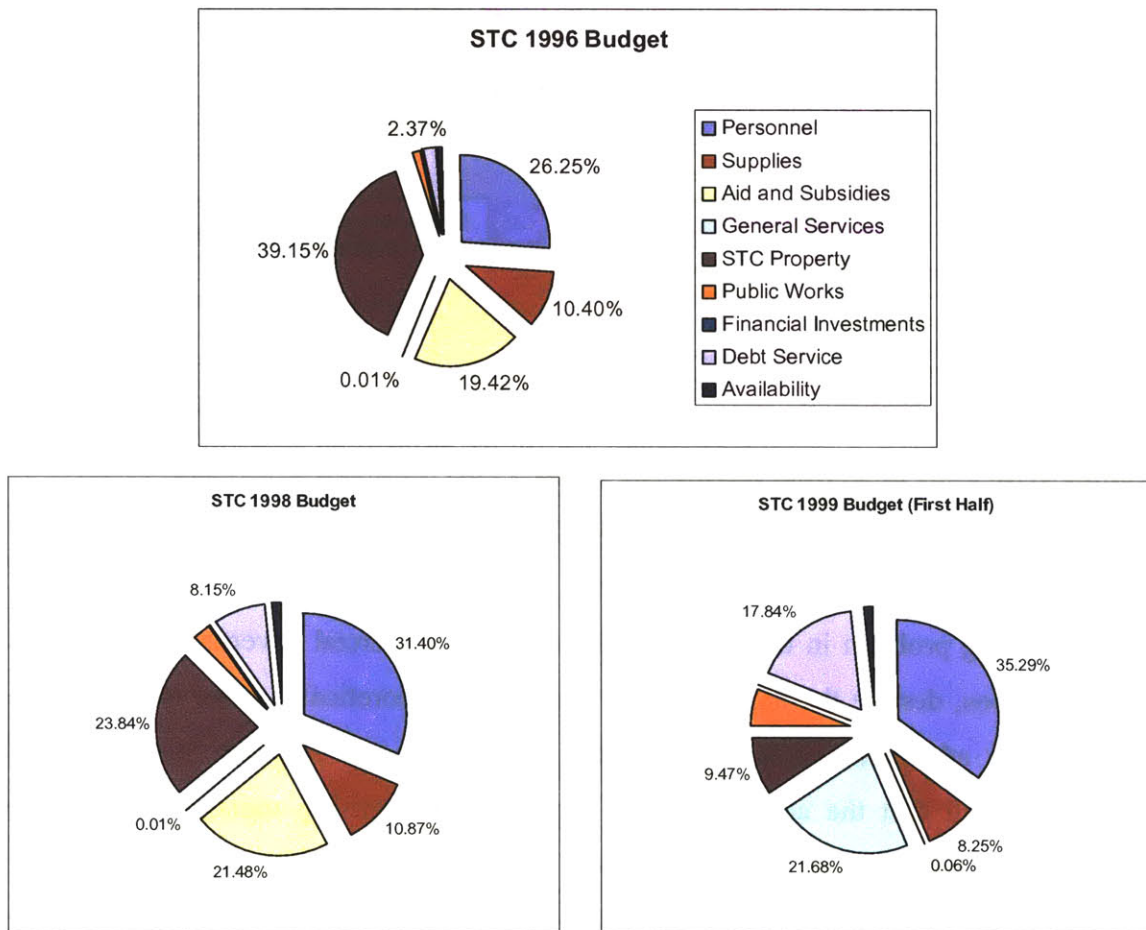


Figure 3-21: Breakdown of the STC budget

Source: STC (1999), *Plan de Empresa 2000-2006*

In contrast, the NYCT budget proposal for 2001 has a lot less debt service (5% of the total budget), and has a lot more for salaries, wages, and fringe benefits (74% of the total

budget; subway salaries, wages and fringe benefits were 81% of the total subway budget).⁶³

When the DF was democratized and separated from the federal government, some federal government property associated with transportation, which the government had acquired or expropriated over time, was handed over to the STC, which was now under the newly independent DF. The STC is currently creating an inventory of the real estate it owns. So far, the STC has not made serious efforts to capitalize on the property it owns. The potential for real estate development of STC facilities will be further explored in the next chapter.

The STC's poor ability to gain additional revenues from advertisement and real estate is typical of government-run agencies all over the world, but it is all the more glaring considering that the Metro is cash-strapped and in need of additional revenue.

In the 1990s an attempt was made to build a Metro line, the Ecotren, into the northwestern EM, which would be financed and operated by the private sector. An alignment was chosen for the line and a concession was actually granted to a private firm. However, the chosen firm could not come up with the necessary financing, because the banks deemed the project too risky and no bank was willing to provide loans. In addition, residents of the trendy Polanco district through which the line was supposed to go objected to construction. The project thus ran aground before any work could start. The government is currently trying to secure financing, so far without success. If the line cannot be constructed privately, there are plans for the government to take over construction as part of the Metro master plan. It would then be built as line 11 of the Metro system.

⁶³ NYCT (2000), p. 29.

3.9.7 Institutional Problems of the Metro

Even though the Metro serves many people in the EM, and even though much of the planned expansion of the Metro system is into the EM, the EM does not participate in the costs of Metro construction, which are now paid entirely by the DF government. That is the main reason that the first stage of the Metro expansion plan will occur entirely in the DF.

Another institutional problem in the DF is the separation between the STC, which runs the Metro, and the STE, which runs the light rail and trolleybus services. While the STE's services now have a negligible mode share, the master plan of the Metro and light rail system calls for a substantial expansion of light rail service and the creation of nine new light rail lines. This brings us to the coordination problem. Even though the STC and the STE are owned by the DF, and the master plan, as we will see in the next section, uses light rail lines as feeders to the Metro system, there is currently no fare integration between the two modes. Passengers taking the existing light rail line have to pay again when they transfer to the Metro. Unless this issue is addressed, it could reduce ridership on the expanded system. Perhaps the STC can take over the operation of the light rail lines, or even merge completely with the STE.

One potential solution to this problem is the smartcard. The DF government is currently beginning to deploy a contactless smartcard across all government-run modes. Once its deployment is completed, fare integration could be implemented quickly if the political will exists. In New York City, the free bus-subway transfer has increased bus ridership by 18%, and even eliminated jitney services that used to operate in some neighborhoods.⁶⁴ As Darido (2001) has pointed out, a reduction in bus fare can have significant mobility and emissions benefits by making the bus more competitive with the colectivos and thus eliminating some colectivo trips.

⁶⁴ *Ibid.*

The lack of fare and route integration with other modes is even more serious with regard to the colectivos. Competition with the colectivos is another problem. Since regulation of the colectivos is weak, especially in the EM, colectivo operators are free to place their profit above all other considerations. Wherever it is more profitable for them to provide feeder service to the Metro (particularly in the EM), they complement the Metro. Wherever it is more profitable for them to compete with the Metro, they offer fierce competition. Some Metro stations serve as intermodal terminals, and have platforms for buses and colectivos, but are still chaotic, with traffic jams, informal commerce, and crime. Better intermodal and intramodal integration is necessary in order to increase the efficiency of the transit system, reduce travel time and cost, and reduce congestion and pollution. While having a strictly hierarchical system, with colectivos feeding into the Metro will be less profitable for colectivo operators and will reduce competition, it will reduce colectivo trip lengths and reduce congestion and pollution. This is a tradeoff, but we must keep in mind that the environmental situation in Mexico City is poor, and our objective function should be to minimize pollution above all else.

3.9.8 The Planned Metro Expansion

Mexico City has a very ambitious master plan for its Metro and light rail system. It calls for the addition of four new rubber-tire lines, nine new light rail lines (in addition to the single under-performing line that exists today), and two new steel-wheel lines, as well as extensions to several existing lines. As a result, route kilometers will more than double, reaching 483 kilometers by the scheduled completion date of 2020. Based on the 1994 Origin-Destination survey that found that most movements in the MCMA are in the DF or between the EM and the DF, the plan is very radial in nature, bringing many lines into the center. At the same time, it also completes the original “grid” of lines mentioned previously.

The process of planning the Metro expansion and carrying it out involves the following organizations:

- SETRAVI – The DF’s Department of Transportation prepares the Master Plan through a division called the DGPP (General Directorate of Planning and Projects).
- SO – The DF’s Department of Public Works does the engineering and construction work through a division called DGCO-STCM (General Directorate of Construction for the STC-Metro).
- STC – The DF-owned company that operates the Metro. It also participates in the planning in an advisory role through a division called the GP (Department of Planning).

The following figures show the planned stages of the expansion plan. Figure 3-22 was originally the planning horizon for 2003, but PROAIRE 2002-2010 (an action plan for improving the environmental situation in the MCMA) sets 2005 as the new target date for the completion of the first phase of the expansion.⁶⁵

⁶⁵ CAM (2001b).

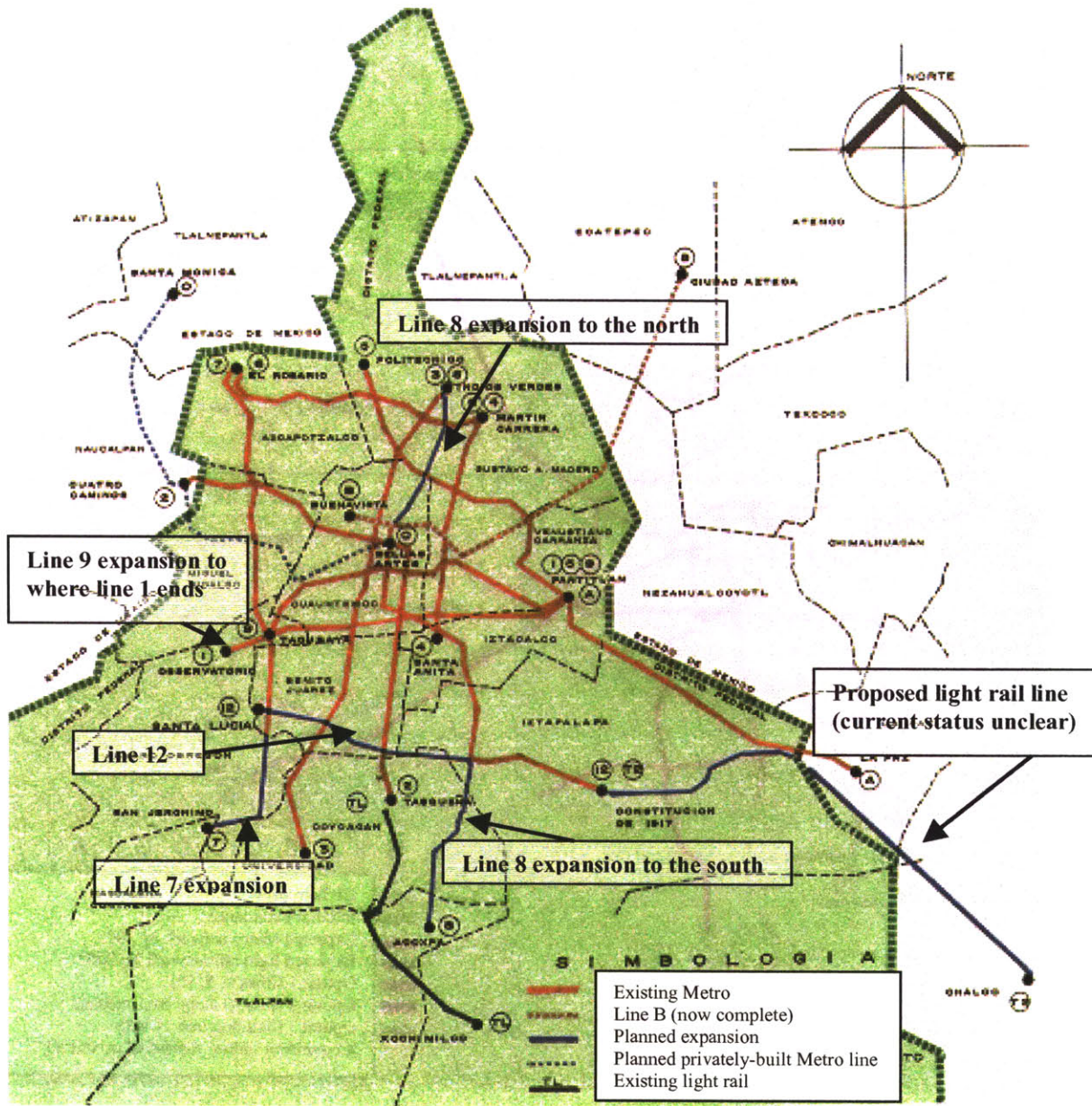


Figure 3-22: Planned expansion by 2005

Source: STC (1999), *Plan de Empresa 2000-2006*

The second phase of the expansion plan includes the options shown in Figure 3-23. PROAIRE 2002-2010 assumes that option 1 will be chosen. However, the original Master Plan assumes that in the long term all three options will eventually be built by the end of the third phase.

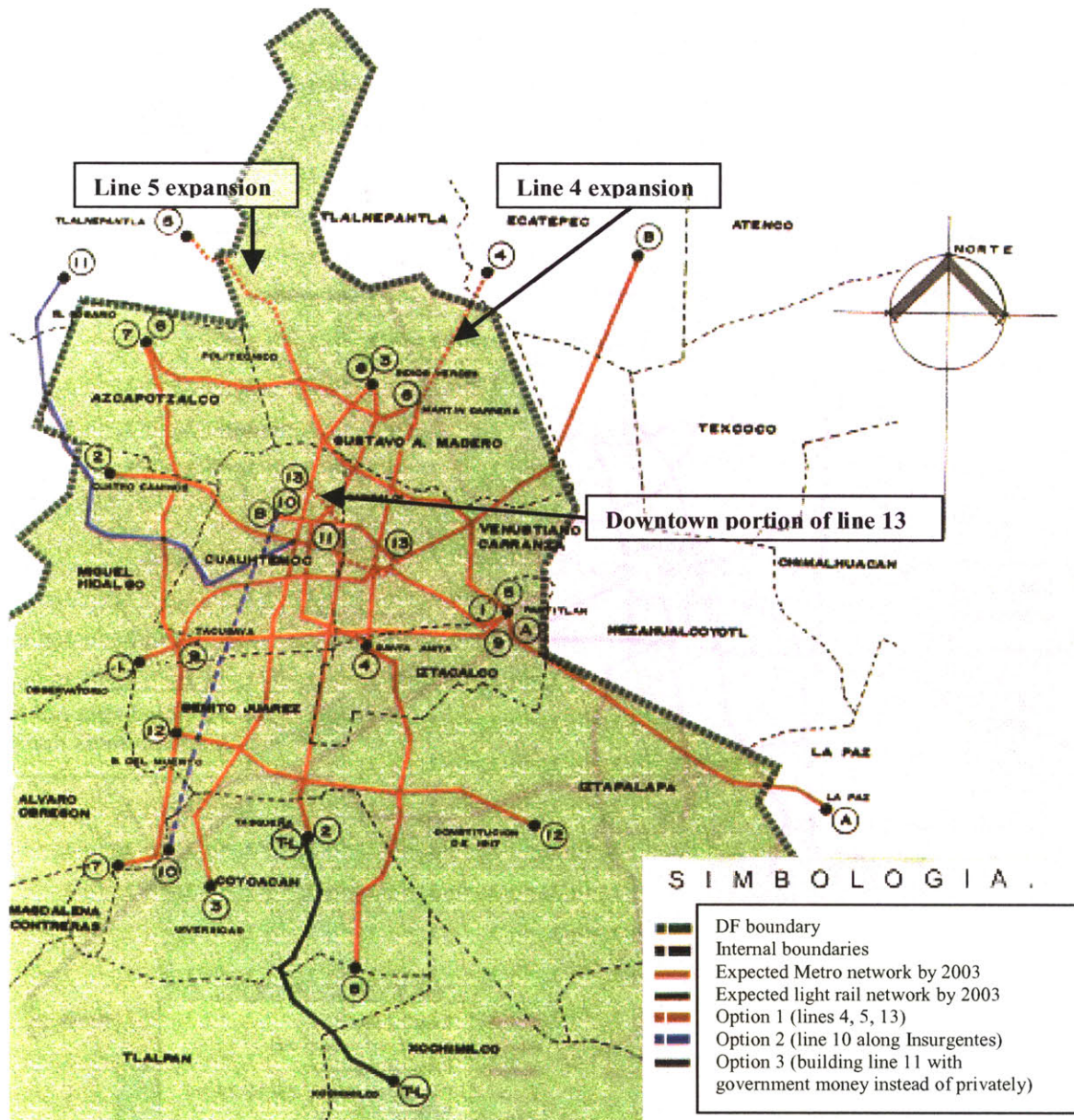


Figure 3-23: Options for expansion by 2009

Source: STC (1999), *Plan de Empresa 2000-2006*

Figure 3-24 shows the final Metro and light rail network after completion of the Master Plan.

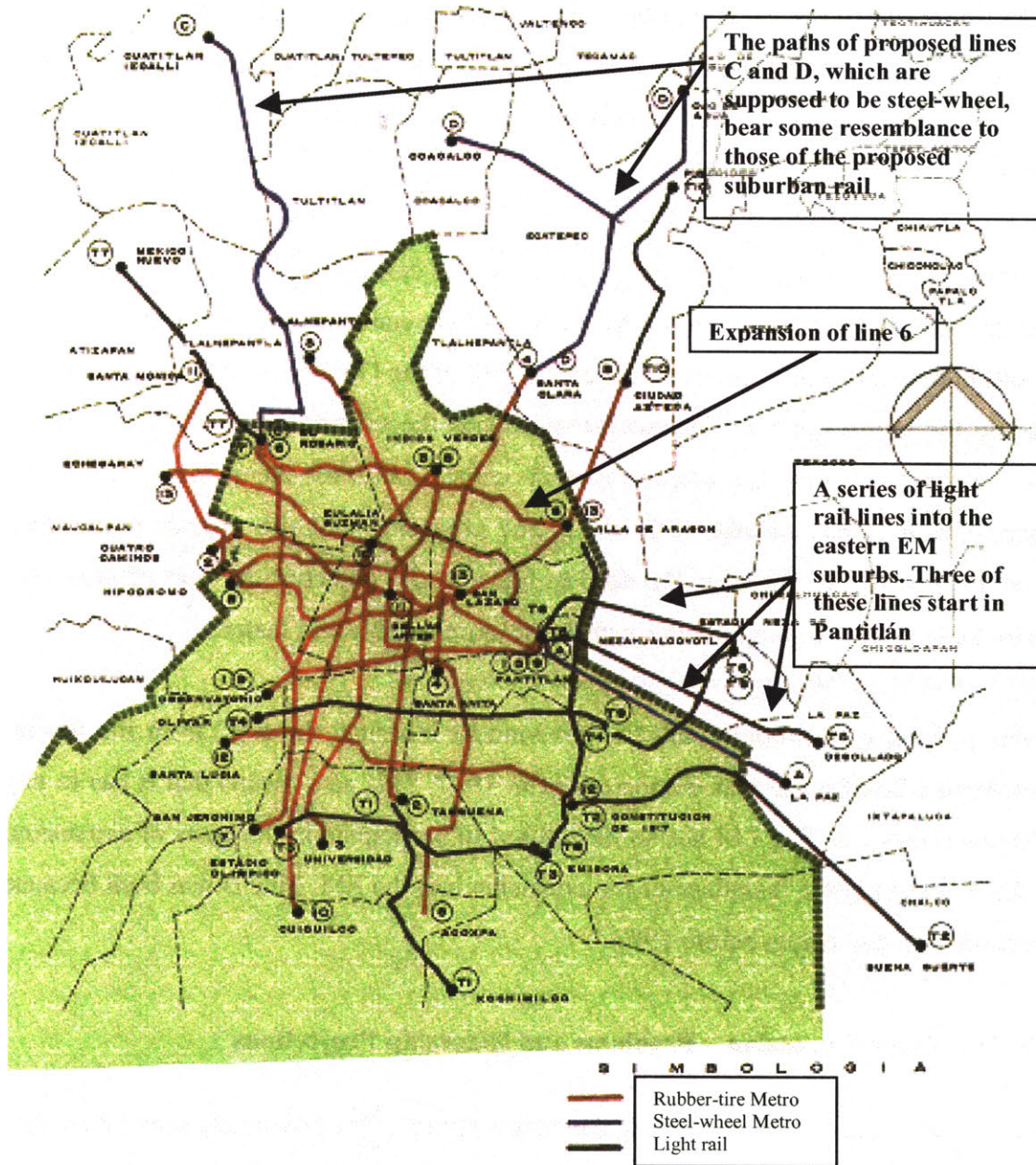


Figure 3-24: Planned expansion by 2020

Source: STC (1999), *Plan de Empresa 2000-2006*

The PROAIRE does not specify which lines will be built during the third phase. It only provides the number of kilometers to be built. However, judging by that number (26 kilometers of rubber-tire Metro and 52.6 kilometers of steel-wheel Metro) and by the length of each line as it appears in the Master Plan, one can assume that the PROAIRE calls for the construction of lines C and D (steel-wheel), and the expansion of lines 6, 12

and 13 (rubber-tire). Line B would then not be expanded westwards, and lines 10 and 11 will not be built. The PROAIRE is also vague about the light rail component. It simply calls for the construction of 74 kilometers by 2020, as opposed to 126.5 in the original Master Plan.

According to Figure 3-24, the heavy rail lines are concentrated in the denser north, northeast and northwest, whereas the light rail lines are concentrated mostly in the eastern EM and in the less densely populated southern part of the DF. Many of the light rail lines feed into the Metro system. The expansion extends the system into the EM in order to draw commuters (and the colectivos that carry many of them) away from the overcrowded terminals of lines 1, 2, and 3. The expansion will also provide more direct service for people, saving them the need to transfer to a colectivo for part of their trip, thereby making their trip considerably cheaper, more reliable and faster.

As was previously mentioned, the DF government inherited the STC from the federal government when the DF was democratized in 1997. This also means that it has to pay for Metro expansion. The EM has so far refused to participate in the costs of expansion, and that is currently the main barrier for expansion into the EM. Line B was built because its construction had begun before 1997.

3.9.9 The Metro Expansion – Problems and Ridership Projections

There are many barriers to expanding the Metro system. The previously mentioned lack of cooperation between the DF and the EM is an important one. However, the greatest single barrier to the expansion plan is the chronic lack of funds. In fact, it has been decided that no new lines will be built in 2002, and implementation of the first phase will not start until 2003. Currently it is not clear how much of the planned expansion will actually be completed by the target date of 2020. Based on the costs of line B, the author has estimated that construction of the first phase of the expansion would cost about 21

billion pesos (about US\$ 210 million) for a project that will last three years. In contrast, the annual budget of the DF (which has to pay for all of it) is about 60 billion pesos.⁶⁶

The lack of fare integration between the Metro and light rail that was mentioned before is another problem. The Master Plan envisions many light rail lines beginning at points in which heavy rail lines end. These chains of lines will make people pay double and change mode unnecessarily. Looking at the expansion maps raises the question of whether it is wise to have even more lines converge on Pantitlán, which is already the busiest station in the system. One alternative could be expanding one of the lines that end at Pantitlán into the suburb of Nezahualcoyótl instead of the three light rail lines that are currently planned. It would probably be cheaper, and it will mean less congestion in Pantitlán. One possible obstacle, according to STC officials, is that rubber-tire trains have a maximum length of about 25 kilometers, because of concerns about heat dissipation from the tires. Steel-wheel trains have no such problem. However, line B functions well at 23.7 kilometers.

Another problem is that the ridership projections used by the planners seem to be very optimistic. The COMETRAVI report of 1999, as well as the Master Plan of 1996, estimated that once the Metro expansion is completed in 2020, ridership would be more than 12 million people a day, triple the current ridership. If one picks out from the Master Plan only the Metro lines mentioned in the PROAIRE, without the light rail lines, ridership is expected to be about 8.8 million people a day. These projections seem overly optimistic, and were perhaps based on the assumption that everyone living near a Metro station will ride it.

A more pessimistic projection done by the author predicts about 5.5 million daily passengers by 2025. The underlying assumptions are that the Metro will only be built at an average pace of 5 kilometers per year (as opposed to more than 10 kilometers per year that would be required to finish the entire Master Plan on time), that the expansion will primarily occur in the DF, and that the network will therefore still not be complete and

⁶⁶ Alejandro Villegas.

will not cover much new ground in the EM. Furthermore, it is assumed that the light rail lines would not be built.

3.10 Suburban Rail

There is a plan to build a federally financed suburban rail system connecting the DF with the EM using existing rail rights-of-way. This plan is separate from the Metro master plan, and there does not seem to be any fare integration between them. Figure 3-25 shows the entire planned suburban rail network. However, at this point only the Buenavista – Cuautitlán – Huehuetoca line and the Ecatepec – Naucalpan line are being seriously evaluated, with the former more likely to be built than the latter.

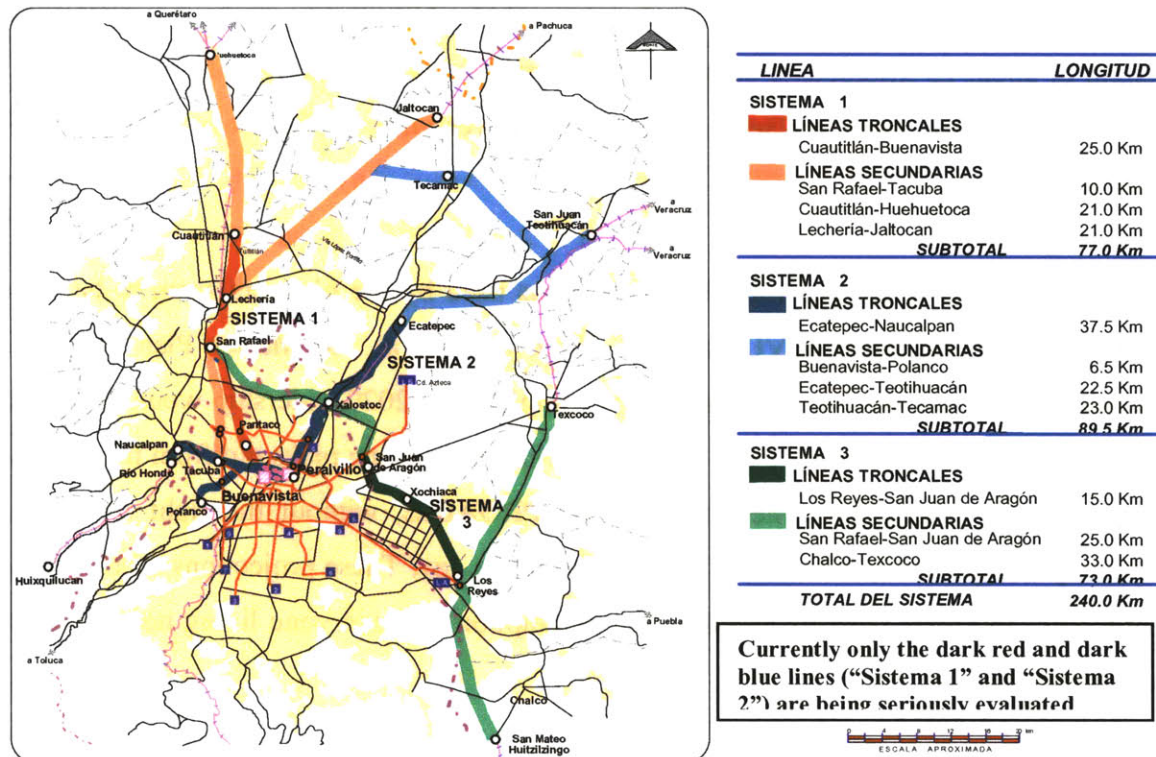


Figure 3-25: Planned suburban rail system

Source: SETRAVI (1999)

The suburban rail is supposed to be a public-private partnership, in which the government will build the infrastructure, and a private concessionaire will operate the train service. According to the suburban rail plan, they plan to charge 9.25 pesos to go from Cuautitlán

to Buenavista. This is expensive, but apparently somewhat cheaper than taking the colectivo and Metro on a similar route, which, according to the plan, costs 10.50 pesos.⁶⁷ The time saved by taking the train on this stretch is expected to be 1 hour and 20 minutes (30 minutes instead of 1 hour 50 minutes), since the suburban rail runs parallel to one of the most congested roads connecting the northwestern suburbs to the DF. The project actually markets itself as an alternative to parts of the Metro Master Plan.

The estimated cost of the suburban rail is \$15 million USD per kilometer, including vehicles.⁶⁸ The DF terminus of the first line, Buenavista, is Mexico City's former central train station, and is no longer used for passenger transport. If built, the second line (Ecatepec – Naucalpan) will have a downtown terminal at Peralvillo, which is on Reforma Avenue.

Most importantly, the suburban rail project represents an opportunity to create a new transit product aimed at middle class suburbanites (many of whom live in the northwestern suburbs), as opposed to the Metro, which is perceived as an inferior good by the middle class. The suburban rail project also offers opportunities for Transit-Oriented Development (TOD), which will be discussed in the next chapter.

The next chapter looks at the possibilities for TOD and other transportation – land use interventions in Mexico City, particularly in the context of Metro expansion.

⁶⁷ SCT (1999), vol. 1, p. 12

⁶⁸ CAM (2002).

Chapter 4: Coordinated Transportation and Land Use Planning in Mexico City – Opportunities and Challenges

As Mexico City faces enormous problems of pollution and sprawl fueled by population growth, motorization, and the lack of affordable housing, the use of coordinated transportation and land use planning methods such as Transit-Oriented Development (TOD) becomes more and more relevant. The object of this chapter is to show that Mexico City already has some of the prerequisites for TOD, and to demonstrate the opportunities for coordinated transportation and land use planning and the challenges facing it. This chapter begins by stating the need for coordinated transportation and land use planning in Mexico City, continues by looking at the suitability of the Metro system for TOD, then examines the ability of the MCMA's planning institutions to do coordinated transportation and land use planning, and then looks at several options for coordinated transportation and land use planning and steps that need to be taken to implement them.

Coordinated transportation and land use planning is needed in the MCMA for several reasons:

- To control the growth of the MCMA, particularly the EM and the southern parts of the DF, and thus reduce the negative impacts of sprawl on the environment and on equity (i.e. higher transportation costs for the poor on the outskirts).
- To revive the downtown area, attracting back population that abandoned it in recent decades.
- To increase the mode shares of high capacity electrically powered transit, as well as that of non-motorized transportation (NMT), at the expense of gasoline and diesel-fueled modes, thus reducing both congestion and pollution.
- To improve equity and increase economic opportunities for the poor by providing them with easy access to low-fare mass transit for both the journey-to-work and other purposes.

4.1 The Mexico City Metro, its Impacts on Land Use, and Its Suitability for TOD

The following section examines the impact of the planned expansion of the system on land use, Metro ridership, equity and the environment and examines the suitability of the Metro (and proposed light rail lines) for TOD.

4.1.1 Land Use Effects of the Metro Expansion

The Mexico City Metro provides a physical infrastructure that can support TOD. In that respect Mexico City has an advantage over other cities in the developing world (or even the developed world), because it already has an extensive Metro system with 11 lines, although most of them do not go far enough into the EM, which is the fastest growing part of the MCMA. By expanding the Metro system, a better match would be achieved between the Metro system and the urban form, and more Origin-Destination pairs would be served without the need for taking a colectivo. This would enable more people to benefit from the Metro.

The use of TOD in tandem with the expansion of the Metro system can reduce colectivo trips, thereby reducing pollution, congestion and accidents, and encourage NMT as a means of reaching the stations, instead of colectivo feeder trips, or even instead of taking colectivos from origin to destination.

Some critics of the proposed Metro expansion claim that it would only increase sprawl, since it would cut travel time from the outskirts to downtown, and make the downtown area more accessible for people living on the outskirts.⁶⁹ This opinion has some merit considering the effect that trolley lines and later highways have had on cities in the developed world, and considering the rapid sprawl that accompanied the construction of the existing Metro lines in Mexico City. The Metro currently brings people from areas

⁶⁹ Robert Cervero during a talk at MIT, spring 2001.

adjacent to the DF-EM boundary into the downtown area, and expanding it would make the downtown more accessible for people coming from deeper inside the EM, both by Metro and by new colectivo routes connecting the new Metro stations to even more distant suburbs. This might result in more sprawl. However, we do not know how much of the sprawl was caused by the Metro, and how much would have occurred anyway given the explosive population growth during that period. In addition, evidence from other cities shows that a well-developed Metro system with a good coverage of the metropolitan area tends to increase the attractiveness of the downtown area for businesses, and slows the suburbanization of jobs. It can also create corridors of development.⁷⁰

Some people question whether it is really desirable to improve the mobility of low-income EM residents into the DF. They claim that these people should be encouraged to leave the MCMA in favor of the ‘Corona’ (‘Crown’) cities (Toluca, Pachuca, Puebla, Cuernavaca, Querétaro) around the MCMA, which have more capacity to absorb incoming population.

4.1.2 Quantifying the Effects of Metro Expansion

The following section examines the effects of Metro expansion. It begins by illustrating the effects of simply having more people live near the Metro and light rail, before any deliberate efforts are made at TOD or other forms of coordinated transportation and land use. It then adds the possible effects of TOD on the number of people living near the Metro and light rail.

Currently, approximately 1.3 million people live within 500 meters of a Metro or light rail station, and can access the Metro by walking, without a feeder trip by bus or colectivo. If the full Master Plan is carried out, and no TOD occurs, this number will increase to about 3 million.⁷¹ The 500-meter radius is often used in the context of TOD in

⁷⁰ Halcrow Fox (2000).

⁷¹ Since GIS was unavailable, a street atlas (Guia Roji, 2000) was used to make a rough measurement of the total area of the MCMA within 500 meters a Metro station. Since the Metro passes entirely through

the developed world. Poor people in a developing country can be assumed to be willing to walk more than 500 meters to get to a Metro station and travel cheaply. The number of people living within one kilometer of a Metro or light rail station would be perhaps three or four times as large as that for a radius of 500 meters. Of course, proximity to the Metro does not guarantee its use, but the larger the system, the more destinations it serves, and the more convenient it becomes to people.

The following example will illustrate the savings from Metro expansion, or from relocating near the Metro. Let us assume that employed people who live in the EM make two motorized trips every day. We also assume that they are traveling into the DF and make a colectivo-Metro multimodal trip. The EM colectivo fare is 4 pesos for the first 5 kilometers and 0.14 pesos for each subsequent kilometer.⁷² The average trip length within the EM up to the boundary is assumed to be 12 kilometers (the average colectivo passenger trip length in the MCMA is 8.4 kilometers, but a lot of that is from short trips in the downtown area)⁷³. The one-way fare is 4.98 pesos for the colectivo plus 2 pesos for the Metro. In total, a person spends 13.96 pesos a day on transportation. According to the 2000 census, 45% of the employed population of the MCMA earn less than two minimum salaries (the minimum salary in the MCMA is about US\$ 4 a day, or 40 pesos). 64% earn less than three minimum salaries. A person earning two minimum salaries will thus spend 17.45% of his daily income on transportation, and a person who earns three will spend 11.63% of it. This expenditure could be higher if colectivos are taken for the DF leg of the trip as well.

If the Metro is expanded to the EM, these costs will go down, even if there is no fare integration between the Metro and light rail. Even if people need to pay twice, the total

urbanized areas, and since the density of the urbanized area of the MCMA is fairly constant, the area was multiplied by this density to obtain a rough population estimate. The calculation was then repeated for the Metro expansion using alignment information from the Master Plan.

⁷² According to the official table of colectivo fares on the EM SCT website:

www.edomexico.gob.mx/sct/index.html. The table does not say how many kilometers are covered by the 4 peso flat fare (3.50 pesos in other parts of the urbanized EM). In other parts of the EM, like Toluca, the fare is flat up to 10 kilometers. However, according to COMETRAVI (1999) the fares in the EM sections of the MCMA are flat up to a distance of 5 kilometers. Even if the 4 peso flat fare were for up to 10 kilometers, it would still be more expensive than the Metro.

⁷³ COMETRAVI (1999), vol. 7.

fare will still be only 4 pesos, or 8 pesos roundtrip. This already cuts peoples' transportation costs almost in half. With fare integration (for example using the new smartcard currently being introduced in Mexico City), the cost is halved again.

The expansion of the Metro has two effects on colectivo ridership. First, some people stop using the colectivos altogether or use them less frequently. Second, since the network extends further out, colectivo feeder trips from areas still not served by the Metro become shorter. The result is a decline in average colectivo trip length.

Let us assume that the Metro Master Plan has been completed and that 3 million people now live within walking distance of the Metro (if we use the conservative assumption that walking distance is only 500 meters). Let us also assume that due to the wide reach of the Metro after the expansion, it is very attractive to passengers, and some of the 3 million people have abandoned the colectivo completely in favor of the Metro, and that the number of colectivo vehicle trips drops as well in the face of the decline in demand. We will now make a series of calculations to determine reductions in colectivo use. For example, if half the 3 million people abandon the colectivo, and each one of them used to make two daily colectivo trips, we get 3 million daily colectivo trips eliminated. The average passenger trip length on colectivos in the MCMA is 8.4 kilometers, as was mentioned above. If we multiply this by 3 million passenger trips and then by 365, we get 9,198,000,000 annual passenger-kilometers traveled (PKT). If we assume that there are 13.5 colectivo PKT per colectivo VKT (vehicle-kilometers traveled),⁷⁴ we get 681,333,333 annual VKT. The 1998 emissions inventory provides grams of pollutants per VKT for colectivos and other modes.⁷⁵ Table 4-1 shows the emissions saved in metric tons. Compared with the colectivo emissions data in Table 3-4 above, these savings represent a significant reduction in colectivo emissions. For example, colectivo CO emissions are cut by about a quarter.

⁷⁴ We assume for now that this ratio remains constant, i.e. that colectivo vehicle trips decline at the same rate that colectivo passenger trips decline.

⁷⁵ CAM (2001a).

Pollutant	Grams/VKT	Annual Metric Tons Saved by Metro Expansion
HC	7.57	5,158
CO	82.63	56,299
NO_x	2.61	1,778
PM₁₀	0.029	20
SO₂	0.115	78

Table 4-1: Colectivo emissions that could be eliminated if Metro expansion causes 1.5 million people to abandon the colectivos completely

The Metro should be able to handle three million new trips. After all, the expansion plan is designed to handle a demand of 12.2 million passengers, triple current ridership. Presumably, the planners included people who live near the station in their calculations.

We conduct a sensitivity analysis of the attractiveness of the Metro to people living near it. We do the same calculation we did before, but we change the percentage of people who completely abandon the colectivos for the Metro. We still assume that they used to make two trips per day, and we still assume 13.5 PKT/VKT. Table 4-2 shows the emission savings.

We can also test the sensitivity of emission reduction to changes in the PKT/VKT ratio. We assume again that half the 3 million people living near the Metro abandon colectivos completely. We then compare three cases. In the first case, the ratio remains 13.5, i.e. the reduction in colectivo passenger trips and is matched by a reduction in colectivo vehicle trips. In the second case, we assume that passenger trips go down faster than vehicle trips, so the PKT/VKT ratio is 20% lower, at 10.8. In the third case, we assume the opposite, and use a PKT/VKT ratio that is 20% higher, at 16.2. Table 4-3 shows the emission savings.

Percent of people near Metro who abandon colectivos completely	Annual metric tons of HC saved	Annual metric tons of CO saved	Annual metric tons of NOx saved	Annual metric tons of PM ₁₀ saved	Annual metric tons of SO ₂ saved
10%	1,032	11,260	356	4	16
20%	2,063	22,519	711	8	31
30%	3,095	33,779	1,067	12	47
40%	4,126	45,039	1,423	16	63
50%	5,158	56,299	1,778	20	78
60%	6,189	67,558	2,134	24	94
70%	7,221	78,818	2,490	28	110
80%	8,252	90,078	2,845	32	125
90%	9,284	101,337	3,201	36	141

Table 4-2: Colectivo emissions eliminated by Metro expansion: sensitivity to percent of people near the Metro or light rail who abandon colectivos for the Metro or light rail

PKT/VKT ratio	Annual metric tons of HC saved	Annual metric tons of CO saved	Annual metric tons of NOx saved	Annual metric tons of PM ₁₀ saved	Annual metric tons of SO ₂ saved
10.80	6,447	70,373	2,223	25	98
13.50	5,158	56,299	1,778	20	78
16.20	4,298	46,915	1,482	16	65

Table 4-3: Colectivo emissions eliminated by Metro expansion: sensitivity to PKT/VKT ratio (assuming 50% of population abandons colectivos for Metro)

We now introduce the possible impact of TOD on the number of people living near the Metro and light rail. We will repeat the calculation from Table 4-2, using numbers other than 3 million as an assumption of the number of people living near the Metro. We will use a lower bound of 2 million people (a limited Metro expansion occurs, and some TOD), and go up to 5 million people (full Metro expansion and maximum TOD, based on the affordable housing option introduced in section 4.3.1 below). We will still assume 2

daily trips per passenger, an 8.4 kilometer colectivo passenger trip length, and we revert to a PKT/VKT ratio of 13.5. We also revert to the assumption that half the population living near the Metro and light rail will abandon the colectivos completely. The results are summarized in Table 4-4.

Number of people living near the Metro or light rail	Annual metric tons of HC saved	Annual metric tons of CO saved	Annual metric tons of NOx saved	Annual metric tons of PM ₁₀ saved	Annual metric tons of SO ₂ saved
2,000,000	3,438	37,532	1,186	13	52
2,500,000	4,298	46,915	1,482	16	65
3,000,000	5,158	56,299	1,778	20	78
3,500,000	6,017	65,682	2,075	23	91
4,000,000	6,877	75,065	2,371	26	104
4,500,000	7,737	84,448	2,667	30	118
5,000,000	8,596	93,831	2,964	33	131

Table 4-4: Colectivo emissions eliminated by Metro expansion and TOD (assuming 13.5 PKT/VKT, and 50% of population abandons colectivos for Metro)

Another possible effect of Metro expansion (with or without TOD) is a reduction in colectivo passenger trip lengths. Next, we look at the effect of Metro expansion on the average colectivo passenger trip length in the entire MCMA (both in areas near the Metro and far from it). Let us assume that the average length of a colectivo trip in the MCMA is reduced from 8.4 kilometers to 6 kilometers. We assume a total of 11,332,927 daily colectivo passenger trips in 2000.⁷⁶ We multiply by 6 kilometers and then by 365 to get 24,819,110,130 annual PKT. We then divide by 13.5 PKT/VKT to get 1,838,452,602 annual colectivo VKT. We then do the same calculation for the current 8.4-kilometer trip length, and the difference between the two is the amount of colectivo VKT lost. Using the same emission factors used in Table 4-1, we get a third less colectivo CO emissions than in Table 3-4. We can also conduct a sensitivity analysis here, examining several trip

⁷⁶ Based on research done by the MIT Mexico City team, which is based on population and GDP figures, as well as COMETRAVI (1999) trip rate estimates.

lengths ranging from the current 8.4 kilometers to as low as 5 kilometers. The results are summarized in Table 4-5.

Colectivo passenger trip length	Annual metric tons of HC saved	Annual metric tons of CO saved	Annual metric tons of NOx saved	Annual metric tons of PM10 saved	Annual metric tons of SO2 saved
5.0	7,886	86,083	2,719	30	120
5.5	6,727	73,424	2,319	26	102
6.0	5,567	60,765	1,919	21	85
6.5	4,407	48,105	1,519	17	67
7.0	3,247	35,446	1,120	12	49
7.5	2,088	22,787	720	8	32
8.0	928	10,127	320	4	14
8.4	0	0	0	0	0

Table 4-5: Colectivo emissions in the MCMA assuming different passenger trip lengths (assuming 13.5 PKT/VKT)

The results indicate that Metro expansion and TOD can eliminate significant amounts of pollutants. The more interconnected the Metro system is, and the more attractive it is, the greater the emission reductions will be.

4.1.3 The Metro and the Three D's of TOD

The area around Metro stations in Mexico City already meets some of Cervero's basic criteria (the three D's mentioned in chapter 1) of what constitutes TOD.⁷⁷

- Density – On the whole, densities near Metro stations are the same as in the rest of the city. There is currently no policy of densifying land uses near Metro stations. That said, the densities found throughout the MCMA are sufficiently high to support TOD, despite the relative lack of high rises. Buildings tend to be closely stacked. In the

⁷⁷ Cervero (1997).

center of the DF, buildings usually have 3-5 floors, and several apartments on each floor. In the EM suburbs, small private houses are often stacked very close to each other. In both instances, the densities are higher than the American “standards” mentioned in chapter 1.

- Diversity – While there is no policy of mixing land uses, they do exist in practice. The downtown area has always had a mix of land uses. Informal commerce near Metro stations provides some of the benefits of mixed land use. While informal commerce is often perceived as a nuisance by middle and high-income people, the poor rely on informal commerce for much of their shopping needs, and can combine some of their shopping with a Metro trip.
- Design – In the center of town the Metro is integrated with the surrounding neighborhoods, but in outlying areas the Metro often runs on the medians of major roads, making access from surrounding neighborhoods possible only via pedestrian bridges. The expansion plan calls for several new lines to be built on road medians. While it is cheaper to build the Metro on a median, it hampers the integration of the line into the surrounding neighborhood, and diminishes the opportunity for land use development in the vicinity of the station.

So, it would appear that TOD is potentially a viable option for the MCMA. The next section examines the institutional capacity for coordinated transportation and land use planning in the MCMA.

4.2 The Institutional Aspect of Coordinated Transportation and Land Use Planning in the MCMA

Strong institutions are necessary to coordinate transportation and land use planning, particularly at the metropolitan level. On the institutional side, the MCMA has some of what is necessary for coordinated planning to work, but there are a lot of problems as well.

4.2.1 Zoning and Property Tax Collection

In the DF, zoning power is in the hands of the delegaciones, whereas property taxes are collected directly by the DF government. In the EM, the situation is similar. Therefore, the delegaciones have no incentive to zone for higher densities near Metro stations, because they do not necessarily get more tax revenues out of it. However, the DF government wields the real power. It not only controls the taxing (and the resulting allocation of money to the delegaciones), but also has a veto on zoning done by the delegaciones. Actually, it is fortunate that the DF government has these powers. If the delegaciones could collect their own taxes (like towns in Massachusetts) and do their own zoning, they would all be competing to build shopping malls and office parks, including in the outermost delegaciones, and the interests of the greater metropolitan area (i.e. mobility, accessibility, equity, environment) would suffer.

4.2.2 Coordinated Metropolitan and Interdisciplinary Planning

Proper coordination of transportation and land use planning requires an institutional effort involving many departments. Mexico has little experience with coordinated land-use and transportation planning or interdisciplinary coordination in general. In particular, the EM is said to have less institutional capacity in this regard than the DF. The transportation planning literature in Mexico City (official transportation plans, government and academic studies of transportation in the MCMA, etc.) sometimes takes note of the prevailing land uses and income levels in different parts of the MCMA, but makes few if any references to coordinated transportation and land use planning, except for attempting to ensure adequate parking supplies for automobiles.

In the MCMA, Transportation, environment and land use are handled by the following organizations:

	Federal Government	DF	EM	MCMA
Transportation	SCT	SETRAVI	SCT	COMETRAVI
Land Use	SEDESOL	SEDUVI	SEDUOP	COMETAH
Environment	SEMARNAT	SMA	SE	CAM

Table 4-6: Transportation, urban planning and environmental organizations in Mexico City

The MCMA already has the beginnings of metropolitan planning organization. In that respect, the MCMA is well ahead of many other cities in the developing world. However, the metropolitan organizations do not have enough powers. They serve a largely consultative role, and have few executive powers (except CAM, which also has some of its own financial resources). For example, COMETRAVI, the metropolitan transportation agency, is paralyzed by the lack of cooperation between the DF and EM representatives. The situation is exacerbated by the fact that currently the DF, the EM and the federal government are controlled by different parties: the DF is run by the PRD, the EM is run by the PRI, and the federal government is controlled by the PAN. Since political power in Mexico was monopolized by the PRI for so many years, there has been relatively little experience of power sharing in Mexico compared to other countries. Figure 4-1 illustrates the political fragmentation.

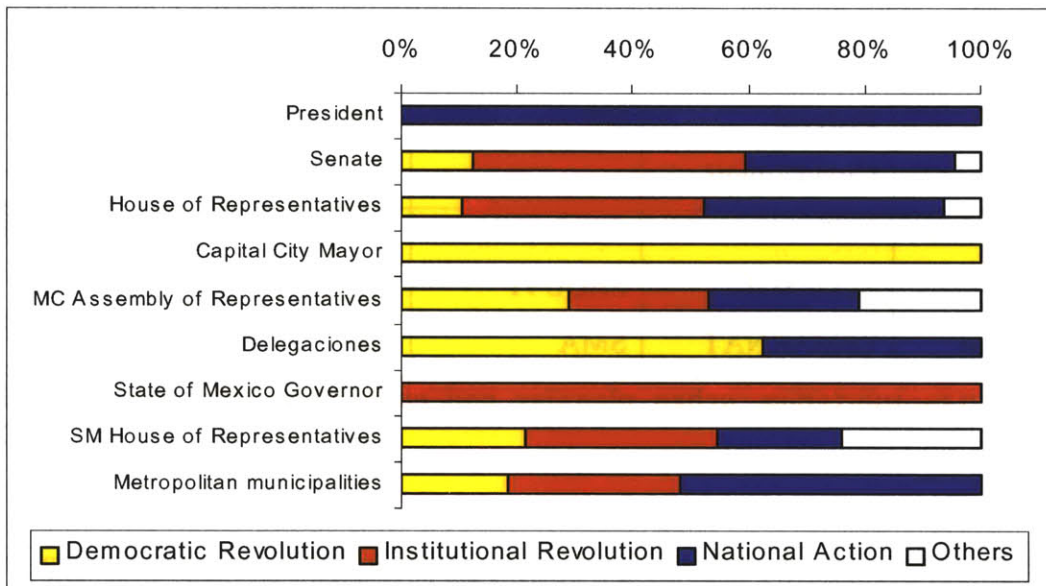


Figure 4-1: Political fragmentation in the MCMA

Source: Talk by Alejandro Villegas at MIT, March 20, 2002

Sometimes, DF government policy seems to ignore the EM’s existence. This was evident with Mayor Uruchurtu in the 1950s and early 60s, who thought he could control the city’s growth by banning heavy industry and squatters, only to have them move to the EM. In more recent times, the DF has been making a rather heavy-handed attempt to encourage downtown development by banning large-scale residential and commercial development anywhere outside the four central delegaciones, without offering sufficient incentives for developers to build in the downtown (which could cost the city money). This policy, like Uruchurtu’s policies, could only cause development to move to the EM, for example to areas like the suburban rail corridor, or in the more distant future to the new roads bypassing the DF or the new airport at Texcoco.

Moreover, there appears to be a competitive dynamic between the DF and EM. The DF is wealthier, while the EM is growing faster and has more available land. The EM would naturally want to increase its tax revenues by attracting big developments, and large projects like the Texcoco airport. This further highlights the need for effective metropolitan level planning. It is the only way to keep sprawl under control. Having said this, accomplishing this integrated planning will be quite difficult.

4.2.3 Other Institutional Problems

Mexico suffers from many of the institutional problems discussed in chapter 2. The political culture is one of single-term officials, who never face reelection, and so have little incentive to meet the demands of the public. There are too many political appointments, and not enough career civil servants. As a result there is a period of disorder in government agencies after each election. Moreover, the high turnover rate leads to low institutional memory and to corruption (because there is less accountability).

4.3 Opportunities for Coordinated Transportation and Land Use Planning in the MCMA

There are four ways in which we can combine land-use and transportation planning to improve mobility and reduce congestion and pollution in the MCMA. They are:

1. Locating affordable housing near unsaturated lines of the Metro and light rail.
2. Downtown redensification through infill and redevelopment (including affordable housing).
3. TOD along the proposed suburban rail alignment near its stations.
4. TOD in the form of real estate development near Metro stations, as well as within the larger ones.

4.3.1 Using Affordable Housing to Enhance Metro Ridership and Improve Equity

Affordable housing, when placed near Metro and light rail stations, can be seen as TOD, since it brings more people to within walking distance of high capacity transit. It can be used to densify areas near transit stations. This option has significant mobility and equity benefits. It can reduce the travel costs of the poor and increase Metro ridership, giving

low-income people a faster, cheaper and more reliable alternative to the colectivos, and allowing them better job opportunities.⁷⁸

If affordable housing and convenient mortgages become more widely available, and if affordable housing can be concentrated near high capacity transit, the Metro could have significant ridership gains, particularly if this is combined with the Metro expansion. For example, in the MCMA there are 1,010,317 people who earn between 3 and 5 minimum salaries (for comparison, a Metro driver typically earns 4-5 minimum salaries, or US\$ 480-600 a month). About half live in the EM. If income thresholds for mortgages were lowered (see section 4.4.1 below), they could benefit from affordable housing. If any significant fraction of them could find housing near a Metro station or in the central delegaciones, the impact on Metro ridership could be significant. Similarly, there are 1,340,392 people who earn between 2 and 3 minimum salaries, half of whom live in the DF.⁷⁹

Clearly, this does not solve the housing problems of everybody, particularly not the poorest of the poor who live in shantytowns, but it still helps a very large segment of the population that wishes to buy housing in the formal sector (as opposed to illegal occupation of land, the so-called “land invasions”) but has trouble finding affordable housing.

4.3.2 Downtown Redevelopment and Redensification

This option is not necessarily TOD, although much of the development proposed here will probably occur near the Metro, since the Metro system is “densest” in the center of town. This option, though, is not strictly aimed at promoting transit. It has several aims:

- To promote NMT.
- To promote infill development and make better use of the land in the center of the city instead of building at the outskirts in areas poorly served by public transportation.

⁷⁸ The following anecdote illustrates the problem. A Mexico City businessman told the author that whenever he interviews job applicants, the first question he asks them is where they live. If they need to take several colectivos to get to work, he will not hire them, because they would never get to work on time.

⁷⁹ INEGI census data online, www.inegi.gob.mx.

- To attract middle class and high-income people back into the city center.
- To revive decaying neighborhoods near the historical center, and to do so equitably, by providing affordable housing, so as to prevent the marginalization of the poor.
- To strengthen the role of the city center as a commercial center and the top trip destination.

This option can be combined with the affordable housing option. It can allow low-income people, who were forced out of the four central delegaciones by the earthquake and rising land prices, to return to a transit-oriented, pedestrian-friendly, and equitable environment, where their transportation costs will be very low.

More affluent people should also be enticed to live in downtown neighborhoods. This could reduce auto trips, and allow people to walk to work in the office towers of the CBD along Reforma and to be closer to downtown cultural life. The main barrier to this is the high crime rate in the downtown area, which creates an intimidating atmosphere for middle class and wealthy people.

Within the downtown area of the DF, urban redevelopment can consist of mixed high-density commercial and residential development along existing Metro lines, e.g. construction of high-rise office towers with adjacent shopping malls.

Downtown redevelopment can attract people of all social classes. Office towers, for example, draw people of all social classes, from the wealthy executives sitting in their office on the top floor to the low-income people who clean their windows, and all the people in between. Similarly, shopping malls attract both customers and employees. Since the Metro system is downtown-oriented, it will be easy for low-income people to get to work, and if we combine this with the Metro expansion into the EM, they will have few, if any, transfers to colectivos, thereby reducing their travel time and expenses, and reducing congestion and pollution. In addition, as congestion increases, we want to provide middle-class people with an opportunity to live in the center of town, where

public transportation, including the Metro, is more effective, and walking is a viable option. This will eliminate many auto trips.

4.3.3 TOD Around the Proposed Suburban Rail

The suburban rail project (background in chapter 3) poses some interesting challenges and opportunities for TOD. The first line to be built, the Buenavista – Cuautitlán – Huehuetoca line, is located on an existing rail right-of-way in an area that has pockets of affluence. Its alignment runs through a declining industrial area, and passes near some middle class and high-income suburbs, but does not really enter them. Its operators (it will be privately operated) plan to charge a high fare and to market it as an alternative to the perennial traffic jams that plague the northwestern entrance to Mexico City, touting the 1.5-hour time savings. It is an interesting attempt to provide public transportation for the automobile-owning middle class. While the middle class perceives the Metro as an inferior good, a crowded, intimidating place, and a place for the poor, the suburban rail offers an opportunity to create a different transit product aimed at middle class people.

There are many opportunities for real estate development along the alignment. Already there are attempts to turn the old industrial areas along the alignment (in Delegación Azcapotzalco and in the EM Municipio of Tlalnepantla) into a high-tech area. The planners of the line mention the development possibilities of the line's DF terminus at Buenavista, which used to be the main passenger railroad station in Mexico City back when there were intercity passenger rail services.⁸⁰ Buenavista lies on the fringe of the downtown area, and the suburban rail could bring a lot of new development to the area. There is an opportunity to create a development corridor for middle class people, with housing, commerce, jobs and entertainment, with the rail line as the backbone. People who live in the vicinity of the lines may use their cars less. In addition, there could be American-style park-and-ride lots and shopping opportunities at stations for middle class commuters who come from nearby suburbs.

⁸⁰ SCT (1999).

4.3.4 Real Estate Development Near Metro Stations

Another potential TOD opportunity is station development involving the private sector. In some parts of the world, like Hong Kong and Tokyo, there is considerable private involvement in the construction and operations of Metro stations. Mexico City has some very busy stations. As shown in Table 3-9, about 350,000 people board the Metro at Pantitlán every day, and about 150,000 each pass through Indios Verdes and Cuatro Caminos. Pantitlán is also a major bus terminal. Smaller stations located in the downtown area also offer opportunities. A private owner or operator can build offices, housing, shopping arcades, etc. Commercial development, for example, does not necessarily have to be an upscale mall. It just has to be better organized than it is today, and less of a nuisance to passengers and vehicles. Regulating and organizing station commerce will improve the users' feeling of safety, making the operation of the station more efficient, and generally improving the image of the Metro system. A private owner can further improve safety by employing private security guards in the stations, since the police in Mexico have an image problem. A private owner or operator can even operate some private feeder bus or colectivo service to surrounding areas.

4.4 Implementation of the Policy Options

The following section examines issues concerning the implementation of the options outlined above. These issues include feasibility, geographical scope, coordination with the planned expansion of the Metro and light rail systems, possible combinations of the options, and actions that need to be taken by the local governments of the MCMA to implement these options and reap the greatest possible benefits from them. Table 4-7 summarizes some of these issues. In general, the broader the geographical scope, the more government involvement is necessary, and the larger the potential impact can be.

Policy Option	Geographical Scope	Implementation Issues
Affordable housing near Metro and light rail	Station-area, or corridor, or citywide	<ul style="list-style-type: none"> • Willingness by government or private sector to build affordable housing • For citywide effect, metropolitan coordination is needed • Availability of land • Capacity on Metro
Downtown redevelopment	The four central delegaciones of the DF	<ul style="list-style-type: none"> • Availability of land • For greater effect, affordable housing is necessary
TOD along suburban rail	Station-area or corridor	<ul style="list-style-type: none"> • Availability of land • For corridor-wide effect, metropolitan coordination is needed • Private sector interest • High ridership on suburban rail will bolster private sector interest
Station area development near Metro	Station-area	<ul style="list-style-type: none"> • Availability of land • Private sector interest • At the largest stations, possible confrontation with informal commerce

Table 4-7: Geographical scope and implementation issues for coordinated transportation and land use options in Mexico City

Figure 4-2 shows possible locations for TOD along the Metro, light rail and suburban rail. The Metro network on this map is the one projected for 2009. It does not show the entire projected Metro and light rail network.

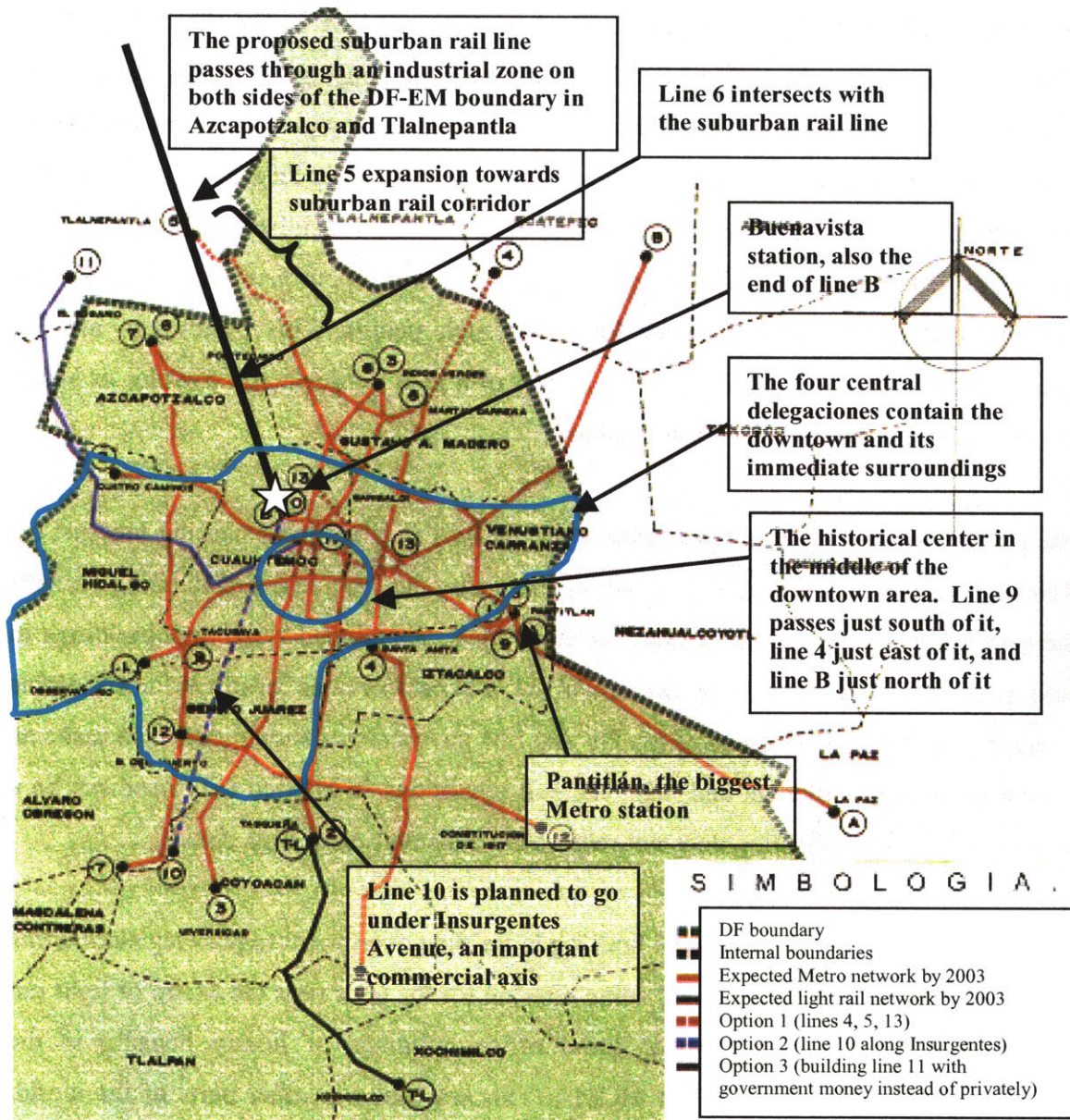


Figure 4-2: Possible locations for TOD along the Metro, light rail and suburban rail

Source: STC (1999), *Plan de Empresa, 2000-2006*

4.4.1 Affordable Housing Near the Metro and Light Rail

This option is the most expensive to implement and requires the most commitment and investment by the government, but it can also have the most dramatic impact if implemented across the entire MCMA.

In an ideal situation, the governments involved (DF and EM in coordination with the federal government – depends where the funding for the housing is coming from) would issue ordinances that require that all or most affordable housing projects in the MCMA be built within walking distance of a Metro station, or in a centrally located, highly walkable area like the downtown. Government funds that provide subsidized mortgages should adopt a policy of either providing money only to people who purchase housing near high capacity transit, or, offering better loans for such people. This policy can also be implemented in the DF or EM alone, or as part of a plan for a specific corridor or Metro station, but the effect would be less dramatic.

Since there is much underutilized land in the MCMA (e.g. open-air parking lots just off Reforma Avenue, or buildings made uninhabitable by the 1985 and still standing vacant), there should be little difficulty locating empty lots, abandoned buildings, buildings in serious disrepair that have to be torn down, etc. that can serve as locations for affordable housing projects. One of the steps the DF and EM governments should take is to make an inventory of such buildings and lots. The soil conditions in Mexico City need not be a major concern. Densification does not require the construction of high rises.

Another way of building affordable housing is for the government to pass legislation that requires private developers to build some housing for the poor near the Metro or light rail in exchange for allowing them to build office buildings or luxury housing in the downtown or in other parts of the MCMA. This was done in other parts of the world. Many housing projects in the US were built that way in the 1950s (although there many social problems associated with them, and many were subsequently torn down, but this does not necessarily have to be the case in the MCMA).

The main problem with implementing the affordable housing option is that currently the government does not want to spend money on public housing.⁸¹ In the 1970s, the government was heavily involved in public housing. Government agencies and funds

⁸¹ GDF (2000). Also Martha Schteingart.

supplied housing to various sectors. INFONAVIT was aimed at working class people with a job in the formal sector, FOVISSTE at middle class state employees, FONHAPO at low-income people who did not necessarily work in the formal sector, FOVI at middle-class people.⁸² In the beginning, these agencies really served their target publics. However, as the economic situation worsened in the 1980s, and the government became increasingly neo-liberal, the housing funds ran out of money and toughened their mortgage criteria, and it became more and more difficult for low-income people to get public housing. FOVI, for example, only serves people who make more than 6 minimum salaries, and for that they get an apartment of 45 square meters (450 square feet), while in the past the limit was 3 minimum salaries. INFONAVIT demands at least 5 minimum salaries. INFONAVIT, which was aimed at low-income people, now caters to the middle class.⁸³

Public housing is aimed almost exclusively at homeowners. There is little public housing for renters, as opposed to the situation in the United States. The private sector mostly stays away from affordable housing. Commercial buildings and luxury residential developments are much more lucrative and safer. However, some private companies do specialize in affordable housing, often working together with funds like INFONAVIT. Unfortunately, most of them operate outside the MCMA, where it is much cheaper to build houses. INVI, a housing agency run by the DF government, offers assistance to people who earn at least 3.7 minimum salaries, but gives priority to repairing existing houses, although it also builds new ones.⁸⁴

The new idea of the location efficient mortgage might help in Mexico City. It can help the poor afford public housing. For them, the effect of TOD on transportation costs and ability to repay a mortgage is a lot more dramatic than it would be for middle-class Americans, because the poor in the MCMA spend so much more of their income on transportation. It can make the banks and housing funds more willing to lower their income requirements, assuming that they recognize the central claim of the proponents of

⁸² Ward (1998).

⁸³ GDF (2000).

⁸⁴ Ibid., and also Ward (1998).

the location-efficient mortgage, i.e. that people who live near transit or in walkable communities have lower transportation costs and therefore tend to be lower credit risks.

In planning these affordable housing developments, the government could think ahead and place limitations on parking spaces in new affordable housing projects, and thus establish early control over the supplies of parking before the majority of the population can afford to own an automobile. The best way to place parking limitations would be by internal policy changes within government housing funds like INFONAVIT (i.e. they will amend their policy so that all future housing projects they are involved with will have limits on the amount of on-site parking).

As for location, affordable housing should be placed near lines of the Metro that are not saturated or lines that are under-performing. This basically includes all lines except lines 1, 2, and 3. However, location decisions should be made while keeping the future Metro expansion in mind, and the changes it might cause in demand. Depending on which lines actually get built, lines 1, 2, and 3 might become decongested, while other lines might become saturated. For example, the Metro and Light Rail Master Plan claims that once the entire expansion is completed, line 8 would have the highest ridership, at 1.289 million passengers a day (compared to the current situation, where lines 1, 2, and 3 each carry about 750,000 passengers a day).⁸⁵ Affordable housing can also be developed in conjunction with some of the other options, and additional location suggestions are provided in the following sections.

The lack of political will to spend large amounts of money on subsidies for affordable housing means that this policy is not very likely to be implemented in the short term, at least not on a citywide scale. Nevertheless, the institutions involved (government ministries, governmental housing funds, etc.) should plan to adopt and gradually phase in a Metro station-proximity requirement for future housing projects that they fund, even if currently there are not many projects in progress. It is always possible that a future government will show more willingness to build affordable housing, and hopefully by

⁸⁵ SETRAVI (1996), and also COMETRAVI (1999), volume 4.

then the institutional foundation for large-scale citywide transit-oriented affordable housing projects will be ready.

4.4.2 Downtown Redevelopment

Current downtown redevelopment projects mostly involve commercial high rises and a few luxury housing developments. Government intervention is necessary in order to reverse the ongoing decline in downtown population. The DF government has already shown interest in downtown redevelopment. As was previously mentioned, it has tried to ban large-scale developments outside the four central delegaciones (Cuauhtémoc, Benito Juárez, Miguel Hidalgo, and Venustiano Carranza). However, unless accompanied by incentives for developers to build in the downtown area, they are likely to build in the EM instead.

The DF government, together with the local administrations of the four central delegaciones, need to design a downtown development plan that will include minimum density requirements (to get rid of phenomena like open-air parking lots and gas stations in central areas like Reforma Avenue), and also tax breaks and higher floor-area ratios for developers who build mixed use developments or provide affordable housing. There are many abandoned buildings in the center of town (many abandoned after the 1985 earthquake). The city should also consider acquiring abandoned buildings in the downtown area and either building affordable housing on those sites or selling them to private sector investors below market prices on condition that they build mixed use developments at certain minimum densities.

In addition to redevelopment of the entire downtown area, there are also specific development opportunities along Metro lines in the area. Metro lines passing through the four central delegaciones (i.e. the area containing the downtown and its immediate vicinity) can be targeted for affordable housing development. The government can also encourage the creation of commerce and service-sector jobs along those Metro lines in order to increase ridership on them. For example, line 4 has the lowest ridership of any

Metro line. It passes through mostly residential neighborhoods just east of the historical center. If the government could give incentives for commercial development along line 4, more jobs could be created along that line, thus creating trip destinations and increasing ridership. Similarly, line 9 passes through the downtown area south of the historical center, and is not saturated. Line B passes north of the historical center through a run-down area that could be revitalized to provide housing and jobs. The proposed suburban rail line will have its DF terminus in Buenavista, just north of the current CBD. Development there could be integrated with overall downtown redevelopment. The government could also change Metro expansion plan so that the construction of line 10 is given a higher priority. This line is planned to run along Insurgentes Avenue, which is one of the main commercial axes of the city and has a lot of colectivo traffic along it.

4.4.3 TOD along the suburban rail corridor

Since at present not many people live next to the proposed Buenavista – Cuautitlán – Huehuetoca suburban rail line, TOD is in the direct interest of the concessionary that operates the line. The amount and income level of people who move to new developments near the stations will be important to its success, and will help determine the ridership profile of the suburban rail, and the fares it can charge.

That, in addition to the location of the suburban rail line along the main entrance to Mexico City from the northwest (and parallel to the congested Periférico highway) makes it likely that some real estate development will occur. The suburban rail plan already mentions the real estate potential of Buenavista terminal on the DF end of the line. However, the potential for real estate development is much larger than just the Buenavista terminal. Real estate development could occur along the entire suburban rail corridor. In order for real estate development to occur on a corridor-wide level, the DF and EM governments, together with the local governments of the relevant municipios and delegaciones, need to prepare a joint development plan for the suburban rail corridor, which will offer incentives to developers, such as permission to build extra floors, tax breaks, parcel assembly, etc. The government should make an inventory of property

along the tracks that is owned by the Mexican National Rail Company (Ferrocarriles Nacionales). They have potential for joint public-private developments.

New jobs created along the suburban rail corridor could also attract low-income commuters from the eastern MCMA, and thus increase ridership on Metro lines 5, 6, and B that reach the suburban rail corridor (line 5 will reach the corridor after it is expanded). In fact, this option can be combined with the affordable housing option. Affordable housing can be built along lines 5, 6, and B to provide low-income people a short and fast commute to jobs along the suburban rail corridor. The Metro master plan should be modified to give higher priority to the expansion of lines 5 and 6. Priority should be given to real estate development along the intersections between the Metro and the suburban rail line.

4.4.4 Real Estate Development Near Metro Stations

Station-area development is probably the easiest option to implement, because it does not involve too many institutional actors. It is very desirable for the STC (the DF-government-owned company that operates the Metro). Involving the private sector in the operation of Metro stations can bring considerable financial benefits to the cash-strapped STC, increasing its revenues and reducing its dependence on government subsidies. This also makes this option desirable for the DF government.

The biggest potential obstacle to real estate development at Metro stations is that the street vendors at the stations may feel threatened by this kind of development. The informal commerce sector currently dominates many of the larger stations, and will probably resist attempts to displace it or compete with it. In smaller stations this is less of a problem. It is, of course, entirely possible that a compromise agreement could be reached with the informal commerce sector at the larger stations. Another potential obstacle is that the soft soil may make the construction of high rises above Metro stations very expensive. This is less of a problem in the western, hillier part of the city.

The planned expansion of the Metro holds great potential for station-area development. Development can be done while stations are under construction, before informal commerce can “settle” in the new stations. TOD in newly built stations is thus the most promising option for coordinated transportation and land use planning in the short term, because it offends no one and brings revenue to the STC, thus saving money for the DF government.

To aid implementation, the next version of the Master Plan should include an analysis of the real estate development opportunities of each new station, and the STC should aggressively seek private-sector partners for such development, similar to what WMATA did in Washington, DC (see chapter 1). In the future, stations and the accompanying TOD should be planned and built at the same time in order to reduce planning and construction costs and to achieve better physical integration between the station and the development. The STC should also examine the real estate opportunities of other properties it owns.

Potential areas for real estate development include Metro stations near the suburban rail alignment, for example the planned new terminus of line 5 at Tlalnepantla, and in Metro stations (both existing and planned) in the western part of the MCMA, where land values are high.

4.5 Chapter Summary

The measures outlined above require different levels of government involvement. Greater government involvement can lead to a greater impact on the urban form of the MCMA and on the modal split. The MCMA has some of the foundations for TOD, such as adequate population densities, a Metro system with 11 lines, and embryonic metropolitan planning organizations. However, much more needs to be done to create a more transit-oriented urban form.

The next chapter provides a summary of this study and its main conclusions, and makes some recommendations for future research.

Chapter 5: Conclusions

Having examined the possibilities for coordinated transportation and land use planning, the concluding chapter of this thesis provides a summary of its main arguments and findings, and offers suggestions for further research.

5.1 Summary

5.1.1 Anti-Sprawl Measures and Transit-Oriented Development (TOD) in the Developed World

In the United States, planners in recent decades have sought to contain suburban sprawl and its negative social, economic and environmental effects. A series of interrelated policies and ideas have been developed, including downtown revitalization, urban growth boundaries, New Urbanism, “Smart Growth” and Transit-Oriented Development (TOD). These policies share a desire to use existing land resources more efficiently, reduce auto trips, promote non-motorized travel (walking and biking), and increase transit ridership.

The three main principles of TOD are called the “Three D’s”: Density of residents and jobs near transit stations; Diversity of land uses (residential, commercial) near stations; and Design, i.e. urban design elements that make the station more integrated with the surrounding area and more accessible to pedestrians and bicyclists. TOD can work given the following conditions: an extensive transit system that covers a large part of the city; government organization with planning and taxation powers concentrated above the level of the single town (i.e. at the metropolitan or regional level); government incentives to developers; most importantly, the local economy and real estate market have to be strong. TOD is a controversial topic in the US, with critics saying that the required population densities would be higher than what most Americans would tolerate, and that some measures advocated by TOD supporters and New Urbanists, like mixed land uses and a grid street pattern, would actually encourage auto use.

In the US, TOD has succeeded mostly at the single transit station level, and has not made an impact at the metropolitan level. Most Americans still live in auto-oriented suburbs, and many do not even work in the city centers that are served efficiently by high-capacity transit. In Washington, DC there are several successful examples of TOD at the station level. In Europe, gasoline is more expensive, central governments have more power, are more directly involved in the planning process, and invest more money in transit. While suburban sprawl exists there as well, auto use tends to be lower, and transit and non-motorized travel have higher mode shares. Stockholm is an example of successful TOD in Europe.⁸⁶

The next part of the thesis examined whether TOD (and other forms of coordinated transportation and land use planning) would be useful and feasible in the developing world.

5.1.2 The Prospects for Coordinated Transportation and Land Use planning in the Developing World

In the developing world most people are poor and do not own automobiles. The cities are growing rapidly, and many of the poorest people live on the outskirts, where they depend on expensive low-capacity transit, and thus spend a great share of their low income on transportation. This diminishes their economic opportunities. Mixed land uses still prevail in the centers of the cities, including apartments, commerce, both formal and informal, and in some places also light industry.

These conditions also present opportunities for TOD and other methods of coordinated transportation and land use planning. With proper planning, the urban form of rapidly growing cities can be designed to be transit-oriented. This can slow down the onset of motorization and sprawl, and mitigate their effects. This can also have beneficial socio-economic and environmental effects, by concentrating the population along corridors of high-capacity transit, which has lower operating costs and emissions per seat, and can charge lower fares.

⁸⁶ Cervero (1998).

Although the opportunities are great, there are some serious barriers to TOD in the developing world. Planning institutions are less developed and have fewer resources than their counterparts in the developed world. Interdisciplinary planning and metropolitan planning are poorly developed in most places. Nevertheless, successful TOD is possible in the developing world. Curitiba, Brazil is a prime example of coordinated transportation and land use planning on a citywide level. This city has been dominated for 20 years by Jaime Lerner and his team of architects and planners. It has a strict zoning code that concentrates growth along transit corridors and prohibits high densities elsewhere. It also has an efficient bus rapid transit system that emulates a metro system for a fraction of the cost. While Curitiba is a lot smaller and less complex than Mexico City, it still offers valuable lessons, especially its use of zoning and the attention given to equity issues.

5.1.3 The Prospects for Coordinated Transportation and Land Use Planning in Mexico City – Key Findings and Conclusions

Mexico City has many of the prerequisites for TOD. It is densely populated, despite the lack of high rises, although it could perhaps be denser, particularly the downtown areas. The center of the city has mixed land uses. In fact, the informal commerce present at many Metro stations provides many of the benefits of mixed land use, since the poor, who are the majority of Metro riders, can use it for shopping on their way to and from work. While urban design around Metro stations is not very developed, and some stations are located in highway medians, most stations are easily accessible from the surrounding neighborhoods.

Mexico City has an extensive Metro system with the lowest operational costs of any major world Metro. It may not be extensive enough, and does not go far enough into the EM, where half the population lives, but it is still one of the world's largest systems, one that many other cities can only wish for. Still, the system needs to be expanded in order to stem the use of colectivos (a form of low-capacity informal public transportation which is more expensive than high capacity transit) and their emissions, and to reduce the travel expenses of low-income people living on the outskirts. Currently, the busiest

stations in the system are those that are located along the DF-EM boundary. The downtown is still the main destination of trips in the MCMA, and the busiest lines are those that pass through it. However, due to disagreements between the DF and the EM over financing of Metro expansions, the next phase of expansion will occur exclusively in the DF, even though the EM is where expansion is needed most. Line B, which does go into the EM, has so far performed very well, and has eliminated some colectivo trips.

The MCMA has some of the institutional structure required to support coordinated transportation and land use planning, but a lot more needs to be done. There is insufficient interdisciplinary planning. There is a metropolitan transportation planning organization (COMETRAVI), but has little power. Zoning in the DF is in the hands of the delegaciones, while the DF government collects property taxes and has veto over zoning decisions. This situation is not a bad situation for TOD and other coordinated planning measures if the DF government decides to pursue such a policy. It prevents the delegaciones from pursuing their own interests (e.g. attracting big office development) at the expense of the interests of the rest of the city (e.g. mobility, accessibility, equity, environment).

Coordinated transportation and land use planning at the metropolitan level is the key factor in maintaining control over the urban form of the MCMA.

The urban development trends in the MCMA highlight the need for greater coordination between transportation and land use planners, as well as between the DF and the EM. Recent urban growth in the MCMA has concentrated in the EM and outer delegaciones of the DF, while heavy industry has been moving out of the MCMA. American-style shopping malls and office parks have been built in the more affluent western areas, often without adequate transit access. The EM's ambitious transportation plan includes interstate roads that bypass the DF, as well as a new airport in Texcoco. These will have profound impacts on the urban form of the MCMA, and could lead to further sprawl, which in turn could result in longer and more numerous colectivo and automobile trips

and diminish the effectiveness of the Metro system, which is ill suited for a polycentric urban form.

Time is fast running out for exercising control over this expected growth. A metropolitan government with zoning powers is necessary in order to control the urban form of the metropolitan area and facilitate the provision of high-capacity transit, while taking into account the economic interests of both the DF and EM. It is also necessary that this organization employ more career civil servants, in order to provide continuity across administrations, improve institutional memory and strengthen the organization.

There are many opportunities for coordinated transportation and land use planning in Mexico City. The Metro can serve as a backbone for efforts to redensify the downtown and create infill development there, thereby containing sprawl. Station-area development, like that done in Tokyo and Hong Kong, is also an opportunity, although it cannot be done in the larger stations without the consent of the powerful informal commerce sector.

There are opportunities for TOD along the proposed suburban rail line in the northwestern part of the MCMA, which will be privately operated. The suburban rail line will run through decaying industrial areas and near middle-income neighborhoods. There are already plans for real estate development near Buenavista station in the DF, and these can be expanded to the rest of the alignment.

Affordable housing presents a big opportunity. Ideally, the government can require that all new government-sponsored affordable housing projects in the MCMA be located near the Metro, light rail, or suburban rail. There is currently a shortage of affordable housing in Mexico City, but it will be necessary in order to densify low-income neighborhoods and encourage people to return to the central delegaciones. Government housing funds like INFONAVIT are supposed to help the poor buy houses, but they are too expensive for most poor people, and are used more often by middle-income people. However, a new concept, the Location Efficient Mortgage (LEM), could help here. The

LEM, which is now offered in several American cities, is based on the assumption that people who live in walkable, transit-oriented neighborhoods spend less money on transportation, and thus have a better debt-to-income ratio. These people can thus become eligible for mortgages, or can afford higher mortgages than they could otherwise. Low-income Mexicans probably spend more of their money on transportation than lower middle-class Americans, and could probably benefit from LEMs if they were offered in Mexico City.

The various options require different levels of institutional effort and commitment. A policy of locating all new affordable housing near the Metro probably has the highest potential impact, but is also the most expensive, requiring a large investment in affordable housing and subsidized mortgages. Downtown redevelopment requires a downtown redevelopment plan and incentives (tax breaks, construction bonuses, parcel assembly) for developers. TOD along the suburban rail alignment requires incentives as well as a corridor plan. Station-area development at Metro stations probably requires the least institutional effort but can still have significant impact.

Each option can have some local impact without extensive government involvement, but can have larger impacts if the government does become involved. Government commitment to building affordable housing, and locating most or all of it near Metro, light rail or suburban rail stations could lead to a significant increase in Metro ridership. If this housing is located near underutilized Metro lines, it could increase ridership on those lines and help alleviate congestion on the saturated ones. Downtown redevelopment is already occurring, although it is mostly confined to commercial high rises and hotels, but with government involvement in the form of affordable housing and incentives for mixed use, it can halt the depopulation of the central city. Some development will probably happen along the suburban rail alignment, for example in Buenavista. However, metropolitan coordination in the form of a joint DF-EM suburban rail corridor plan can significantly increase the potential for the development of a transit-oriented corridor along the suburban rail alignment. And the addition to the Metro Master Plan of a detailed study of real estate opportunities in Metro stations, in addition to aggressive

marketing of these opportunities, can make possible their development, bring money to the STC and reduce its dependence on subsidies from the DF government.

If more people can be concentrated near Metro stations through an expansion of the system and a policy of locating housing and other developments near it, the equity and environmental effects can be great. People who have the option of using the Metro without a colectivo feeder trip have significantly lower transportation expenses. They are not affected by road congestion, and can reach their destination more quickly and predictably. This could increase their job opportunities. In short, TOD can be a great force for equity in the developing world. As Curitiba and Bogotá show, an expensive Metro is not necessary in order to have an extensive high-capacity system in smaller cities.

The ideal urban form created by coordinated transportation and land use planning would preserve the importance of the downtown area and channel development outside that area into corridors served by the Metro, light rail or suburban rail for maximum accessibility by people of all income levels.

On the environmental side, TOD can significantly reduce colectivo-related emissions (like CO) by eliminating and/or shortening colectivo trips. However, the most significant environmental effect of TOD is indirect and long-term – creating a transit-oriented urban form, where people will continue using high-capacity transit (at least for the trip to work) even after they can afford an automobile, thereby mitigating the increase in pollution that accompanies motorization. That was one of the main achievements of Curitiba, where 75% of the population still commute to work by bus, even though it has Brazil's second-highest auto ownership rate. Much of that was due to the fact that Curitiba was able to control its growth and was that able to control the supply of parking spaces. As part of a policy of transit-oriented affordable housing, Mexico City can include limitations on parking supply before the residents can afford automobiles thereby averting political backlash.

TOD probably cannot turn back the clock for people who already own a car. This is because the Metro is perceived as a mode for the poor (which is currently largely true), and because the auto is such a status symbol in Mexico. Middle class people do not return to transit unless congestion becomes extreme (the case in places like New York, and a definite possibility in the MCMA). TOD is not a cure for congestion. It can be thought of more as a vaccine, mitigating the amount of future congestion by slowing down the pace of motorization. Nevertheless, the suburban rail project offers an opportunity to provide transit service for middle class people. Its first line is located at the northwestern entrance to the DF, which is a highly congested corridor, and will only get worse with time.

The most pressing needs of Mexico City are environment, mobility, accessibility and equity. TOD could potentially address all these issues. TOD can be an important component in an overall pollution reduction strategy. Pollution reduction strategies that depend only on reducing tailpipe emissions will not solve congestion and equity problems. Even if clean, zero-emission automobiles and colectivos could be introduced, they will just end up stranded in clean, zero-emission gridlock in the not-so-distant future. TOD will enhance accessibility by ensuring that important trip destinations are located near high capacity public transportation.

5.2 Recommendations for Further Research

There is a strong need for more quantitative research on the way transportation, land use and the environment affect each other in the MCMA. SETRAVI, the transportation department of the DF, possesses travel demand software and has GIS data about the transportation system. There is currently no land use – transportation model for Mexico City. The costs of constructing such a model for a city of this size are very large. Nevertheless, the model could be very helpful to planners.

Future quantitative research is needed on the costs of sprawl. This research could use one of the methodologies evaluated by the US EPA for estimating the transportation and environment impacts of large urban development projects if they are built at different

locations. Essentially, these methodologies compare the environmental costs of infill projects versus “greenfield” projects (i.e. projects that are built on rural land at the fringes of the metropolitan area). They are the following:⁸⁷

1. This method assumes that if the infill project does not occur, growth will occur at one or more specific greenfield sites. Run a four-step travel demand model twice: once assuming the development (represented by the number of jobs and dwelling units it creates) occurs at an infill location, and then again assuming that it occurs at a specific greenfield site. Enter each set of results into an emission model like MOBILE. This methodology is limited because the greenfield site is chosen subjectively and arbitrarily.
2. This method assumes that if the infill project does not occur, growth will be dispersed among the 20 fastest growing travel analysis zones (TAZ). Run the model twice: once assuming the development occurs at an infill location, and then again assuming that it is dispersed among the 20 fastest-growing TAZ. Enter each set of results into an emission model like MOBILE. This method is a lot more objective (the infill site could be located in one of the 20 TAZ), although using 20 fastest-growing TAZ is also arbitrary.
3. This method assumes that if the infill project does not occur, growth will be dispersed throughout the region according to the local land use model. Run the land use model twice: once with constraints that represent the infill location, and once again with no such constraints. Enter the transportation outputs into an emission model. This is the most objective method, but it requires that the city in question have a regional land use model.
4. This method assumes that if the infill project does not occur, growth will be dispersed proportionately to all other future growth in the region. Estimate the growth of trips and their associated emissions in the metropolitan area over a certain time period. Calculate VKT and emissions per each new job or dwelling unit. Multiply these factors by the number of jobs and dwelling units created by the infill development, to obtain new VKT and emissions if the growth associated with the infill project occurs

⁸⁷ EPA (2001).

elsewhere. During the next stage, using future population and infrastructure development projections, run the four-step model twice: once with the infill project and once without it. The difference between the outputs yields the new VKT and emissions created by the infill development. Compare these with the VKT and emissions calculated at the previous stage. This method is quite objective, but it assumes that factors like trip rates and modal splits will remain constant or predictable over time.⁸⁸

In Mexico City, these methodologies can be used to compare the environmental costs of development projects along the Metro, light rail or suburban rail with the costs of doing those developments elsewhere. Since Mexico City has no land use model, and since the modal split, trip rates, and auto ownership rates are still evolving, it would seem like the second method would be the best one for Mexico City. If an investment is made in a land use model, then the third method should be used.

More research is also needed on travel patterns and trip chaining in the developing world, particularly those of low-income people. These are likely to be quite different from those in the developed world. This is important since most land use and transportation models were developed in the developed world, and make many assumptions that might not be valid in the developing world.

5.3 Final Word – Contribution to Research

Mexico City is facing an acute crisis of mobility, equity and environment. Its urban form is threatening to sprawl out of control, even though Mexico City, due to its geographic situation in a high-altitude bowl, is one of the places that can least afford uncontrolled sprawl. Coordinated land-use and transportation planning offers a significant measure of control over the urban form and the modal split. While it is difficult to achieve, and requires infrastructure investments and sophisticated government organization, it is absolutely necessary in order to avoid the impending gridlock and unmitigated sprawl.

⁸⁸ Ibid.

Mexico City has many of the prerequisites for this, and is somewhat better situated than other cities to achieve it.

There is relatively little research about coordinated transportation and land use planning in the developing world. Most research on methods like TOD has focused on developed countries, especially the United States. Moreover, there is little research on the subject in Mexico City. The transportation literature in Mexico City makes very few references to land use issues, and says almost nothing about coordinated planning. The author hopes that this thesis sheds some light on the subject by presenting solutions used in the developed world, examining them in the context of the developing world, and attempting to apply them in the case of Mexico City. The author also hopes that this research will be useful for people contemplating the use of similar policies elsewhere in Latin America and the developing world.

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