METROPOLITAN MEXICO CITY MOBILITY & AIR QUALITY

White Paper

FOR THE
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URBAN, REGIONAL AND GLOBAL AIR POLLUTION

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I. INTRODUCTION

As cities grow in population, area and wealth, their transportation systems inevitably become more complex, with more people and goods traveling greater distances to more dispersed origins and destinations. This complexity not only challenges the primary objectives of transportation – providing residents access to jobs, education, and other daily needs and wants and facilitating the exchange of goods and services – but it also gives rise to a host of environmental, financial, and social constraints which often inhibit transportation system development. Furthermore, as populations swell and activities spread, additional problems arise stemming from the need for multi-institutional, multi-jurisdictional, and multi-governmental coordination for system planning, development, operations, and management.

The case of the Mexico City Metropolitan Area (MCMA) offers an illuminating case study of these complications. Over the past half century the city has grown tremendously - Mexico City is today one of the world's five largest cities. It also holds the dubious distinction of being one of the worlds' most polluted cities, suffering from dire air pollution problems for much of the year. To help alleviate the city's air pollution problem, MIT recently launched the Integrated Program on Urban, Regional and Global Air Pollution, a multi-disciplinary initiative being led by MIT Professors Mario Molina and Greg McRae, and involving a number of universities, consultants, and government agencies from Mexico and the United States. This paper has been developed within the context of the Integrated Program.

While this paper was developed with a particular eye on transportation-related air quality issues, its ultimate scope extends – necessarily – beyond air pollution, since only through a careful consideration of all aspects of the metropolitan region transportation system can viable long-term mobile source emission reduction measures be compared and ultimately implemented. Transportation pollution control measures simply cannot be developed without a broad understanding of the larger transportation-land use system of the city.

To facilitate such an understanding, this paper broadly profiles the MCMA's transportation system, providing:

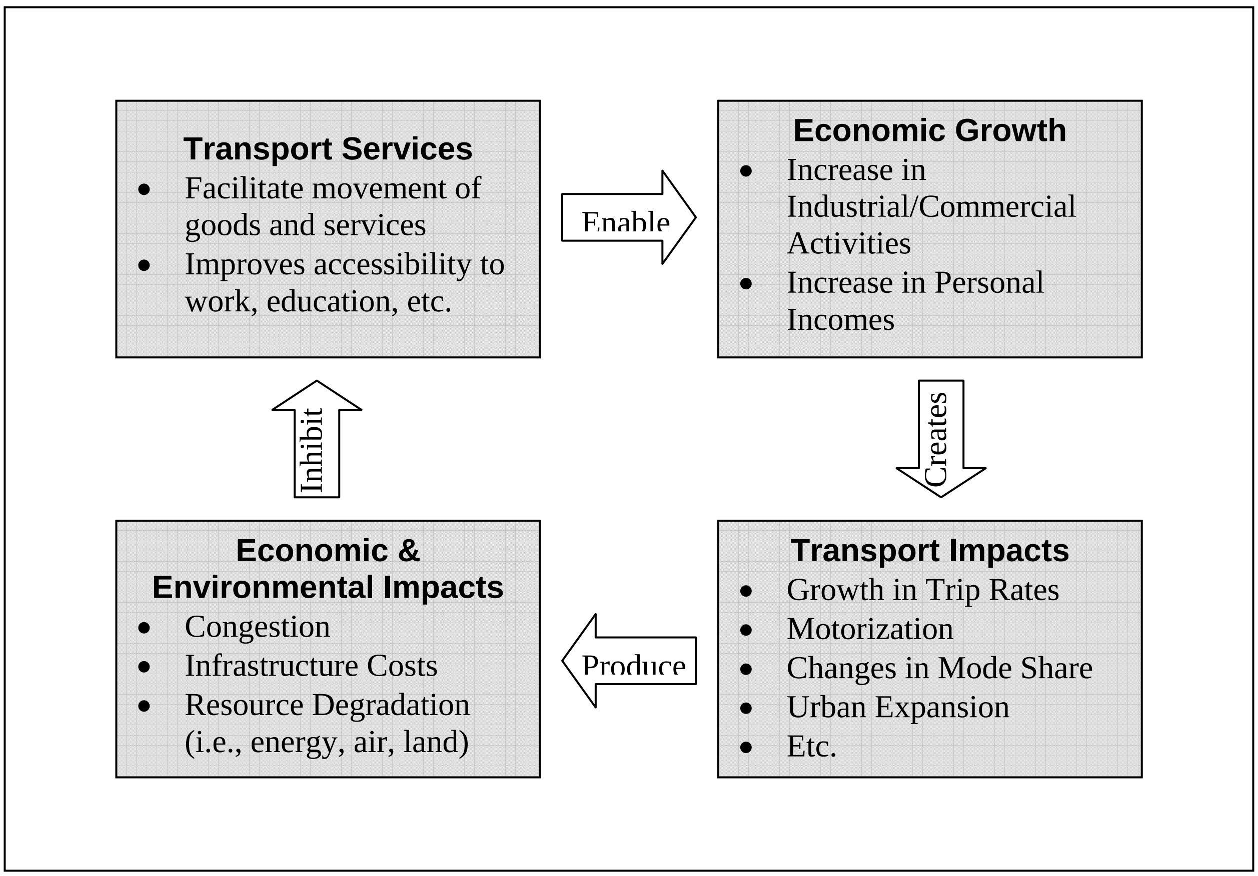
- a background on socio-economic growth and land development over the last half century;
- a general characterization of traveler and freight transportation demand, by mode;
- an inventory of transportation supply, including infrastructure, vehicles, and levels of service;
- a brief overview of air pollution and other negative effects of the city's transport system;
- a description of responsibilities, relationships, and dynamic issues among the relevant institutions; and
- a review of current transportation-land use plans.

Drawing from this profile, the paper concludes with a categorization of the major problems confronting the city from a transport-environment perspective and a presentation of general recommendations to help guide the next phase of the Mexico City Project in devising interventions to simultaneously confront the MCMA's mobility and air quality challenges. Only the first stage in a multi-year initiative, this paper does not develop specific policy measures and initiatives; instead general guidelines are provided, with the hope that such guidelines can help steer the future development of policies that can simultaneously satisfy the city's mobility *and* air quality needs.

The Economic Cycle of Urban Transportation

To better understand the challenges confronting a large developing country city like Mexico City, it is first important to consider the economic cycle which drives the urban transport dynamic (see Figure 1.1). Transportation serves as a primary backbone of any urban area. Through transportation-facilitated activities, economic growth is enabled; this economic growth, in turn, creates transportation impacts, most often manifested through increasing trip rates, rising motorization, shifts towards more rapid travel modes, and growing trip distances. These transportation effects themselves then produce economic impacts, often negative "external" effects, such as congestion, air pollution, and accidents.

Figure 1.1: Urban Transport's "Vicious" Cycle



Source: Zegras, 1998

Not only do such effects often undermine the effective provision of transportation services, they also themselves can further inhibit economic growth, representing lost resources in the form, for example, of wasted time and impaired health. It is at this stage of the urban transport "cycle" where conflicts most often emerge – on the one hand some form of investment or intervention is needed to reduce transportation's negative impacts and continue enabling economic growth; on the other hand, many interventions are rendered difficult or impossible, due to constraints such as air pollution (producing, for example, roadway construction moratoriums) or simply lack of financing. The dilemma arises of how to mitigate or eliminate transportation's negative effects while continuously allowing it to serve its role as backbone to the urban economy.

While this cycle is attributable to a large degree to transportation in any city in the world, it is particularly important in cities of the developing world, where urban growth is often occurring most rapidly, where financial constraints are often the most pronounced, and where pollution (and other negative effects) are often the most severe. Within this context, the study of the MCMA proves valuable. The city has: experienced rapid demographic, physical and economic (albeit sometimes sporadic) growth in recent decades; gone through rapid motorization and important modal shifts in recent years; grappled somewhat successfully with the implementation of improved motor vehicle technologies; and, invested heavily, though geographically disparately, in major urban road and rail infrastructure. Nonetheless, the city continues to suffer from almost overwhelmingly complex problems of chaotic traffic conditions and dire air pollution – no easy single solution is in sight.

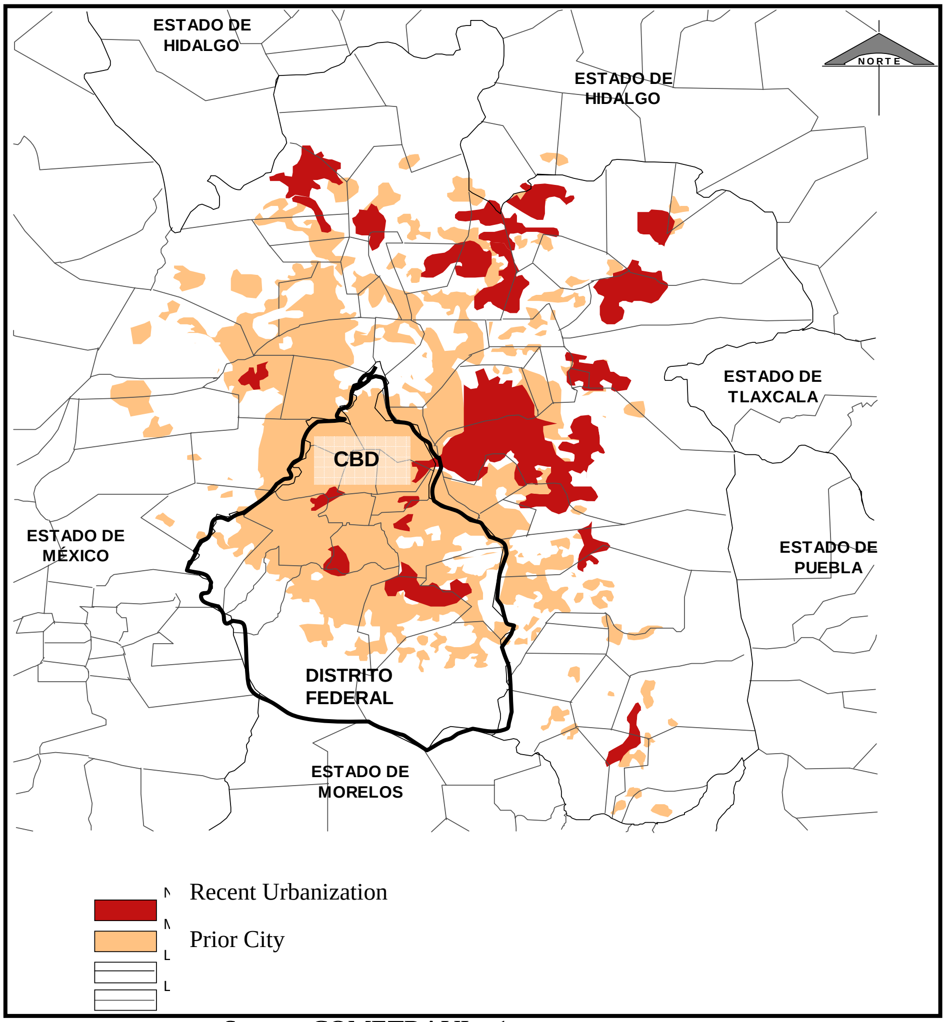
II. THE CITY, THE REGION, THE "MEGAPOLIS"

As one of the largest cities in the world, the MCMA has undergone massive transformation in urban area and demographics throughout its history. In the last half century alone, the urbanized area of the region has increased by 13 times, from just 118 km^2 of urbanized area in 1940 to approximately 1,544 km^2 by 1995. The expansion pushed the city beyond the Federal District (Distrito Federal or DF) and into the State of Mexico (Estado de Mexico or EM) as well as some parts of the State of Hidalgo (Ward, p. 57; SEDESOL, p. 75) (See Figure 2.1).

The actual size of the Metropolitan Area depends, of course, on how one defines the "area." There are at least three different perspectives that can help in understanding the Metropolitan Region and its context. First, there is the Federal District, which contains the historical city center and continues to serve as a major population center and commercial and services center (CBD) of the region. Second is the MCMA, comprised of the 16 *delegaciones* of the DF plus 57 of the major urbanized municipalities (*municipios*) from the State of Mexico (sometimes including one *municipio* from the state of Hidalgo). Finally, there is the so-called "megapolis," which extends beyond the MCMA to include the "crown of cities" (including Puebla-Tlaxcala, Cuernavaca-Cuautla, Pachuca and Toluca) – a literal ring of cities surrounding the MCMA at a radius of 75 – 150 kilometers from the city center.

Including the "crown of cities" within the region of influence of the MCMA, one gains an appreciation of the overall importance of this region to the entire country in terms of population and contribution to GDP. In 1995, 9% of the country's population resided in the DF, another 9% resided in the urbanized regions of the MCMA, while almost 7% resided in the so-called "crown" cities. In total, the "megapolis" contains 23 million residents (25% of the nation's population) and accounts for nearly 42% of GDP. While for the most part this report will focus on the MCMA, reference will be made to the "megapolis," particularly since there are important transportation implications arising from plans/efforts to integrate the "crown of cities" into the metropolitan region.

Figure 2.1: The MCMA & Environs: Recent Growth



Source: COMETRAVI, v1

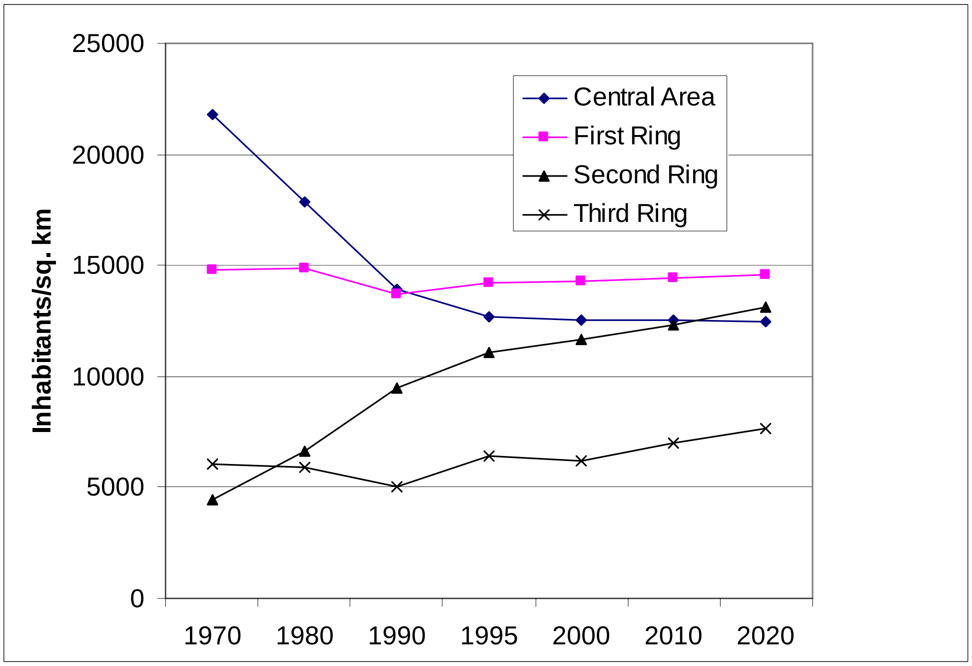
Urban Growth

As mentioned previously, the MCMA has exhibited strong urban outgrowth/ decentralization trends, particularly from 1970 onward. Between 1970 and 1995, the 'central city' area's population declined by between 1.7 and 2% per year, while the successive "rings" around the city absorbed a growing share of the city's population. The area immediately around the CBD[1] – historically the focus of population expansion - while still growing, declined from 3.6 percent growth during the 1970s to just over 0.5% growth by 1995. While the first ring still concentrates the greatest single share of the MCMA's population, more distant areas are experiencing the most rapid growth. The result of these trends has been a flattening in the population density patterns across the MCMA. Looking just at the Federal District data, we see that by 1995, although the Central areas of the city

[1] Miguel Hidalgo, Benito Juarez, Cuauhtemoc and Venustiano Carranza delegaciones are the downtown or inner city.

still have the highest density levels, these have declined and become more uniform with other parts of the city (see Figures 2.2 and 2.3).

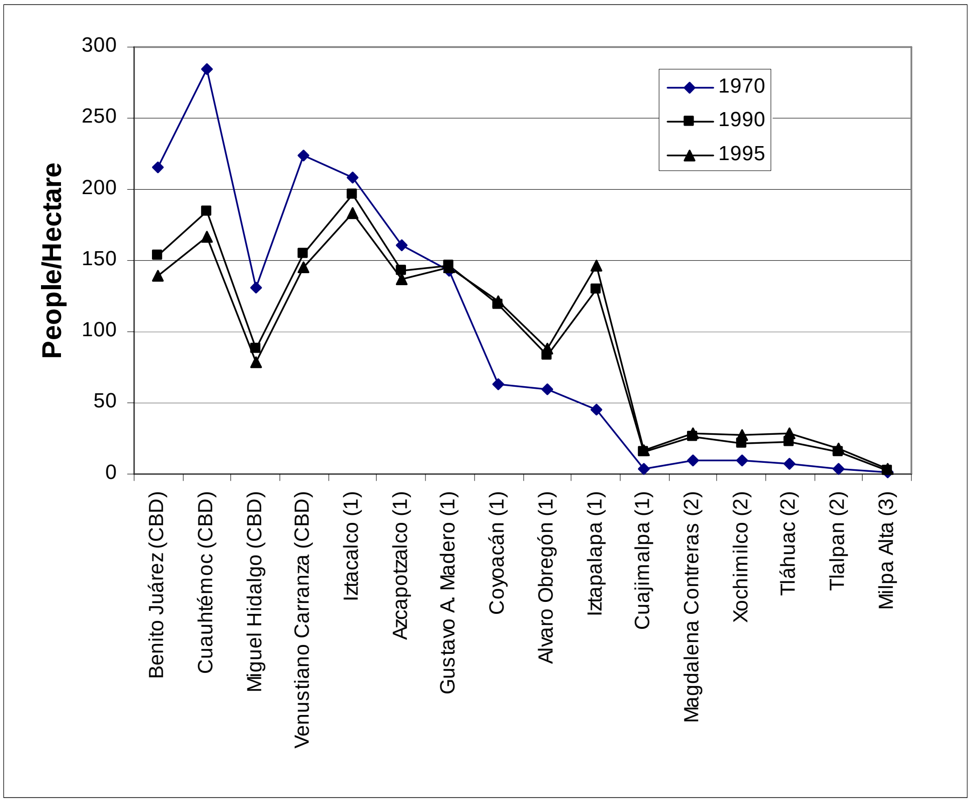
Figure 2.2: Evolution of Federal District Population Densities



Source: Villegas, undated

Figure 2.3: Federal District Densities by Delegación[2]

[2] Note: Delegacion is considered to be in traditional central city (CBD), or ring 1,2, 3 (see Ward, 1998, p. 48).



Source: Ciudad de Mexico, 1999

At a micro level, Graizbord et al (1999) evaluate densities at the district (unit of analysis of the 1994 O-D survey) level. They also find a general declining trend in densities according to distance from the Zócalo (center of the central city). Nonetheless, there are several points of very high density settlements at distances of up to 30 km from the Zócalo (CBD).

Demographics

Historical patterns of urban growth are tightly linked to socioeconomic trends and migration patterns. Because the growing city has been a major national employment magnet during the twentieth century, the settlements formed by migrants largely define the expansion of the metropolitan area as successive waves of arrivals create residential communities on the urban edge. In broad terms, the western and southwestern parts of the MCMA have been the foci of wealthier populations, although some of the delegaciones in this region (Alvaro Obregon and Magdalena Contreras) have a relative mix of rich and poor. Within the DF itself, the eastern and southern delegaciones contain the greatest proportion of poor residents. Graizbord, et al (1999) point to a general pattern of higher income groups being concentrated towards the city center, with income levels declining with increased distances from the Zócalo (p.13). Again, however, many higher income districts can be found at distances relatively far from the city center, particularly Huixquilucan a high income residential area located at some 25 kms from downtown.

Population Growth

Ward (1998) estimates that migration will play a smaller role in Mexico City's future growth, relative to other demographic factors, particularly aging. While the city has shown declining fertility rates from 1970 onward, the population "remains heavily 'loaded' in the young parent age group (20-35)…The whole demographic equation, therefore, hinges upon these future parents' decisions regarding family size" (Ward, 1998; p. 52). Additional implications arise from the expected increase in the over-65 age group - expected to double in size between 2000 and 2020 (to about 8 % of total population) (Ward, 1998; xiv). We cannot ignore the growth in importance of these two age cohorts (baby boomers and increasing "gray" population) in terms of transportation service provision.

In 1995, the DF had over 2 million households, with an average size of 4.2 persons per household, while the State of Mexico had 1.8 million households, with an average size of 4.7 persons/household. By 2020, average household size is expected to decrease to 3.3 for the DF and 3.7 for the State of Mexico (SEDESOL, undated; pp. 66-70).

Table 2.1: Urban and Regional Population - 1995 and Projections to 2020

	1995			2020 - "Current Trend"			2020 - "Programmed" Growth		
	Pop. (mns)	% of "Megapolis"	% of Country	Pop. (mns)	% of "Megapolis"	% of Country	Pop. (mns)	% of "Megapolis"	% of Country
DF	8.5	36.5%	9.3%	9	25.1%	6.9%	9.7	28.7%	7.4%
Urbanized EM	8.6	36.9%	9.4%	17.2	48.0%	13.2%	12.1	35.8%	9.3%
MCMA	17.1	73.4%	18.7%	26.2	73.2%	20.1%	21.8	64.5%	16.7%
"Corona"	6.2	26.6%	6.8%	9.6	26.8%	7.4%	12	35.5%	9.2%
"Megapolis"	23.3		25.4%	35.8		27.4%	33.8		25.9%
Country	91.6			130.5			130.5		

Source: CdM, 1996; 22-24, 35

Under current trends, the population of the MCMA will increase by 2% per year between 1995 and 2020 – compared to the nation's expected growth of 1.7% per year. By 2020, the MCMA population will reach 26 million, 1/5th of the country. Including the "corona" of cities, the entire Megapolis will contain 27% of the nation's population, some 36 million people. On the current trajectory, the urbanized/urbanizing municipalities of the State of Mexico will undergo the highest rates of growth (approximately 4% per year). In so doing, the EM will greatly increase its share of the regional population from roughly equal to that of the DF in 1995 to nearly double by 2020 (see Table 2.1).

The government has developed alternative growth projections for the region, based on general objectives of fostering regional development, taking advantage of existing urban infrastructure, reducing current growth tendencies in the State of Mexico, and protecting ecologically sensitive areas from further settlement. Under this scenario – the so-called "programmed growth" plan – the government would be able to alter somewhat the current patterns of growth. The overall size of the "Megapolis" would have 2 million less residents than currently projected, signifying an attempt to direct future population growth towards other regions of the country. Furthermore, within the "Megapolis" the distribution of population would change significantly. Growth rates within the State of Mexico would be more than halved (from 4% per year to 1.6%) and the state would account for 36% of Megapolis population (55% of the MCMA). The "corona" cities would be an increasing focus of population growth, comprising 36% of the regional population and the DF would account for a slightly larger share of regional population than under the current trends scenario (see Table 2.1). These results reflect the goals of decentralizing national population growth away from the Mexico City Region, while within the region focusing growth on the "corona" cities, containing growth in the State of Mexico and increasing growth rates in the DF.

In terms of future land requirements, the city will spread across 2,520 km^2 under the "current trends" scenario; under the “programmed growth” scenario the size of the city would be 1,920 km^2(SEDESOL, undated; p. 75). Transportation infrastructure and service provision will have an important impact on whether these growth goals can be achieved.

Employment/Economy

The MCMA has always been wealthier than the nation as a whole, although in more recent decades the disparities have lessened somewhat. In 1998, the GDP per capita in the MCMA was 1.75 times greater than the country’s (Delgado et al, 1999, Cuadro 1). As has been the case with the Mexican economy in general, services and other “tertiary” activities have become an increasingly important share of the MCMA economy in recent decades. And, while manufacturing continues to play an important role in the region, this activity has increasingly decentralized out of the DF and towards the more distant municipalities of the State of Mexico. The DF, on the other hand, has become a focus of commercial and service activity (58% of the region). From 1980 to 1990, employment in the industrial sector in the DF decreased from 42% to 28%, while the percentage of the workforce employed in tertiary activities grew from 52% to 71% (CdM, 1996; 25). Despite these trends, the government still hopes to maintain a healthy industrial base in the DF, focusing on “clean industries.”

Land Uses

Economic influences have had an important role in the formation of the urban space and land uses, particularly the relationship of the DF with the State of Mexico and the rest of the “Megapolis.” Five major highway arteries intended to link the City with the rest of the country became corridors of development (focusing an important share of shopping centers, etc.) and have also contributed to the DF’s increasing importance as a center of finance and technology (CdM, 1996; 19). The result has been a polycentric urban form, yet with still heavy dependence on central city functions (CdM, 1996; 19) or what others have characterized as a “hierarchically structured multi-centric space” (Graizbord, et al., 1999).

Within the Greater MCMA, the DF contains 49% of the entire urbanized area, 47% of the housing, 31% of industry, and 81% of mixed/commercial land uses (CdM, 1996; 18). The DF is expected to continue serving as a major point of concentration of commercial and service land uses, while the State of Mexico is expected to absorb an increasing migration of industry and housing. Within the DF, four major, relatively distinct areas can be isolated according to the following (general) characteristics, which are expected to continue in the future: the center city will continue to serve as the center of services and commerce; the first ring will remain as a high quality, well serviced and diversified region; the second ring will be a transition zone, with an important rural face; and the third ring will continue as an essentially rural zone, providing important ecological services (CdM, 1996; p. 31). The ongoing concentration of commercial uses in the center city was accelerated by commercial office space development brought on by NAFTA – between 1992 and 1995 some 800,000 m^2 was added to the stock of office space, 75% of which remained unoccupied in 1996 (CdM; 1996; 16).

In the DF, an estimated 4% of the urban area is considered vacant or barren - available for urban development. 20% of this land is located in the center city itself, with the rest concentrated primarily in the poorer, east and southeast (CdM, 1996; 16). While the overall developable land is concentrated in the south and southeast, the number of lots is equally distributed between the city center and this region. On average, land values in the center city are three times higher than those on the DF's periphery (CdM, 1996; 16). Overall, while there has been something of a rejuvenation of the center city, authorities still suggest that the urban space, infrastructure and services of the area are underutilized (CdM, 1996; 22).

Interventions

Efforts to control urban growth patterns have met with little success over time. For example, the effectiveness of a 1954 ban on further subdivisions in the DF was effectively neutralized by the fact that settlements already actually existed in the areas that it was intended to affect. Furthermore, it stimulated the supply of land in the State of Mexico, where the ban did not apply (Ward, 1998; p. 57). More recent efforts include a project aimed at preserving over 50% of the land surface of the DF as an ecological reserve ("Proyecto de Decreto del Convenio de Gestión de la Reserva Ecológica del entorno del Distrito Federal" (CdM, 1996, 15)). To date, however, only 5% of the land area has effectively been set aside in large part because of illegal development in these areas, often by poor immigrants. This pattern is unfortunately common: an estimated 29% of the city's total urbanized area currently has illegal tenure status (Pezzoli in Krebs, 1999; Appendix 1).

III. TRANSPORTATION DEMAND

THEORY/OVERVIEW

These urban growth patterns underlie the demand for transportation in the city. Before discussing that demand, however, there are some important methodological issues that should be highlighted. The principal foundation for passenger transportation demand analysis is the origin-destination survey, a detailed travel study which is typically comprised of a survey of households representing sample demographic segments of a city. The survey is often done via telephone, by home interview, by mail, or by a combination of these techniques. The sample size varies greatly, from a few hundred households to many thousands, although as a "rule of thumb" the sample size for a city of more than 1 million residents should be 1% to 4% of households. In the United States, sample size for (relatively) recent surveys has ranged from 0.25% to 1.3% of the urban population (Purvis, 1989). In Santiago, Chile, a survey conducted in the early 1990s covered 33,000 *households* – roughly 3.3% of the city's homes – at a cost of US$1.3 million (Malbrán, 1994). Carrying out such surveys is no small task, typically consuming at least two years, including complementary activities such as more detailed home travel diaries, traffic counts, data analysis, and report preparation. Once completed, comprehensive O-D surveys can often be updated in cheaper and simpler ways – through, for example, traffic counts, motorization rates and smaller surveys.

The basic unit for travel demand analysis is typically the traffic analysis zone (TAZ), which disaggregates the urban area based on criteria such as socioeconomic characteristics and physical or historical boundaries. The size of the TAZ is important and requires the balancing of two key factors: 1) manageability of data and network representation – the smaller the TAZ, the more work required in terms of conducting surveys and ultimately developing and running a travel model; 2) accuracy of data and network representation –

the larger the TAZ, the less complete the profile of trip characteristics (particularly short trips) and network behavior. There is no hard rule for TAZ size and number. As a recent example, the 1991 O-D survey in Santiago was based on a total of 535 TAZs (521 internal to the city and 14 "external"), for an urban area of approximately 420 km^2 (SECTRA, 1991; p. 8) – approximately 1.2 TAZs per km^2.

Passenger Trips in the MCMA

In the case of Mexico City, origin-destination (O-D) surveys have apparently been done in 1977/78, 1983, and 1994 with an intermediate (public transport) survey done in '87 (Molinero, 1999b). The1994 O-D survey was apparently conducted by the National Statistics Institute (INEGI), in cooperation with the DF. According to Graizbord et al (1999), the 1994 O-D survey was based on 135 *distritos* (districts). Taking the *distrito* as the equivalent of a TAZ, there were approximately 0.08 TAZs per km^2. To date, we have not had access to the source O-D documentation to confirm this and other information such as: survey technique(s), sample size, trip definition, "trip-maker," etc.

Based on the available documentation (COMETRAVI, v6, 1999), in 1994 approximately 29.1 million *vehicle* trip segments (tramos de viaje) were made in the MCMA. These trip segments apparently represent a leg of any trip, aiming to capture multi-modal travel. Approximately 24 million trip segments (82%) were via public transport (including taxis) and 5 million (18%) were by private transport (including bicycle and motorcycle). If we accurately interpret tramo de viaje to be a segment of a full trip, then approximately 8.5 million public transport trips were pieces of a full (multi-modal) trip, while nearly all private transport trips did not involve a transfer to another mode. According to this interpretation, 75% of all *vehicle* trips were by some form of public transport or combined public transport, while 25% of all *vehicle* trips were be private transport (primarily auto). The total number of full vehicle trips is approximately 20.6 million.

While total trips do include bicycle trips, walking trips - which often make up an important share of total trips in a metropolitan area – are not included in the data available. In other large Latin American cities, walk mode share ranges from a reported 10% in Buenos Aires to 20% in Santiago to over 30% in São Paulo (Rivasplata et al, 1993; SECTRA, 1991, p. 26; World Bank, 1994).[3] If we conservatively estimate that 15% of total trips in Mexico City are walking trips then at least another 3.6 million trips per day occur in the city, increasing the total number of trips in the city to 24.2 million.

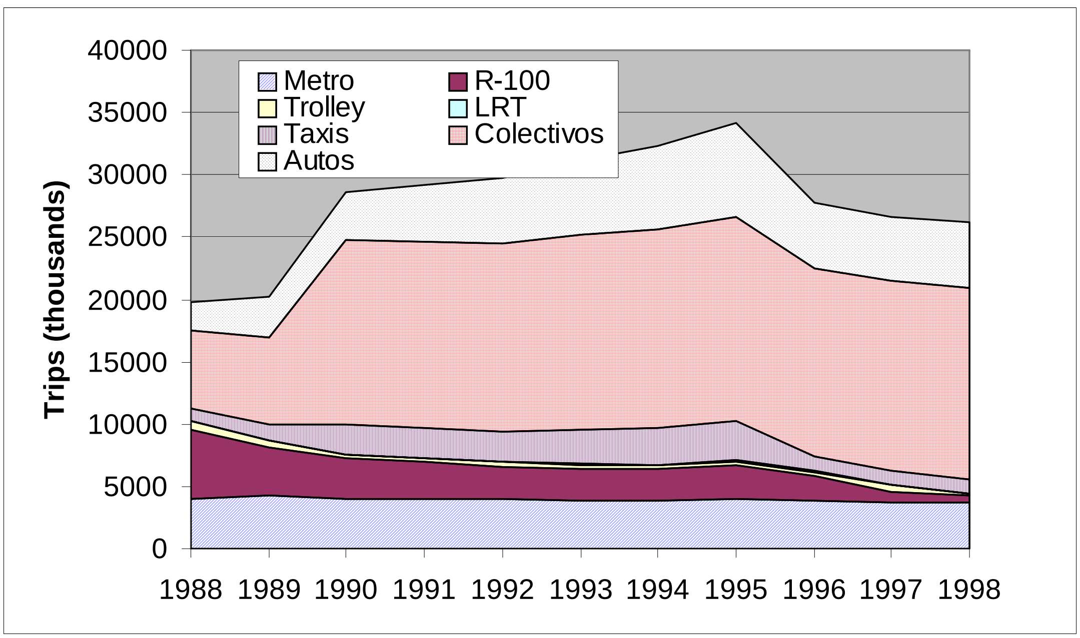
Based on these estimates, the total number of *vehicle* trips per person per day is 1.2 (5.4 per household); if our rough walk trip estimate is correct than this number increases to 1.4 (6.4 per household). This number seems quite low and suggests undercounting of trips and/or misinterpretation of the data by the authors. For comparison, in Santiago de Chile in 1991, there were approximately 2.12 total trips per person (8 per household) and 1.7 vehicle trips per person (6.4 per household) (SECTRA, 1991, p. 48). Other sources for trips in the MCMA suggest higher demand levels – the 1996 Land Use Plan for the DF, for example, reports that travel demand in the MCMA increased from 19 million trips per day in 1983 to 30.7 million in 1994) person trips per day – an increase from 1.35 trips per

[3] In the case of Santiago, trips of less than 3 city blocks (approximately 400 meters) were not counted in the survey, thus underestimating total walk trips.

person to 2 (CdM, p. 20). Unfortunately, no additional details on these estimates were provided.

It is important to point out data inconsistencies in these numbers. As can be seen in Figure 3.1 (the data for which does not coincide with that presented in the previous paragraphs), total trip-making in the *Federal District* has apparently been highly variable over the past decade, with a large increase occurring after 1989, mostly in the form of additional "colectivo" trips. The increase from some 20 million trips per day to almost 30 million in one year suggests that: 1) the liberalization of the colectivo market released a large pent-up demand for trips and/or 2) the data is inconsistent. The subsequent (apparent) decline in trip-making from 1995 to 1996 came primarily from a reduction in taxi and buses (Ruta-100), along with a slight decline in auto trips – these might be explained by the economic crisis (not to mention the demise of R-100). We are not able to confirm what factors might be ultimately playing a role in the trends outlined in Figure 3.1; nor are we able to confirm why the trip numbers presented in Figure 3.1 differ so drastically (for the entire MCMA) from those reported in the previous paragraph.[4]

Figure 3.1: Total Average Daily Trips in the Federal District



Sources: SETRAVI, 1999, p. 3-22; COMETRAVI, v1, 1999, p. 184.

Mode Share

In terms of overall mode share, using the COMETRAVI data on trip segments in 1994, we see clearly the phenomena that "low occupancy" modes dominate the landscape.

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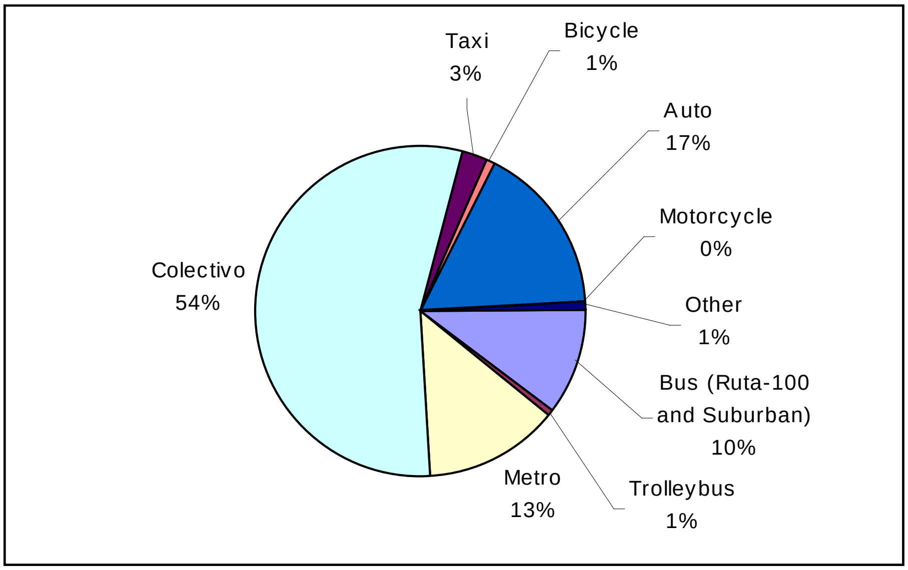
[4] The numbers shown in Figure 3.1 are derived from the same sources as those presented in previous paragraphs and shown in Tables 3.1 & 3.2 (COMETRAVI, 1999 and SETRAVI, 1999).

Colectivos account for over 50% of trip segments and autos and taxis another 20%. Among the "high occupancy modes" the metro accounts for roughly 13% of all trips, followed by urban and suburban buses with 10% (see Figure 3.2).

Figure 3.2: Mode Share for Vehicle Trip Segments in the MCMA (1994)



Source: COMETRAVI, V6, 1999; p. 3.

As would be expected, auto use is highly concentrated among the wealthy. Half of all automobile trips are produced in just 23% of the MCMA (Graizbord et al, 1999; p. 15). Auto trip destinations are even more heavily concentrated – 50% of the trips go to just 16% of the MCMA (p. 16).

Spatial/Temporal Distribution

Regarding the spatial distribution of trips, 54% of the MCMA trips are concentrated within the DF, 26% occur between the DF and the State of Mexico, and 20% occur within the state of Mexico (COMETRAVI, v6, 1999; p. 2). In terms of trip attractions, the center city accounts for the single largest share of trips – 23%, roughly half of these trips are generated internally. The next largest areas in terms of trip attraction include a northern area of the DF and two large portions of the State of Mexico in the west/northwest and directly north of the city center. These areas account for 11 – 14% of trips attracted. In each case, the majority of trips are internal to the general vicinity, although for the two zones in the State of Mexico, this may be in large part due to the large overall spatial area considered. A small central area of the DF generates and attracts a significant share (27%), with the next largest share (17%) generated and attracted by the large northern zone of the State of Mexico. In a general sense, these trip flows represent the polycentric hierarchy of the region – the DF still accounts for a significant share of trip attraction and generation, drawing a major share of trips from throughout the region. Even in the most distant areas of the MCMA, the majority of trips are destined for a central area of the DF (excluding each zone's internal trips) (COMETRAVI, v6, 1999; pp. 5-12). Furthermore, when considering only automobile trips, over 60% of these trips occur within a radius of 10 kms from the city center (Graizbord et al., 1999; p. 43).

When examined according to mode, the majority of public transport trips descend on the city center, while automobile trips are much more dispersed in their destinations. For auto trips, the focus of the Graizbord et al (1999) study, less than half of trips are work trips, 27% are shopping trips, and 25% social trips (p. 15).

Due to its importance in the national economy, the MCMA is a focus of inter-city travel, either beginning or ending in the city or passing through it. Many of these trips use local roads for part of their journey as well as highways which carry an important share of intra-urban travel. In 1995, there were some 300,000 vehicles per day on the five principal accesses to the city (COMETRAVI, v1, 1999; p. 147).

In general and across the network, the morning peak from 7:15 am to 9:30 am is the time of highest travel demand, with heavy concentration between the EM and DF occurring on the early side of the peak. In the afternoon/evening, demand is more distributed across a longer time period producing a less acute – but more prolonged – peak (COMETRAVI, v1, 1999; pp. 150 – 151).

Future Growth

Future growth in travel demand depends heavily on economic conditions, which influence overall trip-making behavior (i.e., trip rates) and modal choice. According to official projections, overall trip segments in the MCMA will increase from 29 million in 1994 to nearly 37 million by 2020. Virtually all growth is projected to occur in the State of Mexico which will increase from 9.6 million to 16.4 million; in the case of the DF, the increase will be very moderate, from 19.5 million to 20.5 million. Table 3 below shows these projections. Without access to the assumptions behind these projections, it is difficult to comment on them; nonetheless, a quick glance suggests that they are likely to be significant underestimates. The two most noteworthy aspects of these projections, which also make them the most suspect, are:

- An actual decline in trip-making activity per capita
- No change in the modal share between public and private transport.

Table 3.1: Daily Motor Vehicle Trip *Segments* in the MCMA

	1994			**2020**		
	Total Trip Segments	**Mode Share**	**Trip Segments per Capita**	**Total Trip Segments**	**Mode Share**	**Trip Segments per Capita**
MCMA	29,124,242		1.70	36,962,364		1.41
Public	24,011,507	82.4%		30,593,906	82.8%	
Private	5,112,735	17.6%		6,368,458	17.2%	
DF	19,489,476		2.29	20,511,482		2.28
Public	15,888,959	81.5%		16,722,158	81.5%	
Private	3,600,517	18.5%		3,789,324	18.5%	
EM	9,578,528		1.11	16,391,696		0.95
Public	8,079,543	84.4%		13,826,489	84.4%	
Private	1,498,985	15.6%		2,565,207	15.6%	

Sources: COMETRAVI, v6, p. 26; per capita estimates based on "trend" population projections from CdM (see Table 2.1)

Table 3.2: Daily Total Motor Vehicle *Trips* in the MCMA: By Geographic Area

Geographic Area	1994			2020		
	Trips (thousands)	%	Per Capita	Trips (thousands)	%	Per Capita
Federal District	**13,672**	**66%**	**1.61**	**17,425**	**61%**	**1.94**
Interior to the DF	11,598	56%		14,647	52%	
• Within Delegaciones	4,977	24%		6,398	23%	
• Between Delegaciones	6,621	32%		8,249	29%	
Metropolitan Trips	2,074	10%		2,778	10%	
Urbanized EM	**6,900**	**34%**	**0.80**	**10,912**	**39%**	**0.63**
Interior to EM	4,744	23%		8,100	29%	
• Within Municipios	3,168	15%		5,340	19%	
• Between Municipios	1,576	8%		2,760	10%	
Metropolitan Trips	2,156	10%		2,812	10%	
Total MCMA Trips	**20,572**	**100%**	**1.20**	**28,337**	**100%**	**1.08**

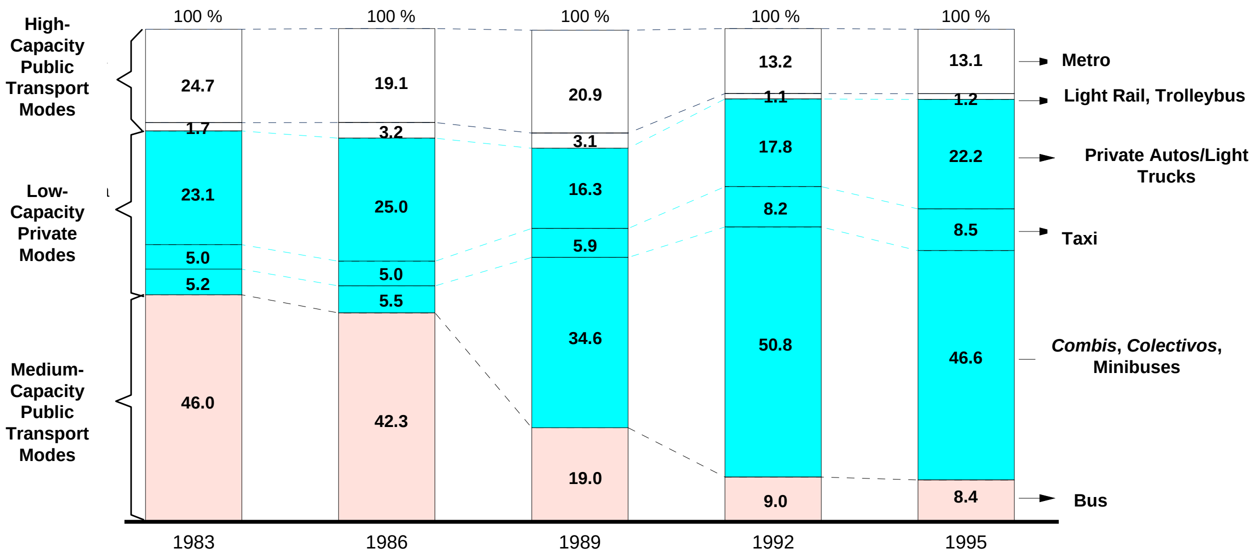
Source: SETRAVI, 1999; p. 2-9.

When the entire trip (not trip segment) is taken into account and trip activity is viewed regionally, we get a better idea of overall motorized trip-making activity (see Table 3.2). Important features to keep in mind from this data is the large apparent disparity in motor vehicle trip-making between residents from the DF and those from the EM – in per capita terms, DF residents made twice as many motorized trips than their EM counterparts in 1994; by 2020, the projections suggest that residents of the DF will make *3 times* as many motorized trips than their EM counterparts. While the per capita numbers for the DF seem reasonable (especially considering these are only motorized trips) it is hard to believe that the EM numbers (for 1994 and 2020) are accurate – it would suggest an extremely low and declining level of mobility for residents of the EM – hard to fathom, especially if the EM becomes more suburbanized with wealthier residents in the future.

While from an environmental and transportation efficiency perspective this continued dominance of public transportation and low level of trip-making activity are welcome, it seems unlikely that such projections will be realized without strong and successful intervention on behalf of the government (which would make them goals not projections). Even moderate sustained economic growth over this period would have important effects on trip-making behavior, both in terms of trip-rates and mode share. For example, using data from Santiago de Chile for 1977 and 1991: trip-making (trips per capita) increased with an income (GDP/capita) elasticity of 1.87; the total number of public transportation trips showed a negative elasticity with respect to income, -0.46; and the total number of private transportation trips showed a positive elasticity with respect to income, 1.69 (derived from data in SECTRA, 1991; pp. 46-48). Although there are some indications that trip-making in some large developing country cities (i.e., São Paulo) has remained stagnant over time – perhaps due to issues such as crime (Menckhoff, 2000) – it is difficult to believe that the Mexico City data currently available is accurate.

From a modal share perspective, the most worrying trend is the massive shift towards low capacity modes (i.e., taxis, colectivos and minibuses) at the expense of Metro ridership and bus use (see Figure 3.3). This is one of the principal policy challenges facing the city's transportation system.

Figure 3.3: Evolution in Mode Share



Source: COMETRAVI, 1999, v1; p. xx.

FREIGHT TRIPS

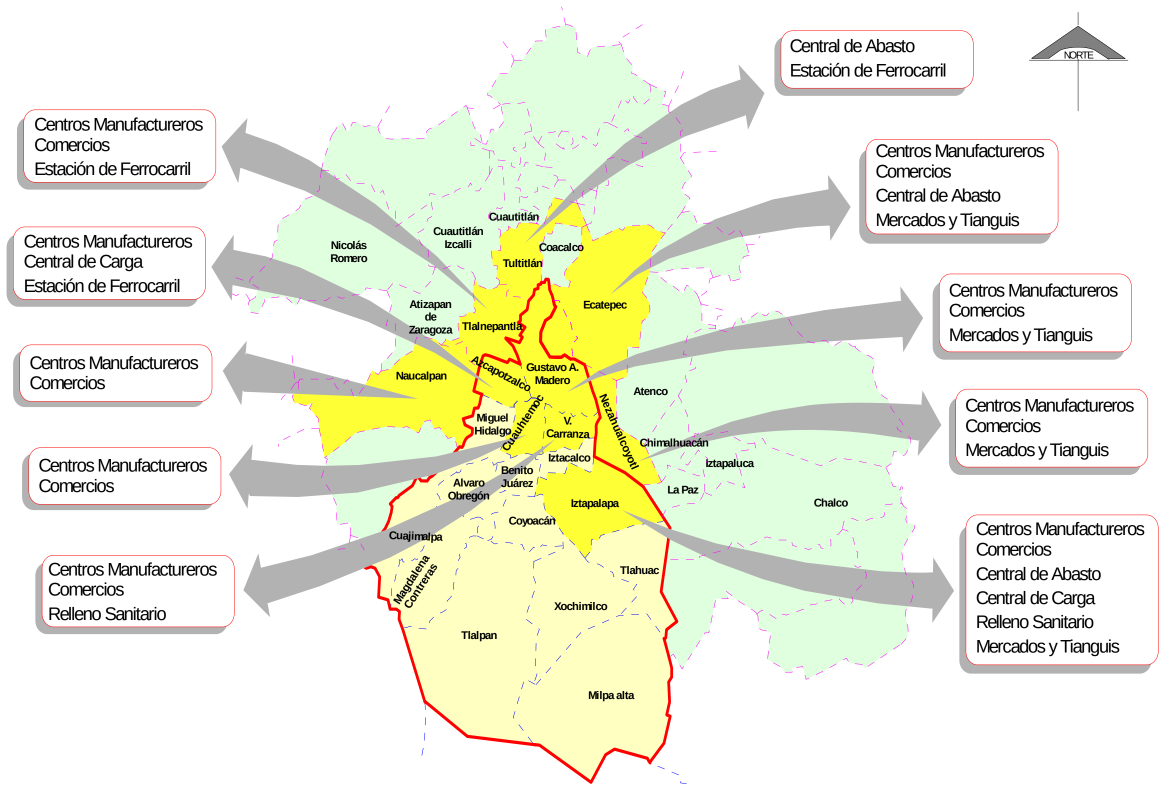
As the locations of residence, employment, and recreation drive passenger travel, the placement of commercial and industrial facilities with respect to areas of demand drives freight travel. The prominence of Mexico City in national economic activity (over a third of GDP) reinforces the importance of freight travel in the metropolitan area. Infrastructure also determines freight travel, especially facilities such as rail rights of way and terminals. Approximately 82% of all rail freight enters the metropolitan area via two terminals, which are located in the delegation of Azcapotzalco and the municipality of Tlalnepantla. Within the metropolitan area, expensive land tends to repel business from the downtown while the traditional central business district acts as a magnet for economic activity. In Mexico City, these forces combine to produce a vast concentration of commercial (63%) and industrial (62%) installations within a half dozen delegations and municipalities centered around the northeastern portion of the DF (COMETRAVI, v3, 1999).

Types of Freight Activity

Cargo trips can be broadly divided into intra-urban and inter-urban categories. In the latter, a significant portion can be "through-trips" with the MCMA as neither origin nor destination. Trucks' control of the market increases as trip-length decreases. In many freight networks, multiple modes and/or vehicles are necessary to complete a single trip. For example, a shipment may arrive in the MCMA by train but must be transferred to a truck for delivery to an address without rail access.

Laws in the metropolitan region prohibit especially large trucks (by weight) from making deliveries during daytime hours. Overall, about 29% of freight originates in delegations of the DF, 12% in EM municipalities, and 59% outside the MCMA. Figure 3.4 shows major freight activity (trip-generation) centers.

Figure 3.4: Location of Major Freight Trip Generators in the MCMA



Source: COMETRAVI, v3

IV. SUPPLY

ROADWAYS AND ROAD VEHICLES

During the last twenty years, the provision of highway infrastructure has struggled to keep pace with the massive population expansion. During the early to mid-1970s, the major accomplishments included the construction of the “Circuito Interior” (first ring road) as well as several feeder roads towards the west (SETRAVI, 1999; p. 2-35). A major development was the implementation of the *ejes viales* in 1979-80, which created a system of high capacity boulevards through downtown. In the early nineties the Pereferico, the DF's beltway, was completed among other modernization projects, many of which focused on introducing grade separations to improve flow on key routes. More recently, major construction activity has included a new toll highway in the west/northwest (La Venta-Lechería), highway expansion in the north (Cuautitlán-Tlalnepantla), and expansions and new construction in the east. As of 1995, the entire northern half of the Third Ring was completed (as a toll highway), with the southern half under construction (SETRAVI, 1999; p. 6-24). In general terms, future highway construction is most restricted in the north and northwest, due to topography. In the north, this most affects transportation among the relevant *municipios* of the EM, while in the northwest the effects are most profound on transport between the EM and the DF (COMETRAVI, v1, 1999; p. 148). Overall, roadway connections between the EM and the DF continue to suffer due to major variations in road design capacities and continuity. There are five principal highway accesses to the city; four of these have toll/non-toll alternatives.

Table 4.1: Summary of Transport Infrastructure in the MVMA

Type	DF	EM
Primary Roads	198.4 kms (67% controlled access)	352 kms highways
"Ejes" Viales	310 kms	47 kms (Vías Rápidas Urbanas)
Principal Roads	552.5 kms	616 kms
Secondary Roads	8,000 kms (8150)	250
Metro	178 kms	-
Trolleybus	377 kms	-
Light Rail	26 kms (13 in each direction)	-
Parking spaces	126,257 spaces (10,000 lots)	
Traffic Signals	1,973 electronic 870 computerized 58 mechanical	298
Bus shelters	2,347	290
Contraflow lanes	13 lanes 186 kms	
Parking Meters	1,535	

Source: COMETRAVI, v6, 1999; pp. 15-16. Molinero, 1991; 131.

As Table 4.1 indicates, there are significant disparities between the DF and EM. Whereas roadways cover 28% of the DF, the comparable coverage is only 12% in the relevant *municipios* (Molinero, 1991; 131). The inequity of infrastructure supply, particularly with respect to the population and trip distribution, highlights a basic cause of the congestion problems that subsequently contribute to mobile source emissions in the EM.

Level of Service

As part of the development of the COMETRAVI reports, a consultant team conducted field surveys of 30 major intersections and 14 principal travel corridors to estimate levels of service (LOS). Adapting the 1985 Highway Capacity Manual to the conditions of Mexico City, the team found that 73% of the intersections exhibited level of service 'F' during the peak. The average delay at these intersections ranged from 85 to 180 seconds (COMETRAVI, v1, 1999; p. 157). At a corridor level of analysis (based on travel speeds during peak period), the levels of service are, in general, more acceptable; only 2 of 14 corridors analyzed had a LOS of D (v1, p. 160). With respect to pavement quality, these same corridors, in general, display adequate LOS, with the toll highways being quite good (COMETRAVI, v1, 1999; p. 163). Observations of peak period traffic flows at major intersections is drawn from the same field surveys used in the LOS calculations. Public transportation comprises anywhere from 7% to 50% of vehicle flow. Freight traffic makes up between 2 and 18% of peak period vehicle flow. In both cases, the highest concentrations of vehicles occur at intersections in the EM and at intersections near the peripheral and major access highways – consistent with the EM's increasing industrial dominance in the region (COMETRAVI, v1, 1999; p. 153).

Traffic Signalization

Synchronization of traffic lights was first implemented in the mid-1970s on the inner ring road ('Circuito Interior'). While additional synchronization schemes have been implemented, challenges to further implementation include: differences in road widths;

inadequate space to provide for left turns; occasionally long distances between intersections; lack of underpasses at critical intersections; and the irregularity of public transportation stops (COMETRAVI, v1, 1999; pp. 165-167). According to estimates by the COMETRAVI (1999) consulting team, improvements to the existing computerized traffic signalization program could improve delays at major intersections analyzed by 8.5% (v1, p. 175).

Parking

Of an estimated (1994) 3.6 million parking spaces in the MCMA, 39% are on-street, 5% are in publicly owned lots and buildings and 56% are in privately owned lots and buildings. Of the latter, the majority are at residences. While there does not seem to be an overall shortage of parking supply in the city, there are discrete points of deficit, particularly in the downtown areas of the DF. In general these points of excess demand occur where trip attraction rates are high, as would be expected. In the DF, the estimated parking deficit – primarily due to work and commercial trips – equals approximately 56% of the total amount of paid parking available in the DF (COMETRAVI, v1, 1999; pp. 169 – 172). Except in some of the dense center city areas, parking fees have generally not been high enough to serve as a disincentive to driving (v1, p. 171).

Vehicles

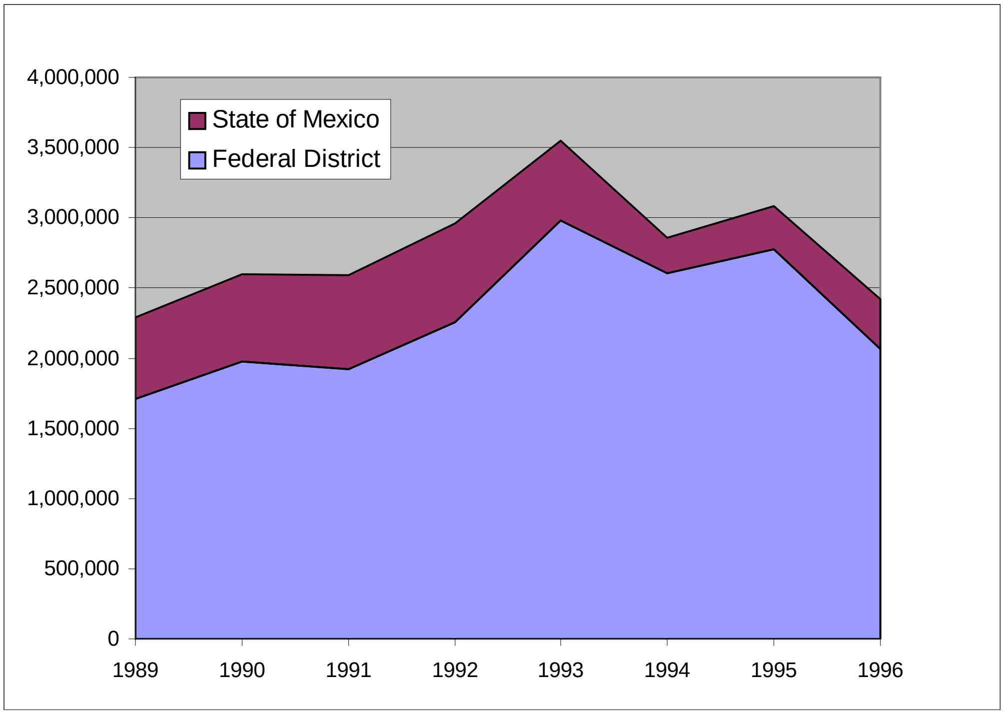
A Note on Data

Similar to the case of trip-making data, there are inconsistencies in the data for vehicle fleets – these inconsistencies are recognized by COMETRAVI (v1, 1999) and are similar to problems encountered in other parts of Latin America. Challenges to accurate data include:

- aggregation – lack of clarity on vehicle types, particularly categorization of taxis and different forms of public transportation;
- inter-fleet migration – vehicles registered as one type (taxi) and then operating as another (colectivo);
- license plate and/or registration swapping – autos becoming taxis, combis becoming micros, micros becoming buses;
- registered vs. operational vehicles – vehicles maintaining a registration although not in operation (sometimes used by concession owners to maintain rights to the concession);
- lack of coordination (or discrepancies) among responsible government entities (i.e., INEGI, DF, EM).

With respect to all highway vehicles in the MCMA, the key questions relate to how the fleets are distributed geographically (specifically between the EM and DF) and how they are divided among the operating modes. In both respects, time-series data is difficult to obtain. One set of data, available from INEGI, suggests that total vehicles have declined during the second half of the nineties (see Figure 4.1) when all other indicators suggest the opposite. Consequently, the following statistics must be interpreted appropriately.

Figure 4.1: Example of Data Anomalies: Total Motor Vehicle Fleet in MVMA



Source: INEGI web site on-line database

The question of actual vehicle fleet size is not unimportant, especially in light of calculating accurate emissions inventories. In an attempt to reconcile vehicle fleet registrations with the 1994 travel demand survey, the consultants for COMETRAVI provided estimates for vehicle fleets in the DF and the EM (see Table 4.2). According to these estimates, there are some 3.5 million vehicles in the MCMA; the DF concentrates the great majority (75 – 80%) of all vehicle types, except trucks which are roughly split equally between the DF and the EM.

Table 4.2: Estimates of Fleet Size MVMA (1994)

Vehicle Type	DF	EM	Total
Buses	**6,180**	**2,000**	**8,180**
• Urban	2,800		2,800
• Suburban		2,000	2,000
• Other Private	3,380		3,380
Colectivos	**88,500**	**26,100**	**114,600**
• Microbuses		10,500	10,500
• Combis	88,500	15,600	104,100
Taxis	21,500	5,000	26,500
Private Cars	2,262,000	577,000	2,839,000
Freight Trucks	195,500	184,000	379,500
Motorcycles	29,000	10,000	39,000
Vehicles in Transit			165,000
All Vehicles	**2,602,680**	**804,100**	**3,571,780**

Source: COMETRAVI, v1, 1999; p. 186.

That private vehicles dominate the landscape is evident in traffic counts at principal intersections (1996). At 28 intersections across the city, automobiles accounted for an average of 65% of all vehicles, taxis for 17%, colectivos 10%, heavy vehicles (trucks) 7%, and buses just 2% (percentages rounded) (COMETRAVI, v7, 1999; p. 33).

Private Cars & Taxis

Most references suggest that the automobile fleet in Mexico City has been growing at a rate of 6% per year (i.e., COMETRAVI, v8, 1999; p. 13). However, according to data in Molinero (1999), the automobile fleet has been increasing by an average 10% per year between 1976 and 1996. Based on that data, the motorization rate (vehicles/capita) has increased by over 5% per year: from approximately 78 autos per 1000 people in 1976 to 91 per 1000 people in 1986 and 166 in 1996.

According to traffic counts on 22 major corridors, average automobile occupancy ranges from 1.21 to 1.76 persons per vehicle, with an overall average of 1.5. The percentage of vehicles with just one occupant ranged from 48% to 83% on the different corridors (COMETRAVI, v1, 1999; p. 173).

Taxis

Regarding the number of taxis, COMETRAVI (v1, p. 186) estimates 26,500 taxis registered in the region, 20,000 of which are in the DF. Approximately 8,000 of these are fixed site taxis – i.e., typically operating from a taxi stand. Nonetheless, other estimates place the total number of taxis in the MCMA at 81,000 - 10,000 of which are fixed site taxis (Martínez, 1997; 82). Taxis are almost always individual operators (or owner/operators), the only formal organization being a taxi union geared towards representing taxi interests to the government. In the EM, "officially" recognized taxi service is virtually non-existent, although an important – if unquantified – number of private vehicles offer taxi services in the EM (COMETRAVI, v7, 1999; p. 25). Taxis from the EM are not allowed to operate in the DF and vice versa. The uncontrolled growth of the taxi fleet is a major policy challenge. Fixed-site taxis are somewhat more structured in their organization, since by their nature they must coordinate amongst each other regarding scheduling and fares at different taxi sites.

Hoy No Circula

A major policy initiative affecting the automotive system has been Hoy No Circula (HNC) a no driving day originally imposed in 1989 as a part of the short-term "emergency program" deployed for the winter months in Mexico City. Based on the last digit of the license plate, 20% of all private vehicles were banned on each weekday. The aim of the program was to reduce congestion, pollution and fuel consumption by reducing VKT. Studies of that winter indicated that fuel consumption did decrease while subway ridership and average speeds on the road increased (Onursal & Gautam, 1997). When the first major air pollution control plan (PICCA) was deployed in 1990 with a five-year time horizon, *Hoy No Circula* was a major component.

This well-known measure has had debateable impacts. In an empirical analysis, Eskeland & Feyzioglu (1997b) estimate that since HNC went into effect, the MCMA has turned from net exporter of used vehicles (avg. of 74,000/year) to net importer (85,000/year).

They also point out that the implementation of “hoy no circula” coincides with a decline in Metro ridership; in 1989, average daily ridership peaked at over 4.2 million; 18% higher than ridership as of June 1999 (INEGI, 1999) (see Figure 4.2). Regarding economic effects, besides the welfare loss, Eskeland & Feyzioglu comment on the inefficient resource use: “the fact that it artificially ties up and idles capital in the wrong places implies that it is costly to the nation” (p. 396). A study in 1995 reported that 22% of drivers obtained a second vehicle in response to the extension of the driving ban (Onursal & Gautum, 1997; p. 156). In fact, the problem was worse in the fact that the circulation ban only affected the drivers not wealthy enough to afford a second vehicle. A major unintended consequence of the policy was that the availability of a second vehicle is thought to have induced additional travel. Specifically, for families with two cars, each banned on different days, there are three weekdays (in addition to the weekend) in which both vehicles are available for use.

During the nineties, a number of changes have taken place with the circulation ban and closely related policies. A major improvement was the inclusion of taxis in the daily ban, which have the highest emissions per passenger mile of any mode because of the driving in search of passengers. A second significant change in Hoy No Circula was the shift in principal objective from circulation ban to fleet turnover incentive. Specifically, older cars are now subject to the ban for 1-2 weekdays as well as some weekends while vehicles with catalytic converters and tighter emission standards (93 and later) are exempt completely. Cars made between 1988, when emission standards were first introduced and 1993 are banned one day per week. Concurrently, 1999 models, which meet the EPA's Tier I standards are exempt from Inspection/Maintenance until 2001 (Sanchez, 1999).

Ongoing criticisms of HNC include the ban’s regressive nature; its generation of unintended consequences (purchase of second cars); and, importantly, the drain on political and administrative resources that the ban implies.

Road-Based Public Transport

Buses

The bus system in the MCMA has undergone several significant changes since the late 1970s. The historically privately owned and operated bus companies reached the brink of collapse by that point and in 1981, the government of the DF took over all 19 companies operating under its jurisdiction. With the creation of the state-owned Ruta-100 bus company, the aim was to provide a clean and efficient service, operating at fixed stops, with good maintenance practices, an integrated fare policy, and well-defined routes and hierarchies (see Molinero, 1999). Despite some positive performance, R-100 fell victim to the dual pressures of labor union demands and the further opening of the public transport market to colectivos/minibuses. Facing high costs, poor maintenance, and falling revenues, R-100 was declared bankrupt in 1995 (by the time of its bankrupcy, R-100 buses required a higher relative subsidy (80% of operating costs) than that required by the light rail or the Metro (COMETRAVI, v1, 1999; p. 205). The bus fleet has shown a precipitous decline over the past 20 years (see Table 4.3), from some 15,000 (split almost equally among DF and EM) in 1976 to a little over 2,500 in 1996 (split equally among DF and EM) (Molinero, 1999). The numbers are not precise however (see COMETRAVI, v1, p. 186).

Table 4.3: Bus Transport in the DF R-100 and After

	Routes	Employees	Average Daily Passengers (Thousands)	Kms Traveled (Thousands)
1986	221	22,729	5,654	883
1987	224	23,492	5,868	891
1988	230	23,818	5,502	879
1989	234	23,323	5,699	911
1990	246	22,181	5,780	918
1991	246	18,716	3,072	734
1992	252	16,386	2,669	615
1993	216	14,845	2,585	565
1994	209	6,098	2,544	642
1995	191	9,577	2,555	485
1996	178	8,611	1,870	385
1997	123	4,477	751	181
1998	119	2,677	414	113
1999	114	2,633	385	120

Source: INEGI, 1999

Since the demise of R-100, the government has undertaken various efforts to concession out new bus services to the private sector. Despite the success of privately owned bus systems in other Latin American cities (i.e., Santiago de Chile), Mexico City has grappled relatively unsuccessfully to date with reviving a vibrant private sector participation. In the first phase of new attempts at concessions, several field studies were conducted (with money invested by the interested companies), but the winner ultimately dropped out because the authorities could not guarantee enforcement of market rights. A second RFP produced 7 concessionary winners, but none could present the requisite fleets – the concessions were revoked and a legal battle ensued (Molinero, 1999b). Further RFPs were issued, with little success. By 1997, three bus companies operated a total of nearly 80 vehicles on 56 routes (COMETRAVI, v7, 1999; p. 97). Recently, the government attempted to bid 17 routes; 30-something companies presented, 2 companies won and they were scheduled to enter into service in December (but small routes – 20-30 vehicles) (Molinero, 1999b).

The challenges to successful concessioning of bus services come from the ongoing competition from the Colectivo oligopoly and the government's inability to guarantee a transparent market for potential bus company investors/operators. As long as Colectivos are able to compete directly within the market for bus passengers, a return to significant bus system operations will be difficult.

Outside of the DF (in the EM), the so-called suburban buses are operated exclusively by the private sector, organized in private corporations or cooperatives. In general, these services are prohibited from entering the DF (as DF services are also prohibited from crossing into the EM), although recent initiatives under the auspices of COMETRAVI have aimed at developing and approving operation of "Metropolitan Routes," allowing companies to offer cross-jurisdictional bus services. The suburban buses also provide important feeder services to Metro terminal stations.

Trolleybuses
Trolleybuses differ from standard buses in several key respects. With respect to mobility, trolleybuses are at a relative disadvantage because they rely on the provision of overhead wires. While this makes service expansion less flexible than normal buses, the investment is much easier and cheaper than rail construction. From the air quality perspective, trolleybuses have the major advantage of having zero local emissions because the energy is generated remotely (which may have different impacts). Significantly quieter operation is another characteristic of the electric form of locomotion. In Mexico City, most service is on the busiest avenues where certainty of demand (not accounting for competition) is greatest.

Table 4.4: Trolleybus System Principal Characteristics

	Lines in Service	Length in Service (Km)	Units in Operation	Kms Traveled (Thousands)	Passengers (Thousands)
1992	n.d.	423	281	16,714	112,000
1993	n.d.	354	254	15,364	99,000
1994	n.d.	360	284	19,500	108,000
1995	13	353	274	21,017	142,589
1996	15	379	294	21,814	143,932
1997	17	406	305	22,369	79,347
1998	17	410	289	20,252	62,528
1999	18	423	263	9,891	34,868

Sources: pre-1995 from COMETRAVI, v1, p. 181; INEGI, 1999. Note: 1999 data through June.

The apparent decline of trolleybus patronage during the 1990s (see Table 4.4) is somewhat disconcerting. The service is operated by the same authority that operates the light rail line (see below) – the Electric Transport Service (STE) – a relatively autonomous authority dependent on the DF. We have been unable to obtain recent financial details on the operation of the STE and those that we have seen do not disaggregate trolleybus operations from the light rail. Based on data from 1992 to 1994 STE only recovers from 8% to 10% of its operating costs (administration, salaries, and operating costs) from farebox revenues (COMETRAVI, v1, p. 181). Similar to the case of bus ridership, the trends in declining trolleybus patronage most likely also stem from the heightened competition in recent years from the Colectivos.

Colectivos
A convergence of liberalization policy, employment policy, poor management of and cost-recovery in alternatives (i.e., Ruta-100) and the decaying institutional capacity in the DF led to an explosion of the ‘informal sector’ public transportation system – represented by colectivos (often referred to as “fixed route collective taxis”). Originally, colectivos were shared sedan taxis (operating on fixed routes); over time the fleet evolved into vans (i.e., 12-seaters) and now minibuses (up to 25 seaters). By 1996, in the DF, 84% of colectivos were minibuses (average age of six years) (COMETRAVI, v7, 1999; p. 35).

In the mid- and late-eighties, expansion of the colectivo network provided a massive employment source and a vast expansion of the network of transportation services. In a rapidly growing metropolis, colectivos, many of which carried a half dozen passengers or less, provided nearly ubiquitous and rapidly responding service. In some cases, bus networks could not respond quickly enough and in other cases it was unmanageable to send buses into unpaved, unplanned roads in areas of irregular development. Colectivos provided access for entire segments of society.

In such areas that bus service was difficult to supply, the availability of colectivos had significant benefits for mobility. In the areas where colectivos were in direct competition with buses, however, there were also costs imposed on the bus industry in the form of declining ridership and revenue (as discussed).

As opposed to private sector buses which in the DF operate under concessions which stipulate fixed stops, frequencies and other service characteristics, colectivos (and suburban buses in the EM) operate essentially with "permissions" which apparently have much less strict operating specifications (not to mention oversight). Despite plans and goals to reduce the role of colectivos in public transport service provision in the MCMA (especially the DF), little real progress has been made – with colectivos playing an increasingly important role.

The typical operating structure of colectivo service is the person-vehicle, the individual owner makes micro level decisions regarding vehicle maintenance, drivers, etc. However, larger route operations decisions are made by route associations – not formal business structures, but still hierarchically structured entities. Some of the more formal route associations undertake functions such as: operational control, vehicle dispatching/scheduling, and market research into new potential areas of demand (COMETRAVI, v7; p. 23). Vehicle owners are not necessarily concession owners; concessions are often owned by another layer in the route association hierarchy (see, for example, COMETRAVI, v7, 1999; p. 24).

In the DF, there are 103 registered routes, operated by some 27,000 vehicles. In the EM, there are 94 registered colectivo companies and 172 route associations (COMETRAVI, v7, pp. 19-20). The routes are further disaggregated into branches. In total, there are an estimated 22,000 kms of total colectivo route coverage in the MCMA, nearly equally split between the EM and the DF. In 1991, approximately 60% of colectivo services passed a Metro station, suggesting that the colectivos provide an important feeder service (COMETRAVI, v7; pp. 34 – 35). A 1994 analysis of a sample of colectivo routes estimated that – on average – vehicles carried 700 passengers per day and the typical vehicle travels about 150 kms per day, covering over 10 route circuits per day (COMETRAVI, v7, 1999; p. 37). For an important share of the colectivo routes, the demand characteristics seem more appropriate for full-size bus operations.

Regarding travel distances on Colectivo, a 1994 study indicates that 63% of colectivo trips are less than 5 km. The average trip distance by colectivo was 8.4 km (COMETRAVI, v7, 1999; p. 41).

In terms of operations, the structure of the colectivo system has important implications. Due to the atomized, individual ownership, there is significant competition within the market (typical to many liberalized and poorly regulated public transport services), which produces dangerous driving habits and high accident rates. There is also often poor coordination of vehicle scheduling and frequencies. Furthermore, the lack of formal, technically capable, larger-scale businesses makes it much more difficult for owners to take advantage of scale economies in operations (i.e., maintenance, repairs, replacements, financing) – the subsequent inefficiencies are ultimately passed on to system users in the form of higher fares (COMETRAVI, v7, 1999; p. 27). Chronic service problems include: failure to obey operating rules, excess supply during off-peak hours, high waiting times (to ensure vehicles filled to capacity) at terminals, and competition among operators (COMETRAVI, v7, p. 40). Typically, vehicle operators do not operate under contract, work six-day weeks and 10-hour shifts, without benefits or accident insurance (v7; p. 23).

There has been a history of conflict between colectivo owners/route associations and the government, although these have reportedly waned in recent years. Various negotiations and agreements among colectivo associations (in both the DF and EM) and the respective governments have touched on a range of issues, such as respecting routes, maintaining insurance policies, providing reduced fares for students/elderly, etc.; nonetheless, according to COMETRAVI (v7; pp. 28 – 30), the main unwavering position of the colectivo operators has been one of pushing for ongoing fare increases.

In terms of fares (fares relative to other modes are discussed below), colectivos in both the DF and the EM operate with a distance-based fare structure, although the structure (and fare levels) differ. In the EM (as of 1996), the fare was flat for the first 5 km and then increased linearly with each additional km. For the DF, block-based fare increments (as of 1996) are used, with fares staggering higher in the ranges 0-5 kms, 5 –12 kms, and over 12 kms. Between 1994 and 1996, colectivo fares in the DF doubled (not clear if in real or nominal figures) (COMETRAVI, v7, p. 41). The fare structure combined with the colectivos' apparent effectiveness relative to other modes has made the business relatively attractive: a 1994 analysis of 72 colectivo lines calculated an average internal rate of return for colectivo operations of 55% (COMETRAVI, v7, p. 44). Whether such high rates of return have been sustained with continued growth in the fleet size (supply) and whether they are representative of the overall system is unclear.

Freight Trucks

The truck industry is divided in two ways: inter-urban versus intra-urban and public versus private. As Table 4.5 indicates, privately owned trucks are the largest segment with respect to the number of vehicles operating in the region. Because most private trucks are owner-operator (very few corporate fleets exist; DHL and similar operations are exceptions), there are few facilities for vehicles to be parked and stored. Other implications of this diffused system of ownership is that economies of scale for maintenance and warehousing are not realized by prospective managers. The lack of parking facilities means that, similar to the colectivo situation, the vehicles are often parked on-street contributing to congestion.

Globally, trends toward "just-in-time" delivery, which allows firms to operate with reduced surplus inventory, favor more frequent and therefore smaller shipments. This leads to greater utilization of so-called "Less Than Truckload" (LTL) vehicles. Indeed, 81% of the MCMA truck fleet has only two axles and most of those run on gasoline – vehicles typical to LTL.

The simple presence of freight vehicles exacerbates the congestion problem that is already difficult with passenger vehicles. Trucks, especially tractor-trailers and other large units, complicate traffic patterns, disrupt flow on side streets during deliveries and often do not realize opportunities to streamline operations through improved management, which would require substantial organization change. Certain specific culprits that have been identified as targets by transportation officials include trucks travelling without cargoes, trucks passing through the region and portions of the fleet that are gross emitters of air pollutants.

Table 4.5: Truck Fleet Size, Age, Utilization

				Average Fleet Age	
Freight Market Segment	**Fleet Size**	**Share of Fleet**	**Share of Cargo**	**> 15 years**	**< 15 years**
Interurban - Public & Private	68,636	16%	69%	43%	57%
Local – Private	344,708	79%	29%	22%	78%
Local – Public	22,444	5%	2%	78%	22%
TOTAL	435,788	100%	100%	28%	72%

Source: COMETRAVI, v3

RAIL TRANSIT

Metro

Since the original construction of three lines in the late sixties, the metro network has grown to nearly 200 kilometers. In the late seventies, President Portillo pushed for a prolonged expansion of the network, at 15 kilometers per year, so that the system would consist of over 400 kilometers by the year 2010. Although opposition from public transport operators in the 1970s and financial crises in the mid-eighties and mid-nineties hampered planned developments, there are now a dozen lines, covering an urban area of approximately 300 km^2 (SEDESOL, p. 101). A key characteristic of the system is the fact that the original three lines (just 1/3 of the network length) carry a majority (65%) of all ridership. These lines have by far the highest peak (and off-peak) ridership levels and in general the most frequent peak and off peak services (see Table 4.6).

Table 4.6: Metro's Principal Characteristics by Line

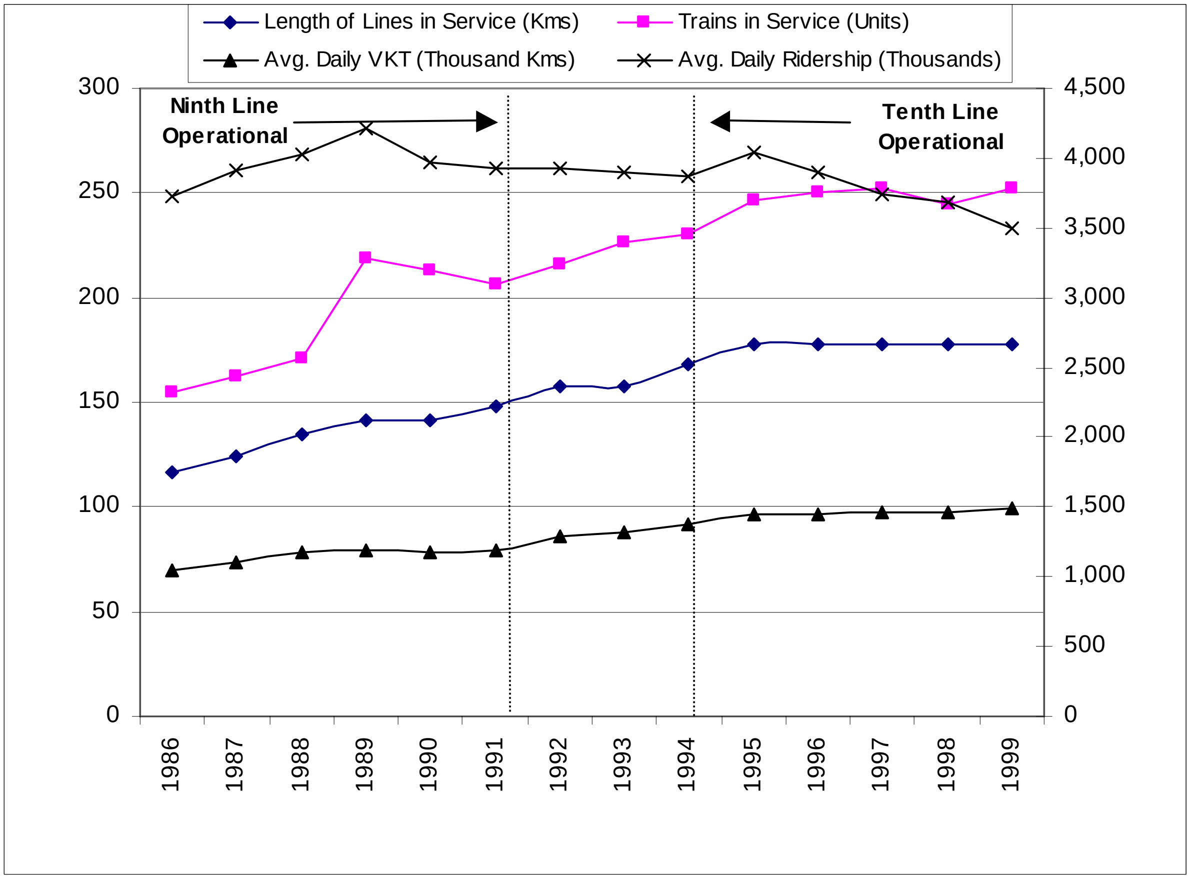
Line	Length (km)	Units	Frequency (peak and off-peak)	Daily Passengers	% of Total	Pass/Hour (peak and off-peak)	Passengers per km
1. Observatorio – Pantitlan	18.83	42	1’55” 2’10”	881,920	22.6	122,750 88,277	46,840
2. Cuatro Caminos – Tasquena	23.43	40	2’10” 2’25”	953,461	24.4	114,721 104,351	40,692
3. Indios Verdes – Universidad	23.61	44	2’05” 2’50”	786,887	20.1	144,450 73,778	33,330
4. Martin Carrera – Santa Anita	10.75	9	5’50” 5’50”	90,142	2.3	11,595 6,914	8,388
5. Politecnico – Pantitlan	15.68	17	4’20” 5’30”	227,035	5.8	22,560 12,365	14,484
6. El Rosario - Martin Carrera	13.95	12	5’50” 5’50”	124,604	3.1	22,187 14,792	8,934
7. El Rosario – Barranca del Muerto	18.89	18	4’15” 4’15”	215,392	5.3	44,380 24,763	11,400
8. Garibaldi – Consitucion de 1917	20.08	21	3’15” 4’50”	203,676	5.1	32,617 20,381	10,184
9. Pantitlan – Tacubaya	15.30	19	2’30” 4’20”	319,862	8.1	71,628 33,521	20,906
A. Pantitlan - La Paz	17.00	19	2’50” 3’40”	220,134	5.5	20,040 8,660	12,949
TOTAL	**178.00**	**239**		**3,908,447**	**100.0**		**208,107**

Source: Villegas, undated(b); COMETRAVI, v1.

Over the last decade, despite important system expansion, Metro ridership has remained stagnant and indeed has actually decreased in recent years. In 1986, the system was comprised of eight lines extending over 115 kms. Incremental extensions included: four kms completed in July 1986, 13 kms in August 1987, six kms in November 1988, 17 kms in August 1991 (when a ninth line became operational), and 20 kms in July 1994 (when a tenth line became operational) (see Figure 4.2). Despite these extensions, the concurrent addition of train units (trains are composed of nine cars), and 20% increase in energy use over the same time period, ridership in mid-1999 stood at 5% lower than 1986 levels (data from INEGI, 1999). Furthermore, as mentioned earlier, Metro mode share has decreased from a peak of 25% in 1983 to below 15% in 1995 (see Figure 3.3). A major reason for the decline in ridership is that while the population of the city is mobile and has expanded further from the urban core, it is far more difficult for the subway to grow.

Metro is run by a relatively independent authority – the Colective Transport Service (STC) – under the responsibility of the DF’s SETRAVI. STC apparently has significant autonomy in network planning and evaluation and has done its own travel forecasting exercises for planning purposes (COMETRAVI, v1, p. 274). In this case, the STC runs the risk often recognized in transportation planning – when infrastructure developers and service providers conduct their own network development evaluations, the tendency is towards optimism and subjectivity in analysis. These are arguments for putting the Metro planning function into an independent planning authority, overseeing all strategic transportation planning for the region (i.e., COMETRAVI).

Figure 4.2: Metro Ridership, Line Length, VKT, & Trains in Service[5]



Source: INEGI, 1999

While we have been unable to obtain detailed financial records for the Metro, data from 1992 – 1993 indicate that the Metro fares covered approximately 50% of operating costs (COMETRAVI, v1, p. 179). Given the high variation in ridership across lines, it is likely that Lines 1-3 more closely cover their operating costs (if not generating a surplus), offering a relative cross-subsidy to the Lines with lower patronage. In 1994, the year in which the 10th Line became operational, fares only covered 16% of operating costs – although it is unclear whether this represents some data anomaly and/or a misinterpretation of the data by the authors. Other data in COMETRAVI indicates that in 1995, the Metro required a subsidy of 37% to cover its operating costs (COMETRAV, v1, 1999, p. 205).

The most recent development has been the creation of two new lines that will enter the State of Mexico. The importance of this development highlights a critical feature of looking to major capital investment, such as metro expansion, as an option for emissions reduction. Unlike surface modes such as buses and especially colectivos, it takes a very long time to plan, develop and deploy a new metro route. Because colectivos can respond nearly immediately to new growth patterns, they develop a fast hold on new market

[5] Note: Average Daily Ridership is measured on right axis; all others on left access. Figures are 12-month averages for each year, except 1999 (average through June).

sectors. In addition to critical institutional barriers, this has made it difficult for the metro to reach the rapidly growing residential areas outside of the DF without coordination with other modes. As the experiences of the lines built after the initial three routes indicate, placement of metro service is fundamental to the mode's future success.

Some Metro critics suggest that the system itself has contributed to urban sprawl (see Cervero, 1997), in which case system expansion is undermining its own viability. Others suggest that there has been an overall failure to effectively incorporate land development into Metro line development (see COMETRAVI, v1, 1999; p. 259).

Light Rail

The MCMA's light rail system is a 13 km, one line system with 18 stations. Two cars comprise an individual train. The line runs from the southern terminal station (Tasqueña) of Metro Line 2 south/southeast into the delegación of Xochimilco.

Table 4.7: Light Rail Transit Indicators

	Total Length of Lines (Kms)	Units in Operation	Annual VKT (Thousand Kms)	Annual Ridership (Thousands)
1992	12.5	8	1,173	6,900
1993	12.5	8	1,290	10,500
1994	12.5	9	1,200	12,000
1995	12.5	9	1,404	25,796
1996	13	10	1,634	32,399
1997	13	11	1,697	19,678
1998	13	11	1,649	15,730
1999	13	12	866	8,981

Sources: pre-1995 from COMETRAVI, v1, p. 181; INEGI, 1999.
Note: 1999 data is through June.

The light rail system has undergone slight supply expansion since 1992, with 1 km of line and four cars added to operations. As a result, annual vehicle kilometers of travel have increased by 40% to 1,649 by 1998. Ridership has also increased since 1992, from 6.9 million per year to 15.7 million per year in 1998, a 127% increase. Despite this long term increase, there has been much fluctuation – annual ridership apparently reached 32.3 million in 1996 – suggesting inconsistencies in the source data.

As previously mentioned, the light rail is operated by the same agency that operates the trolleybus system. According to COMETRAVI (v1, 1999; p. 205), light rail operations require a 60% subsidy to cover operating costs.

Public Transport Passenger Modes: Comparative User Costs

Among the transportation modes, taxis are the most expensive – in 1994, the average taxi trip was almost ten times higher then the next most costly mode, the suburban buses. Suburban buses and colectivos, the privately owned public transport modes, were also significantly higher than the publicly-owned services – the average EM bus trip was more than three times higher than the DF-owned R-100, Metro and trollyebus; while the average colectivo trip was more than two times higher than the DF-owned modes (COMETRAVI, v7, 1999; p. 42). These differences in part reflect the operating subsidy that DF modes received, in part the longer distances traveled by suburban buses and (to a lesser extent) colectivos, and some level of private sector oligopolistic pricing practices.

V. TRANSPORT AIR POLLUTION & OTHER EFFECTS

The rapid growth in the MCMA's population, motor vehicle fleet, and industrial activity over the latter half of the 20^{th} Century – combined with the city's meteorological and topographical situation – has produced notorious levels of air pollution. The city is frequently cited as one of the world's most polluted. The MCMA's high elevation results in incomplete internal combustion and thus higher relative levels of tailpipe carbon monoxide (CO) and volatile organic compounds (VOCs) emissions. Furthermore, due to the city's location in a basin surrounded by mountains, prevailing winds and thermal inversions trap pollutants within the MCMA basin. The high elevation and strong sunlight also intensify ozone formation (ozone is produced through a photochemical reaction of nitrogen oxides (NOx) and VOCs). The problem of pollution concentration and effects on human health is further exacerbated by the fact that winds often come from the northeastern part of the region, carrying pollutants from the areas of heavy industry concentration towards the downtown and the southwestern residential areas (West, et al, 2000; p. 7).

The principal pollutants which systematically violate established air quality standards in the city are ozone, which violates the air quality standard of 0.11 parts per million (ppm) nearly 90% of the year, and respirable particulates (PM_{10}), which violate the standard of 150 micrograms per cubed meter ($\mu g\ m^3$) nearly half the year. Surprisingly, despite the high elevation (and subsequent poor combustion), congested driving conditions, and large share of old vehicles, levels of CO emissions apparently only rarely exceed established standards (West, et al., 2000; p. 8).

While inventory estimates vary somewhat[6] (see Table 5.1), the general indications are that transportation accounts for nearly all of the city's CO emissions and about 25% of PM_{10}. Of ozone precursors, transport accounts for 70% – 77% of NOx and 30% - 50% of VOCs. Most studies concur that ozone pollution in the region is NOx-limited, meaning that controls on NOx would more effectively reduce ozone than controls on VOCs;[7] transport's high share of NOx emissions suggests that transport control measures to address this pollutant would be an important part of an ozone abatement strategy. While transport had historically also been a major contributor to lead pollution in the city, the abolition of leaded gasoline sales in the MCMA in 1997 has effectively eliminated transport contribution of that toxic pollutant.

Table 5.1: Transport Contribution to Total Emissions – By Different Inventories[8]

[6] It is not clear how much the variation in transport contribution from year to year is due to technological changes in the vehicle fleet, changes in transportation and/or other activities, and/or different methodologies and assumptions used in developing the inventories.

[7] The ratio of VOCs:NOx ranges from 3:1 to 8:1 in various inventories, while ambient measures indicate a ratio as high as 15:1 (West, et al., 2000; p. 28). Since NOx levels in the MCMA are lower than VOCs, the formation of ozone is constrained by the presence of NOx.

[8] The 1988 inventory is from PICCA (first major air quality control plan); 1989 is from MARI (modeling exercise undertaken with Los Alamos National Lab); 1994 from Proaire (second major air quality control plan), 1996a from the Proaire Second Report, and 1996b from CAM (Metropolitan Environment

	1988	1989	1994	1996a	1996b
TSP	2%	3%	4%	25%*	26%*
SO2	22%	14%	27%	21%	21%
CO	97%	94%	100%	100%	99%
NOx	76%	71%	71%	70%	77%
VOCs	52%	51%	52%	33%	33%

Source: Derived from West, et al, 2000; Tables 8 and 9.
*Note: for 1996, percentage contributions are for PM10, rather than TSP.

The most recently available official pollution inventory for the MCMA indicates that of the primary pollutants of concern - PM_{10} and NOx – trucks in the MCMA are a major source, with private autos a relatively distant second (see Table 5.2). This inventory varies significantly from the one produced for 1994, in which autos contributed the largest single portion of NOx (and VOCs), while trucks estimated share of all pollutants was significantly less than the estimates for 1996 (estimates for PM_{10} were not given in the 1994 inventory).

Table 5.2: Transport Contribution to Total Emissions – By Vehicle Type (1996)

	PM_{10}	SO_2	CO	NOx	VOCs
Cars & Pickups	2.3%	7.8%	43.9%	19.6%	12.7%
Colectivos	0.2%	1.0%	10.7%	3.7%	3.3%
Taxis	0.5%	1.8%	10.2%	4.6%	2.9%
Buses	1.8%	0.4%	0.2%	3.2%	0.3%
Trucks	20.8%	9.2%	34.3%	46.3%	13.5%
Total	*25.7%*	*20.2%*	*99.3%*	*77.3%*	*32.8%*

Source: CAM, 1999.

The variation in the inventories from 1994 to 1996 is almost certainly due to changes in methods (and/or base data) rather than real changes in emissions for different vehicle types, and so these changes should be viewed as a representation of significant uncertainty in emissions knowledge. Indeed, given the range of uncertainty in vehicle fleet counts seen in the previous section, it is recommended that the inventory of transport emissions by vehicle type in Table 5.2 be viewed with some degree of skepticism.

To get a rough sense of the relative contribution of the different vehicle types to pollution, there are several useful indicators. One would be emissions per vehicle kilometer traveled (VKT); however without data on vehicle utilization rates, such an indicator cannot be accurately developed. Instead we develop here two alternative indexes. The first, is simply an index of emissions contribution per number of vehicles (see Table 5.3); this index shows that relative to their total number, buses are the largest relative contributor of both PM_{10} and NOx, followed by trucks for PM_{10}, and taxis and trucks for NOx. This measure suggests two possible factors playing a role here: poor emissions characteristics of buses, taxis and trucks, and/or their relatively intensive use (high VKT).

Commission).

Table 5.3: Index of Pollutant Contribution per Vehicle[9]

	PM_{10}	SO_2	CO	NOx	HC
Buses	7.50	1.55	0.94	13.09	1.33
Colectivos	0.07	0.29	3.15	1.10	0.98
Taxis	0.68	2.32	12.97	5.79	3.75
Private Cars	0.03	0.09	0.52	0.23	0.15
Freight Trucks	1.85	0.81	3.04	4.11	1.20

Sources: Derived from Table 5.2 and Table 4.2

Table 5.4: Index of Pollutant Contribution per Passenger Mode Share[10]

	PM_{10}	SO_2	CO	NOx	VOCs
Buses	0.15	0.03	0.02	0.26	0.03
Colectivos	0.00	0.02	0.16	0.06	0.05
Taxis	0.18	0.61	3.39	1.51	0.98
Private Cars	0.11	0.40	2.23	0.99	0.64

Sources: Derived from Table 5.2 and COMETRAVI, V6, 1999; p. 3.

Another illustrative index, at least for the passenger vehicles, is one which shows their emissions with respect to the total number of daily passengers transported – thereby indicating relative pollutant efficiency of each vehicle type in delivering passenger transport service. This measure shows that taxis, buses, and cars contribute the highest relative share of PM_{10}, while taxis and autos contribute the highest relative share of NOx (and VOCs) (see Table 5.4). Surprisingly, despite the large number of colectivos, these vehicles exhibit a very low index of pollution per passenger trip share, suggesting that this mode operates at high passenger utilization rates. The high relative pollution index for taxis likely derives from their relatively low occupancy rates and the fact that they spend much time driving without any passengers. For cars, the high relative pollution index comes from their relatively low occupancy rates.

For all vehicle types, age is an important factor contributing to pollutant emissions and, as is often noted in transportation pollution studies, a small portion of old, poorly controlled vehicles can produce a disproportionate share of emissions. In the case of the MCMA, this may be an important factor playing into truck emissions, since an estimated 30% of trucks operating in the city are over 15 years old (see Table 4.5). For automobiles, roadside measurements taken in 1992 showed that 4% of the vehicles accounted for 30% of VOC emissions and 25% accounted for 50% of CO emissions (Beaton et al., cited in West, et al., 2000; p. 16).

[9] This index is based on relative contribution of pollution (vehicle share of total MCMA pollutants) and relative number of vehicles. Note that the emissions inventory is for 1996 and vehicle fleet is for 1994.

[10] This index is based on relative contribution of pollution (vehicle share of total MCMA pollutants) and mode share of all motorized, road-based trips. Note that the emissions inventory is for 1996 and mode share is for 1994.

Additional Transportation Impacts

Beyond air pollution, it is important to highlight other negative impacts of the city's transportation system. These include, but are not limited to: congestion, accidents, noise pollution, among others. These effects must also be taken account of when devising strategies to address the MCMA's mobility and air quality problems. To date, however, little information has been obtained explicitly quantifying these different impacts. No references, for example, have been made in official documents to the problem of transportation noise pollution. The consultants for the COMETRAVI report attempted a rough quantification of the congestion, air pollution, accidents and urban land use costs of transportation in the MCMA. According to those estimates, transportation results in $7 billion in external costs per year, with congestion and accident costs making up 85% of all external costs (COMETRAVI, v1, p. 253). No details were provided regarding the methodologies used to calculate these costs, but the data leaves room for some doubts. For example, the accident data shows that there were some 12,083 traffic accidents in the MCMA in 1993, resulting in 4,671 injuries and 2,179 deaths (COMETRAVI, v1; p. 249). For a city of the size of the MCMA, these seem like underestimates, at least of accidents and injuries. For example, as a comparison, Santiago de Chile, a city with less than one third the population of the MCMA and 1/4th of the motor vehicle fleet, recorded 60% more traffic accidents (19,378) in 1994, resulting in four times as many injuries (16,000), though only 1/5th the deaths (400) (Zegras, 1997; p. 225).

VI. REGIONAL ARCHITECTURE

As is typical to such a large city, the institutional structures in the MCMA involved in regional transportation planning, infrastructure development, service delivery, enforcement, and traffic and system management are complex. There are at least three primary levels of government (see Table 6.1) and three main areas of intervention within each of which there are sub-elements (see Tables 6.2). Detailed descriptions of the primary actors at the national, regional and local level are presented in Appendix 1.

Table 6.1: Key Government Entities Involved in Relevant Areas of Intervention[11]

Area of Intervention	Government Entity			
	Federal	**Federal District**	**State of Mexico**	**Metropolitan**
Transportation	SCT Banobras	SETRAVI	SCT	COMETRAVI
Land Use	SEDESOL Banobras	SEDUVI	SEDUOP	COMETAH
Environment	SEMARNAP (INE, Profepa)	SMA	SE	CAM

Table 6.2: Areas of Intervention in the Land Use-Transportation System

AREAS/SUB-AREAS OF INTERVENTION		
Transportation	**Environment**	**Land Development**

[11] For details on the agencies presented in this Table, see Appendix 1.

• Public Transport Concession Management • Construction • Maintenance • Service Operations • Enforcement/Control • Planning/Modeling/Data Collection	• Inspection/ Maintenance (I/M) • Enforcement • Fuel Standards • Planning/Modeling/ Data Collection • Vehicle Standards	• Zoning • Comprehensive Planning • Real Estate Development

Beyond the government agencies involved and identified in Table 6.1, there are a host of additional actors which play an important role in the sector. These include international funders (particularly the World Bank, but also bilateral donor agencies), the private sector (such as major infrastructure firms, private banks, real estate companies, consultants, and private sector public transport operators), universities, and – to a lesser extent – civil society (i.e., NGOs). Furthermore, as discussed below, recent trends towards decentralization of government seem to be moving some level of power to local governments (municipios in the EM and delegaciones in the DF).

Since the transportation and air quality problems in the MCMA are inherently regional, it is important to make note of the relatively recent attempts to "regionalize" institutional structures in these sectors. As is typical in most large metropolitan areas, attempts to form regional institutions in Mexico City have lagged behind the regionalization of the MCMA; and the formation of truly effective regional institutions continues to lag. Through various fits and starts, beginning primarily in the 1980s, two regional bodies have arisen – one specifically tasked with the metro area's air quality (The Metropolitan Environmental Commission or CAM) and the other with transportation (The Metropolitan Commission for Transport and Roadways or COMETRAVI). Despite similar general mandates for handling their respective sectors, COMETRAVI and CAM have subtly important differences affecting their overall implementation abilities/effectiveness, including (COMETRAVI, v1, pp. 120-122):

- CAM has the access to some level of independent financial resources (via the Fideicomiso Ambiental – Environmental Trust Fund), while COMETRAVI does not;
- CAM has executive and regulatory powers, while COMETRAVI's powers are essentially of a consultative and proposal-making nature;
- COMETRAVI is comprised of the three directly relevant transport authorities at the Federal, State and DF level, while CAM is comprised of 9 Federal level Secretariats, the DF and the State of Mexico, plus four state enterprises.

In addition, there is a regional planning authority, the Metropolitan Commission for Human Settlements or COMETAH. It appears, however, to be institutionally weak, serving primarily as a coordinating unit for urban planning in the region, essentially integrating at a macro level the local plans.

One of the most important recent accomplishments of COMETRAVI has been the publication of a large study of transportation and air quality in the MCMA. This document forms an important first step towards strengthening the Commission's role in the region and also has been an important source of information for this paper. That document also provides a good overview of much of the recent history and the legality relevant to the public sector institutions involved in/responsible for transportation in the MCMA (v1, pp. 117 –143). The document focuses particularly on the State and DF level as well as the multi-jurisdictional (CAM, COMETRAVI) level. Interestingly, and perhaps indicative of the failure to integrate land use with transportation planning in the region, the COMETRAVI document does not include the respective authorities responsible for urban planning (i.e., the DF's General Secretary for Urban Development and Housing) or for public works (i.e., the EM's Secretary for Urban Development and Public Works) as entitites "directly involved in Transport and Pollution" (see, for example, v1, pp. 118 – 119). In addition, the COMETRAVI report does not detail the private sector institutions, citizens groups, and financial institutions involved in the sector.

Dynamic Issues

Beyond the institutional complexity rests a number of dynamic, inter-related issues that play an important role in the sector. Perhaps the most important of these are: political decentralization, institutional capacity, and finance.

Federalism

One of the most important institutional trends underway in the country which has direct impacts on management of the MCMA is the decentralization of power from the national government to lower levels of governance. For the MCMA, because of the unique historical role of the national government in local politics, this change has important consequences. In 1997, for the first time, the mayor of the DF was elected and significant administrative responsibilities were passed down. In 2000, a new mayor will be elected but this time for the traditional six-year term. One major element of change is the planned election of political leaders for each of the delegaciones in 2000. This new level of government, which is not new in the EM municipalities, also includes responsibilities for some traffic planning.

In some circumstances, such decentralization has significant benefits. Greater access to officials at the local level is expected to increase public participation and for some issues, such as local traffic management, this more direct communication has significant benefits.[12] In other areas, such as air quality planning or regional infrastructure development, decentralization has significant drawbacks.

Institutional Capacity

The second major trend is the continuing need to strengthen regional entities that are perhaps best positioned to address the metropolitan transportation, air quality, and land use concerns at hand. Interestingly, the impact of the decentralization pattern on these entities is uncertain. On one hand, reducing the importance of the national government in metropolitan politics may allow the historic maldistribution of attention toward the DF to be corrected by placing the DF and EM on more equal ground. On the other hand, the current inability of any agency to address long term planning may be exacerbated by greater pressures placed on scarce local resources.

As the metropolitan area continues to expand and additional states, such as Hidalgo, are included at this level of government, the importance of strategic regional planning in each area of intervention will also grow. For example, effective administration from

[12] The Legislative Assembly of the DF passed a Citizens' Participation law in November 1998 to encourage public involvement in general and specifically through local associations (SETRAVI, 1999; 2-23).

COMETRAVI, which depends in large part on fiscal autonomy, will be necessary, to coordinate transport services, planning and capital investments across the region.

At the personnel level, administrative changes present the great risk of a lack of staff continuity (institutional memory) and results in weakness in policy development, deployment and enforcement. For entire institutions, cumulative weaknesses from high turnover rates and other factors allows private alliances to gain power, as exhibited by the colectivo operators. For a policy arena, such as air quality planning, fragmented institutions and inter-relationships inhibit effective management. A key example of this effect is lack of coordination between agencies responsible for the emissions inventories from different sectors (IPURGAP, 1999; 14).

In the specific case of transportation, the issue of data collection, modeling and analysis is of major importance; it is not entirely clear where this responsibility rests within the institutions of the MCMA. The effective planning and management of an urban transportation system requires that an entity(ies) be tasked with:

- data collection and maintenance – origin destination (O-D) surveys of trips, traffic counts, physical and operational system inventories;
- the definition of technical criteria, study methodologies, evaluation tools – including travel demand model development, calibration, validation, and use.

Currently, no formal travel demand modeling occurs in the MCMA, although apparently attempts have been made at model implementation in the DF's SETRAVI. Furthermore, the Metro has reportedly used EMME/2 (a commercial travel forecasting modeling package) in evaluations of its network development. Nonetheless a specific authority tasked with modeling does not exist, which seems to be a serious shortcoming in the region. As an indication, the most recent O-D survey was conducted by the National Statistics Institute (INEGI); reportedly, the raw data from this survey has not been made fully available to relevant transportation authorities in the region.

In some cases, non-governmental institutions such as universities and private-sector firms can provide some backup structure and support for the areas in which weaknesses and fractures appear. In recent years, attempts have been made to create a transportation research organization. In its first incarnation, the Urban Transportation Institute would have conducted research on a variety of related subjects from a primarily academic perspective. This initiative, however, suffered a political death, in part due to student strikes at the National Autonomous University of Mexico (UNAM). In 1999, in a revised format, the Center for Studies and Capacity-Building for Transportation and Roadways was created by law in the DF primarily to help improve the management and operation of public transport services, such as the colectivos.

Finance

Another issue relates to financing and revenue-generation. Perhaps most important here are the inequities between the DF and the EM. In the area of federal tax revenue distribution, the per capita share received by the DF was more than twice that of the EM. In addition, the DF has received major direct subsidies through infrastructure investment, of which the metro is a key example (Krebs, 1999; Appendix 1). The lack of financing has also taken a major toll on the EM's ability to participate in planning activities in transportation, air quality and land use.

Nonetheless, the political decentralization trend has necessitated a shift in public finance policy throughout the MCMA. For example, operating subsidies for the metro have been transferred from the federal government to the DF. The tax used to generate revenue for the subsidy has been retained, however, and the DF has passed a law to generate revenue from new sources for a transit trust fund. Capital financing of major infrastructure, such as the Metro, stands to be significantly affected by the new financial structure; in fact, completion of the new Line B of the Metro has reportedly been held up in part due to lack of financing availability related to the fact that the Line crosses jurisdictions (from the DF to the EM). Similarly, the national government has given the EM responsibility for managing highway infrastructure that is now within the metropolitan area and therefore no longer in the inter-urban category of roads for which the national agency takes responsibility.

Long-term financial solvency of the sector is not clear as it is difficult to identify revenue sources and expenditures within the relevant governmental agencies. At the regional level, no significant source of revenues yet exists and COMETRAVI essentially depends on in-kind contributions from its member governments. The Federal District Government, in its recent transport strategy for 1995-2000, does attempt to explicitly identify transportation-related income and expenditures. According to that analysis, transportation revenues included: ownership fees, used car sales taxes, on-street parking fees, and traffic fines. Direct transportation expenditures included those related to planning and regulation, operating subsidies for the metro, light rail and bus services, and infrastructure construction and maintenance. While the numbers provided were rough estimates, they indicate significant deficit in the sector as revenues cover barely one-half of total transport expenditures (SETRAVI, 1999; pp. 3-67, 3-70, 3-74). Metro and light rail *operations* account for a significant share of total expenditures, on the order of 60% to 70%. The SETRAVI document recognizes the troubling nature of these deficits and makes some preliminary indications of potential means for raising revenue in the sector, including additional taxes on fuels and tires, increased fines, and the introduction of pollution-related fees at annual vehicle inspections (SETRAVI, 1999, p. 6-78). While detailed financial information for the EM is not available, it is likely that the situation there is even more dire.

VII. "OFFICIAL" PLANS

Plans and policy programs for addressing the MCMA's transportation problems have been proposed by the DF, the State of Mexico, and the COMETRAVI. The most relevant transport-specific policy documents (plans) include: the DF's integrated Transport and Roadways Program 1995-2000 (Programa Integral de Transporte y Vialidad del DF),which is currently being updated; a Transport "Master" Plan (Plan Rector) and a Transport Restructuring Program (Programa de Reordenación) for the State of Mexico (completed in June and September of 1995); COMETRAVI's 1995-1996 workplan ("Plan de Trabajo); and COMETRAVI's Integrated Study of Transport and Air Quality. In addition, on the side of urban development and land use planning relevant documents include the DF's General Urban Development Plan (1996), the EM's Urban Development Plan (1993), and the multi-institutional (SEDESOL-DF-EM) land use plan for the Metropolitan Region (1997).

The COMETRAVI reports offer the most comprehensive overview and analysis of the transport plans, proposals, and projects in preparation, underway, or hoped for in the MCMA. A summary of those plans and analysis is beyond the scope of this white paper. Nonetheless, it is important to highlight some of the most important structural plans coming from the various relevant government authorities. At the Federal level, the Secretary of Communications and Transportation has several regional plans. For highway infrastructure, currently a small portion of the proposed future 4th ring road (so-called "megapolitan" ring) is under construction. This proposed project is envisioned to eventually link the satellite (*corona*) cities of Cuernavaca, Cuautla, San Martin, Pachuca, Tula, Jilotepec, and Toluca at a radius of some 70 to 100 kms from the city center. The Federal SCT is also looking at the possibility of developing several toll facilities in the region, including a third ring road to be developed at some 25 kms from the city center. The aim of these facilities is to avoid that inter-city traffic pass through the dense parts of the MCMA. Integrated into these plans is the development of the so-called "logistics platforms" – freight distribution centers which would serve to alleviate freight truck traffic congestion in the MCMA.

The DF and the EM also have major plans for new highways, bridges, road expansions, parking, installation of traffic signals (particularly in EM), etc. The majority of the road works are aimed at improving transportation links between the EM and the DF and within the EM. The DF also is considering the development of elevated toll roads (vías expres) on its most congested facilities. The SEDESOL study (undated; pp. 110-114) proposes a series of inter-urban highway investments aimed at integrating the nation's economy.

There are also plans in the works for the development of a new airport, almost 100 kms north of the CBD in the State of Hidalgo, although this idea faces competition from a proposal to expand the existing airport (SEDESOL, undated; p. 106).

The DF has plans – beyond road improvements and expansions – for three near term rail initiatives: Lines A and B (into EM) of the Metro, plus the construction of a proposed Elevated Train (the concession to the private sector of this initiative was granted, but the project is being opposed by local neighborhoods; its future viability is in serious doubt). In the medium to long term additional Metro plans include extensions of Lines 4, 5 and 11, with three new lines proposed for 2020 (SEDESOL, 108). Finally, there are plans to develop a network of radial suburban rail lines, linked with the concept of the "satellite cities." SEDESOL (undated) also proposes utilizing current freight rail right of way to develop a light rail passenger system and to then move the freight rail service (and its industrial customers) to outside the VCT (p. 114).

VIII. KEY PROBLEMS & FUTURE POLICY AREAS

The profile presented in this paper leads to a somewhat disquieting prospective for comprehensive transportation-air quality improvements in the MCMA. The metropolitan region is expanding rapidly, with a growing motor vehicle fleet, major institutional challenges to service and infrastructure planning and coordination, severe transport-related environmental problems, and a general lack of financing available for infrastructure investments and upkeep. This section presents a general categorization of the major problems and, within those categories, outlines policy areas that can help guide the next phase of the Mexico City Project in devising more detailed interventions to simultaneously confront the mobility and air quality challenges facing the city.

Institutions, Finance, Planning and Management Capacity

Several studies have identified institutional issues as a major hurdle to progress in the MCMA's transportation sector. For example, COMETRAVI (v7, pp. 289 – 294) notes several institutional problems in the MCMA, including:

- the lack of a high capacity metropolitan institution to deal with planning and implementation;
- a failure to integrate land use, transportation, and air quality planning and analysis and a lack of compatability/uniformity/centrality in terms of modeling and analysis tools; and
- a lack of adequate financial resources and inequities in terms of subsidies and externalities (both among the EM and DF as well as among income and user groups).

These are not, of course, unique to the MCMA, since metropolitan transportation in any large, sprawling city invariably involves many public and private sector actors, each of which has its own competing interests and responsibilities. Indeed, institutional difficulties are often highlighted as the principal barrier to implementing a coherent urban transport strategy (see, for example, Anderson, et al., 1993; Gakenheimer, 1993). Nonetheless, this study not only reinforces the COMETRAVI conclusions regarding the serious lack of a centralized and capacitated planning, data collection and modeling authority for the MCMA, but it has shed additional light on the various manifestations of these institutional shortcomings, including:

- apparent inconsistencies and major uncertainties relating to trip data (both actual and especially future projections) and the availability of that data for planning purposes;
- inconsistent data related to vehicle fleet size, growth, usage (VKT), emissions, and distribution across geographic areas and across end-uses (i.e., colectivo vs. taxi);
- a lack of consistently applied project evaluation criteria (i.e., economic value of time, fuel, operating costs, etc.), which are crucial to ensuring choice of the best available transportation investments.

The formation of a high capacity, financially secure institution and the establishment of sound project evaluation criteria may well be the most productive measure to comprehensively deal with the MCMA's regional transportation-air quality problems. Such an institution might best actually consolidate the functions of air quality planning and transportation planning into one authority. Absent that, at the very least there must be strong and continuous ties and information exchange between air quality and regional transportation authorities, so that data on vehicle types, age distribution, utilization rates, travel speeds, etc. become consistently collected and modern travel forecasting techniques are integrated with air quality modeling. The ultimate goal should be the development of a comprehensive land use-transportation-air quality modeling tool for the MCMA; while the Integrated Program on Urban, Regional and Global Air Pollution is making important strides forward in the air quality modeling science in this regard, the lack of emphasis on the transportation-land use modeling interaction looms as a major potential shortcoming in any attempt to undertake comprehensive modeling.

Furthermore, the range of transportation impacts (accidents, noise pollution, etc.) should be quantified and incorporated into planning efforts. This requires financial, political, and intellectual investment in a regional transportation agency, with close collaboration with policing authorities, inspection and maintenance databases, etc. Yet, it is not clear how this problem might be overcome, especially given the political differences and competition between the DF and EM (and Federal Government) and the large disparities in infrastructure provision and financial and institutional capacity between the EM and the DF.

LAND USE, URBAN GROWTH AND INFRASTRUCTURE

Urban development has continuously been ignored in the MCMA as a tool for transportation enhancement and seems to typically be an afterthought to most transportation planning efforts. According to Molinero (1999), the uncontrolled urban growth in much of the region has resulted in priority being given to mobility over accessibility, rupturing the cohesion of the metropolitan area; the city suffers from spatial segregation (in terms of land uses) and has not been able to control rapid urban outgrowth of commercial and residential uses. SEDESOL (undated) notes that efforts to-date have not used transportation infrastructure as a potential tool for structuring urban development, and also recognizes that, while current trip patterns show the need for peripheral trunk roadways, these new roadways will only generate new urbanizations and demand. COMETRAVI (v7) also highlights the failure of most plans to account for long term travel generation effects of infrastructure expansion.

The Case of Generated Demand

The failure to account for generated demand within the many infrastructure expansion plans poses a risk to satisfying the MCMA's long term air quality and mobility goals. Generated demand refers to the phenomena that infrastructure provision and/or improvement increases trip demand. In the short term, the increase in demand is referred to as induced (or generated) traffic – an increase in traffic on the affected facilities (Lee et al, 1997, 7). This is comprised essentially of traffic diverted from other routes, other destinations, or trips made by people that were previously in the "market" for travel but chose not to do so in the pre-build situation. In the medium to long-term, the improvement in the trip conditions produce an overall increase in demand – generated or induced demand (Lee, et al.). This induced demand represents an increase in the total number of trips – trips which would not have occurred without the supply expansion.

When congestion is severe, induced demand can quickly undue any effort to improve the situation without prices that accurately reflect the real cost of travel (i.e., congestion charges or some rough equivalent [Small, 1992, p. 113]). The effects are especially strong in areas of rapid growth. Although the ultimate impacts depend on the specific context, almost all empirical studies confirm the phenomena (see SACTRA, 1994, p. 205; TRB, 1995, p. 155). A recent study in the U.S., for example, estimates that between 60% to 90% of expanded road capacity is filled within the first five years with trips that otherwise *would not have occurred* (Hansen & Huang, 1997). A review of evidence compiled in the United Kingdom concludes that road expansion, in the short term, produces 50% more trips and in the long term 100% more trips (SACTRA, pp. 47-48).

In the case of a national analysis of Mexico, Eskeland & Feyzioglu (1997a; 435) estimate that gasoline consumption per car is positively correlated with miles of highway per car: "Thus, new highway construction increases car utilization more than it improves fuel efficiency via better roads and less congestion." Such results offer strong caution regarding the effects of road infrastructure expansion on vehicle distances traveled and pollution. Indeed, COMETRAVI (v1, p. 149) observes that after the completion of a new toll highway on the north-western part of the MCMA new residential, industrial and service developments quickly have sprung up, resulting in the generation of new vehicle trips.

A Path Forward?

The challenge to integrating land use and transportation in practice is not uncomplicated. The rapid and intensifying dispersion of activities across the MCMA is creating new trip patterns/interactions among the DF and EM which the current transportation system does not adequately satisfy. While building infrastructure to satisfy this demand is critical, such interventions will then only reinforce the tendencies towards activity dispersion and further solidify the rapid suburbanization underway. The dilemma is compounded by the fact that most trip attractions remain in the central part of the MCMA creating long trip distances and high congestion. As the currently relatively low trip-making rate of peripheral residents grows to levels seen in the DF, the problem will be magnified.[13] In identification of these problems, Molinero (1999) recommends that: "the peripheral territories …should bring services closer to the user, the home and the neighborhood, promoting the mixed use of land" and avoiding "expansion that increases mobility and automobile infrastructure and that depends on a heavy centralization of activities."

The above suggests that efforts are needed on several fronts: 1) shaping the form of current urban fringe growth to maximize accessibility, while minimizing mobility (i.e., densification and mixing of land uses); 2) focusing road infrastructure enhancements on those areas with most dire deficit, particularly in the western and southern peripheral areas; 3) developing and deploying a strategy to take full advantage of current infrastructure (i.e., creating incentives to focus land development around the under-utilized Metro network and establishing dedicated bus-ways in all major travel corridors) before focusing on expansions. There is a pressing need not only to make land development plans and realities) compatible with transportation development plans, but for both of these to be compatible with a viable long-term air quality improvement plan. Again, this task would be greatly facilitated by the development and implementation (in close cooperation with relevant authorities) of an integrated land use-transportation model.

TRAVEL DEMAND AND INFRASTRUCTURE MANAGEMENT

One important tool to help offset the pressures for infrastructure expansion and tendencies towards generated demand is travel demand management. The principal relevant measure used to-date in the MCMA is Hoy No Circula, which has seemingly outlived its usefulness as any form of effective travel demand management tool. While it may be welcome to see this measure's demise, due to the unintended consequences brought about by its implementation (as discussed in Section 4), the lack of alternative demand management

[13] The fact that current projections (Table 3.2) seemingly fail to account for future growth in peripheral residents' trip-rates (instead actually predicting a decline in trips per person) might further worsen the problem by failing to anticipate it.

measures is worrisome (COMETRAVI (v7, pp. 289 – 294) also emphasizes the inadequate pursuit of travel demand management measures).

Since the costs (i.e., pollution, congestion) produced by urban transportation activity exceed the prices paid by users, demand is higher than economically efficient. The surest solution to the problem is more accurate marginal cost pricing. By designing and implementing effective pricing mechanisms, demand for motorized trips will be reduced, the need for infrastructure expansion is mitigated, and the urban area is made more compact (see, i.e., Lee, 1995). However, the widespread acceptance of efficient transportation pricing mechanisms among transport economists and engineers is typically more than offset by near unanimous rejection of such measures by policy makers, government officials and the general public (Gillen, 1997; p. 193). The MCMA seems to be no exception to this phenomena, except for the apparent fact that there does not even seem to be much consideration among the transportation planning profession in Mexico for implementing efficient pricing.

While there may be little short-term hope for measures such as congestion pricing in the MCMA context, the air quality problem offers the ideal platform to introduce such pricing measures to policy-makers and the general public. At the same time, a suite of complementary and/or "second best" pricing tools need also to be developed and rapidly deployed, including: metropolitan-area fuel taxes, increased parking fees, and more accurate vehicle ownership and usage fees (i.e., registration fees based on emissions levels and vehicle size/weight). Beyond improving efficiency in the transportation market, such measures would work towards drastically improving the major financial deficit that the sector currently faces (as discussed in Section 6).

Demand management measures would be well complemented by efforts at management of existing infrastructure assets and the pursuit of low cost supply management measures (such as intersection improvements). A compatible transport-air quality approach should orient towards maximizing the use of the existing capital stock through: hierarchical classification of the road network, an adequate maintenance system (and user fees to support this maintenance), effective traffic signage and control, initiatives giving priority to high occupancy vehicles (i.e., busways and buslanes), and complementary infrastructure like well-defined bus stops with clear user information. Not only will such measures promote an efficient use of the network, but they also bring additional important effects, such as reductions in traffic accidents (see, for example, Ragland, et al, 1992). Focus should also be placed on infrastructure for non-motorized transportation, both pedestrians and bicycles - traffic calming, pedestrianization, and non-motorized transportation networks can significantly improve the safety and comfort of such non-polluting modes and stimulate their use (see, for example, Pucher, 1997).

VEHICLE & FUEL TECHNOLOGIES

Perhaps the area in which the MCMA has shown the most progress in regards to transportation pollution has been in vehicle technology adoption, the inspection and maintenance program, and fuel improvements. As early as 1994, major reductions in measured roadside emissions of CO and VOCs were being attributed to the successful deployment of emission control technologies (West, et al., 2000; p. 16). The more recent move to unleaded gasoline, the incorporation of catalytic converters in the gasoline fleet, and the adoption (as of 1999) of U.S. Tier I light duty vehicle emission standards mark important further strides in reducing motor vehicle emissions in the city. Nonetheless, major challenges remain, including: reducing emissions from the still large number of older vehicles on the street; accelerating the retirement (scrappage) of such vehicles; and, more effectively expanding emissions controls to heavy duty vehicles, particularly trucks (as seen in Section 5, trucks apparently account for an inordinate portion of criteria pollutants). More detailed measures regarding vehicle technologies and fuel improvements (including the opportunities for the use of alternative fuels) are included in other papers for the Mexico City project.

PUBLIC TRANSPORTATION MANAGEMENT AND MODE SHARE

The MCMA exhibits four major trends affecting the public transportation market:

- a continuously declining public image, due to safety, security (crime), comfort and other real and perceived service shortcomings;
- mode share evolution away from higher capacity modes (i.e., Metro and buses) towards low capacity modes (colectivos and autos);
- a conflict between the commercial viability of competing colectivo and bus operations, driven by the massive growth in colectivos, the political clout of their owners/operators, and subsequent difficulty in successfully concessioning out bus services; and
- high levels of subsidies for DF-operated public transport modes (Metro, trolleybuses, light rail), and stagnant or declining patronage.

A range of measures have been proposed by consultants, government authorities, and others to address the ongoing challenges facing the MCMA's public transport system. The majority of these measures aim at reigning in the colectivo which is widely viewed as the culprit in creating systemic chaos. The typical arguments against the colectivo include:

- their large relative number and low capacity leads to a increased levels of pollution and road congestion per passenger carried;
- their atomized owner-operator structure results in high on-street competition and subsequently unsafe driving practices;
- the lack of formalized colectivo companies produces less than optimal operations and maintenance practices as well as negative effects like informal service terminals and on-street vehicle storage;
- the colectivo "lobby" leads to oligopolistic pricing (high fares), while also limiting the authorities' ability to effectively manage the entire transport system (through, for example, the use of strikes).

Some of the policies identified by government authorities to address the colectivo problem and, in general, improve public transport operations in the city consist of (Villegas, undated(b)):

- fostering the formation of formal colectivo companies;
- introducing training programs both to professionalize the companies (i.e., improved management and administration skills) and improve driving, operating and maintenance practices;
- develop financing schemes for the acquisition of buses and promote the transition from colectivo companies to bus companies;
- allow buses to charge higher fares to improve service profitability; and
- better integrate bus and colectivo service with the Metro.

The general focus on reducing the dominance of the colectivo stems from the perceived negative effects of this mode on the ridership and viability of other public transport modes. While it is certainly true that the colectivo system does create a range of negative system-wide effects, it has responded, apparently, to a real market demand by offering relatively attractive, high-frequency, ubiquitous, door-to-door service. This has been particularly the case given the rapid urban expansion of recent decades – the colectivo can respond most rapidly to new markets (new urbanizations).[14] While colectivo dominance has, in part, arisen due to oligopoly power, predatory practices, and effectively limiting government regulations – it is important to recognize that the colectivo also is a direct response to user desires for a demand-responsive transportation service.

Public transport policies for the MCMA must, therefore, recognize the benefits of the colectivo, both integrating it effectively into the public transport mix and learning from its market attractiveness in promoting other types of service. The market success of the colectivo suggests that the government might pursue a policy of formally differentiating public transport services, aiming to appeal to a range of user groups based on willingness to pay for speed, convenience, comfort. In such a framework, high cost, high quality buses might succeed in attracting higher income users, particularly if dedicated rights of way (i.e., exclusive bus-lanes) could improve the speed and reliability of travel. The government has indicated a desire to develop a "hierarchical" colectivo system, with the colectivos serving as a feeder system to a network of high speed buses operating on densely traveled trunk routes. For such a system to function effectively and to actually succeed in attracting users (and service operators) would require virtually seamless and "timeless" transfers between colectivos and buses plus low-price and/or integrated fares. Implementing such a service would be no small feat, particularly in the face of the almost certain opposition by colectivo operators.

[14] Of course, colectivo supply likely also feeds urban expansion, since people will be able to travel from/to more distant origins/destinations due to the colectivo service.

Regardless of the ultimate specifics of the road-based public transportation solution, the clearest point is the need for the government to develop an accountable, enforceable public transport management system. The political hurdles implicit to this are not trivial, however, little progress can be expected without the development of an effective regulatory scheme. At least one useful example of the potential benefits from regulation of the privately-owned public transport system comes from Santiago de Chile. After complete de-regulation of the system during the 1970s and 1980s, authorities finally raised the political clout to shift the role of the public transport system in the city's dire pollution and congestion problems. The first step was outright state purchase of the oldest vehicles on the streets – 2,600 buses at a cost of US$14 million to the government. That and other measures soon opened the door for a transparent and apparently effective route bidding process which has produced remarkable results in recent years including: a reduction and modernization of the bus fleet (number reduced from 13,500 to 9,000 and average age reduced from 14 years to 4 years), implying a private sector investment of US$500 million in vehicle stock; improvement in service quality (uniform signage, more comfortable vehicles, etc.); improved vehicle emission characteristics (more than half the fleet complies with EPA-91 or 94 standard); modernization of the bus companies; and, importantly, stabilization of the bus fares (Dourthé, et al, 2000; pp. 4 – 8). For the case of Mexico City, it remains to be seen whether the dire air pollution problem can spur the changes necessary to improve the public transport crisis.

APPENDIX 1: INVENTORY OF RELEVANT INSTITUTIONS

National Level

At the national level, the most relevant institutions relating to the transportation sector are:

- The Secretary of Communications and Transport (SCT) – responsible for suburban trains, inter-urban highways (including ring roads), and the airport.
- SEMARNAP (INE/PROFEPA) – responsible for the environment.
- SEDESOL (Federal Secretariat of Social Development) – According to the General Law on Human Settlements (LGAH), SEDESOL has responsibility for supporting planning and regulation in urban areas that cross federal lines. SEDESOL has a coordinating and convoking role among the relevant municipal/state agencies as well as a role in supervising Federal activities related to urban/regional development recently developed a Master Plan for the entire central region. "aimed at improving access to the centers of economic activity and increase housing, infrastructure services and utilities." Uses restrictive zoning and development controls/prohibitions. Unfortunately, enforcement has reportedly been rendered impotent due to politics (Krebs, 1999; Appendix 1).
- Banobras (National Bank of Public Works and Services) – is a national development bank which finances infrastructure, public service and environmental projects. The bank can lend to all levels of government, as well as to private sector entities involved (i.e., via concession) in the delivery of public goods/services. Beyond providing financing to appropriate projects, Banobras provides technical assistance and uses loan conditionality to achieve policy goals (Banobras, 1998, p. 65). Banobras often works closely with multilateral development banks (MDBs) (i.e., World Bank), funneling MDB funds to local projects. For example, Banobras cooperated with the World Bank on the First Urban Transport Project, a $90 million loan which included $73 million to the MCMA (Rodriguez, 1997, 15).
- POLICE – no additional information currently available

Federal District

At the DF level, to some degree the relevant "institutionality" remains somewhat in-flux, as much new local legislation has been passed recently (e.g., towards the end of 1998, under the first democratically elected local government). In May, 1999 the Legislative Assembly of the DF passed a new Transport Law.

- Secretary of Transportation and Roadways (SETRAVI) – SETRAVI recently (mid-1990s) replaced the DF's former Transportation authority. It is divided into three main offices (Dirección General): planning and roadways, regulation, and transport. Among the three offices, SETRAVI is responsible for the great majority of transportation issues in the DF, including: policy-making and planning, enforcement, regulations, issuing drivers licenses, setting fares, emitting and enforcing concessions (for public transport and freight), and inter-institutional coordination (SETRAVI, 1999; pp. 2-29 – 2-32). Somewhat autonomous, yet still dependent on SETRAVI, are the two government authorities responsible for operations and planning of the electric transportation system in the city: the Collective Transport Service (STC), which operates the Metro, and; the Electric Transport Service (STE), which operates the trolleybus system and the light rail line.
- Secretary of Urban Development and Housing (SEDUVI) – housing and urban development

- Secretaria de Obras Publicas (SOP)– public works
- Secretary of the Environment (SMA) - environment
- *Delegaciones* – current plans are to delegate local transportation planning functions to the delegation (municipal) level with the creation of traffic offices in each delegation.
- Secretary of Public Safety (SSP)– as of 1998, the SSP was given legal authority over traffic control, including the traffic signalization program, and drivers education. Certain tasks will remain in the hands of SETRAVI, including signage/markings, traffic control technologies and relevant works and engineering (SETRAVI, 1999; p. 2-22, p. 2-31).
- POLICE – additional information currently not available.

State of Mexico

Below are the principal institutions involved in the State of Mexico; little additional information is currently available:

- Secretary of Communications and Transport (SCT)
- Secretaria de Desarrollo Urbano y Obras Públicas (SEDUOP)– public works
- Secretaria de Ecologia (SE)
- *Municipios*
- POLICE

Multi-jurisdictional

Constitutional law empowers state (or DF) governments to form metropolitan commissions to confront issues of public concern which cross jurisdictional boundaries. For transportation-environment-urban development, there are three relevant institutions at the multi-jurisdictional level, each tasked specifically with handling inherently regional issues. Each has a relatively recent history, although previous institutional precedents in the transportation sector date back to at least the mid-1970s (see Molinero, 1999; p. 2).

- COMETRAVI – In 1989, a Metropolitan Transport Council was formed to help coordinate regional transport, developed a master plan for MCMA (defined as D.F., plus 17 regional municipalities). This council also helped push through transport services across D.F.'s boundary (O&G, 1997; 139). In 1994, (Metropolitan Commission for Transport and Highway Administration) COMETRAVI was created through agreement with MTC, State of Mexico, and the D.F. COMETRAVI functions with a rotating presidency; as of late 1999, the DF held the presidency, this is due to change in March, 2000. It is not clear what the implications of this may be in practice. COMETRAVI has several working groups (i.e., Technical Norms, Legal Issues, Service operation, Fares/Finance) and its tasks include: development of mechanismis to improve transport services and road infrastructure in the region, homogenize the legal structure affecting transport and infrastructure in the region and development of the information necessary for transportation planning and implementation. Among the initiatives of COMETRAVI are included a Metropolitan License Plate (Placa Metropolitana) aimed at authorizing cross-jurisdictional public transport services.

- CAM - created by Presidential Decree in 1992 to define, coordinate, monitor implementation of policies, programs and projects for pollution control in MCMA. Has a President, Technical Secretariat and Advisory Council. Presidency supposed to rotate every two years among mayor of D.F., Governor of State of Mexico, and the secretary of SEMARNAP. Technical Secretariat has a Technical Secretary and one technical agency from each member agency (Secretariats of Health, Treasury and

Public Credit, SEMARNAP, Public Education, Commerce and Industrial Development, Communications and Transport, Comptroller, and Energy; IMP; State of Mexico; FDD. Technical Secretariat is responsible for identifying pollution control measures, specifying schedules and budgets, and institutional responsibilities. FDD's Department of Environment is coordinating body of the Technical Secretariat and the FDD is responsible for the relevant costs (Onursal & Gautum, 1997; 139). Apparently has strong technical capacity, good institutional memory (retention of staff), and much input from international environmental experts (Onursal & Gautum, 1997; 139). The Advisory Council is designed to ensure citizen participation in the design and implementation of projects (i.e., aimed to address the political feasibility of implementation).

- COMETAH (Metropolitan Commission on Human Settlements) – the first regional planning initiative for the MCMA was launched in the mid-1970s with the formation of the Conurbation Commission of the Center of the Country (CCCP). CCCP devised a plan with the overall goals of decentralizing the metropolis and reducing its growth. Despite having legal and financial resources, the CCCP had no practical effectiveness (SEDESOL, et al, p. 11). COMETAH is a more recent incarnation of a regional development commission – comprised of the DF, EM, and SEDESOL – and tasked with proposing planning instruments for "ordered" urban development. Similar to the other metropolitan commissions, COMETAH faces the challenge of respecting local government sovereignty while making recommendations for controlling urban growth. A recently published metropolitan regional plan by COMETAH attempts to provide a general framework for institutional coordination around common goals of managing urban growth (see SEDESOL, et al.).

"Private" Sector & International Community

Beyond these governmental institutions, there are several other private companies, non governmental organizations, and international entities which undoubtedly have important influence on system development and operations. These include:

- Bus/Colectivo operators
- Route Associations – Cervero (1997) highlights the "self-regulatory" role that these associations play.
- Construction companies – major force in Mexico (i.e., Tribasa, ICA)
- Real estate companies
- Financiers
- Universities
- NGOs
- Development Banks
- Consultants
- Technology Vendors

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