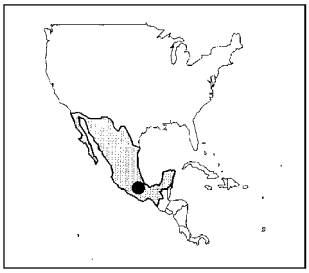

Mexico City: our common future?

Priscilla Connolly

SUMMARY: *This paper describes Mexico City's environmental problems, how and why they arose, and how they have changed over the last ten years. This includes an interest in how the problems have been affected by environmental policies and demographic structures. It highlights how some environmental problems are simply characteristics of large cities while others can only be understood in relation to specific economic, political and geographic factors. It discusses what constrains the cheapest and most effective solutions - for instance the lack of an integrated public transport policy and measures to promote energy and water conservation. The constraints include complex and often deep-rooted political and administrative factors - for instance the lack of funding available to the municipalities which house a large and growing proportion of the low income population and the powerful vested interests which benefit from the lack of an integrated transport policy. The paper also shows up the inaccuracies in much of the general literature when referring to Mexico City - for instance the exaggerations as to its population and size and the assumption that much reduced population growth rates would necessarily bring improved environmental conditions.*

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I. INTRODUCTION

MEXICO CITY IS often cited as the "largest and most polluted city in the world"[1] and is generally thought to epitomize the ecological disaster wrought by rapid urbanization in developing countries. Whether the superlatives are merited or not - and Mexico City is neither the planet's largest nor most populated metropolitan area - it certainly poses serious environmental threats to its own survival as a viable city, with repercussions at a regional and even global level. To the extent that its environmental problems are common to some or all cities throughout the world, the sustainability of Mexico City's future is of global concern. Many of these problems are, however, aggravated or compounded by particular geological, political and economic features. As in all poorer countries, environmental deprivation arising from poverty, or lack of access to resources, compounds with ecological degradation produced by economic progress, or the exploitation of resources. Some of these problems are improving, others are under control or being coped with, while others are deteriorating. Many of the environmental problems described by Martha Schteingart ten years ago in the

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inaugural issue of *Environment and Urbanization*[2] are still with us but there have been changes and some improvements. Needless to say, the solution to certain problems brings about new ones; that is what urbanization is all about.

With these distinctions in mind, this article tries to put Mexico City's apocalyptic image into perspective by examining the following main environmental issues:

- population growth and distribution in relation to the city's capacity to solve basic poverty related environmental problems, namely, access to housing, clean water and sanitation;
- Mexico City's paradoxical hydraulic cycle and its implications in terms of costly public investment, deforestation and subsoil contamination; and
- the notorious atmospheric pollution by industry and, above all, transport.

In each case, a distinction is made between those parts of the problem which are general to all urbanization processes, those which are compounded by the sheer scale of Mexico City's growth and those which are exacerbated by its specific historical and geographical conditions. The policies pursued, if any, regarding each of these issues are also outlined and related to the way the problems are studied, understood and debated. Here again, it is important to distinguish between those types of measures which depend on interactions with global developments, such as the reduction of automobile emissions, and those which are resolved at a local level, such as plant closures or transport subsidies.

II. TOO MANY PEOPLE?

SINCE THE PUBLICATION of *The Population Time Bomb* and *People! Challenge to Survival*[3] raised the spectre of starving hordes threatening world resources, demographic growth has never been absent from debates on environmental issues. Although most of the neo-Malthusian arguments have been discredited (how could the starving hordes be devouring all the food?), the "massive" urbanization trends in the developing world are still seen as an ecological threat causing "…an exponential growth in the volume of resources consumed and of pollution created."[4] As a prime offender, Mexico City has not escaped this kind of demographic reductionism in which the scale and pace of population growth, *per se*, is seen as the main culprit of environmental problems. Reminiscent of the 1960s terminology about the "hyper-urbanization" of Third World cities, Mexico City's "excessive" level of economic and demographic concentration is still frequently invoked as the major cause of its problems. At work here is the "predict and provide" mentality which sees the problem in terms of the impossibility of providing for (inaccurately) predicted needs. Following this, the reduction of the city's growth, or level of economic and demographic concentration, has been established as a target which, also *per se*,

1. For example, by Richard Rogers in his 1995 Reith Lectures. Published in Rogers, R. (1997), *Cities for a Small Planet*, Faber and Faber, London, page 28.

2. Schteingart, M. (1989), "The environmental problems associated with urban development in Mexico City", *Environment and Urbanization* Vol.1, No.1, pages 40-50.

3. Ehrlich, Paul, (1968), *The Population Time Bomb,* Washington; also Vogt, W. (1961), *People! Challenge to Survival,* London.

4. See reference 1, page 27. Similar visions are propagated in recent textbooks, for example Potter R. and S. Lloyd Evans (1998), *The City in the Developing World*, Addison Wesely Longman, Harlow. Here, adjectives such as "staggering" and "record-breaking" repeatedly describe recent urbanization in "the so-called developing world" (page 3).

5. The goal of decentralizing Mexico City and the other two major metropolitan areas has figured in all the national urban development programmes since the

would solve all kinds of problems. The underlying assumption is that if people stay in rural areas or move elsewhere, namely to the middle-ranking cities with populations of between 100,000 and 1 million, the resulting urban development will be more sustainable and environmental conditions will improve.[5]

Some flaws in this kind of reasoning become obvious when looking at Mexico City's demographic and economic indicators compared to its environmental performance. Table 1 shows recent tendencies in levels of demographic and economic concentration.

Table 1: Mexico City Basic Statistics

Mexico City metropolitan zone*	**1950**	**1970**	**1990**	**1995**	
Population (millions)[a]	3.1	9.3	14.7	15.6	
Mean annual growth rate[b]	6.7%	5.6%	2.3%	1.9%	
Mexico City as percentage of total national population[a]	12%	19%	18%	17%	
Primacy index[c]	2.02	2.00	1.60	Nd.	
Total Mexico state and federal district	**1950**	**1970**	**1988**	**1993**	
Total GDP as percentage of national GDP[e]	34%	37%	33%	35%	
Manufacturing GDP as percentage of national GDP[d]	Nd.	50%	42%	43%	
Tertiary GDP as percentage of national GDP[d]	Nd.	39%	35%	37%	
		1977	**1990**	**1993**	**1997**
Total private sector formal employees as percentage of national total[f]		40%	33%	31%	28%
Private sector formal employees in manufacturing as percentage of national total[f]		47%	33%	32%	25%
Total national	**1950**	**1970**	**1990**	**1997**	
Population (millions)[g]	25.8	48.2	81.2	94.7	
	1960-70	**1970-80**	**1980-90**	**1990-97**	
Average annual percentage population growth over decade	3.3%	3.3%	1.9%	1.6%[g]	
GDP per capita average annual percentage growth	3.5%	4.1%	0.1%	0.6%	

* The Mexico City metropolitan zone is taken here as being the Federal District plus 27 municipalities in the state of Mexico.

SOURCES:
a. National population censuses for respective years; 1995, national population count.
b. Figures quoted for the previous decade. For the 1950 figure, see Unikel et al. (1976), *El Desarrollo Urbano en México*, El Colegio de México. For 1970-1995, DDF (1996), *Programa del Desarrollo Urbano del Distrito Federal.*
c. CONAPO (1994), *Evolución de las Ciudades de México*, Consejo Nacional de la Población, México, page 30.
d. Sistema de Cuentas Nacionales, in Zedillo, E. (1998), *IV Informe de Actividades*, anexo estadístico. For 1970 to 1993, INEGI (1996), *Sistema de Cuentas Nacionales por Entidad Federativa.*
e. 1950: Estimates of Kirsten Appendi cited in CONAPO (1991), *Sistema de Ciudades y Distribución Espacial de la Población en México,* Consejo Nacional de la Población, vol. 1, México, page 11; 1970 to 1993, INEGI (1996), *Sistema de Cuentas Nacionales por Entidad Federativa*, Instituto Nacional de Estadística, Geografia e Informática, México.
f. Employees registered at the Mexican Social Security Institute as legally required; excludes construction workers who are temporarily registered. Source: Instituto Mexicano del Seguro Social 1998.
g. Consejo Nacional de Población (1998). Although the current annual natural growth rate, estimated from birth and death rates, is 1.93 per cent, the net population growth rate is 1.62 per cent per annum, the difference being accounted for by emigration, mostly to the United States.

first, in 1976. The most recent *Programa de 100 Ciudades* prioritizes certain cities for urban development. It is not clear, however, to what extent public - let alone private - investment is affected by these plans as data on the actual geographical location of public and private investment is almost non-existent. See Connolly, P. (1997), "Inversión pública y crisis financiera", *Diseño y Sociedad* No.7/97, pages 37-46.

Both national and city populations have grown drastically throughout the twentieth century but especially during the long post-war period of rapid economic growth based on import-substitution industrialization. Investment was particularly drawn to the agglomeration economies provided by Mexico City and, to a lesser degree, to Guadalajara and Monterrey. Equally attracted were immigrants, disproportionately representing the better educated from other cities, towns and rural areas. For most people with ambition, whether this was to avoid starvation, get an education or be president of the republic, Mexico City was the best place to live. It also offered a better chance of escaping the environmental deprivation of unurbanized rural areas (see Table 2). This does not mean that the city was providing adequate living and working conditions for all its inhabitants. Quite the opposite: the lack of housing provision is reflected in the fact that as much as 60 per cent of the city's growth is the result of people, especially women, heroically building their own dwellings on unserviced peripheral land, while informal subsistence work has always accounted for a large proportion of total employment. But the irregular settlements consolidated and improved over time while the expanding urban economy provided opportunities for upward socio-economic mobility.

National and local economic growth rates, net in-migration rates, indices of primacy and economic concentrations all peaked after 1970, coinciding also with the demise of the import-substitution economic model, sharp reductions in fertility rates and the decentralization of educational opportunities. These changes were not really perceived during the 1980s, partly because of an overestimated 1980 population census,[6] but mainly because the sheer inertia of the previous tendencies retarded their impact.

The financial crisis in the summer of 1982 marked a definitive turning point in the Mexican economy. Since then, with the exception of a largely speculative boom from 1989 to 1994,[7] the country has experienced continuous recession while being ruthlessly opened up to the world market. This has had clear repercussions on its economic geography, including a relative de-industrialization of Mexico City and an increase in the services sector. Both the 1980s and 1990s crises hit harder in the largest, more industrialized metropolitan areas, especially in terms of industrial closures and layoffs. While economic activity, measured in terms of GDP or census value added, is still highly concentrated, reflecting perhaps a swifter response to crisis by Mexico City firms, there are clear signs that employment is decentralizing. This has meant increase unemployment and informal activities, for which the larger cities still provide clear better opportunities.

More pronounced than economic decentralization is the reduction of Mexico City's relative advantage in socio-economic indicators compared to the rest of the country (see Table 2). This is partly explained by improvements elsewhere, due to the urbanization of the population in general,[8] but it also reflects a slowing down of improvements to Mexico City's urban environment. Not surprisingly, it was also during these years that eve-

6. Errors in the 1980 national population census and its incompatibility with those of 1970 and 1990 have been widely commented upon. See Camposortega, S. (1994), "Evolución y tendencias demográficas de la ZMCM" in *La Zona Metropolitana de la Ciudad de México: problemática actual y perspectivas demográficas y urbanas*, Consejo Nacional de la Población, Mexico DF.

7. Also, to a lesser extent, from 1996-97.

8. The proportion of total population living in towns and cities with more than 15,000 inhabitants rose from 28 per cent in 1950 to 61 per cent in 1990. However, this does not mean that Mexico is anywhere near being an urbanized country, as is often claimed. In 1990, over 23 million people lived in localities with fewer than 2,500 inhabitants (more than ever previously) with a mean population of 151. This suggests an absolute increase in the number of people living dispersed in rural areas without any kind of basic services and often without road access.

Table 2: Socio-economic Indicators for Mexico and Mexico City

	Total national		Total urban including Mexico City		Mexico City metropolitan area	
Average yearly current monetary household income (in US dollars at 1980 prices)[a]	1977 1992	$4,185 $4,099	1977 1992	$4,224 $4,859	1977 1992	$7,102 $5,798
Percentage households with current monetary income of more than four times minimum wage[a]	1977 1992	18% 36%	1977 1992	18% 44%	1977 1992	36% 48%
Percentage population with primary education or more[b]	1970 1990	30% 63%	1970 1990	 73%	1970 1990	54% 80%
Percentage women over the age of 12 in paid employment[b]	1970 1990	16% 19%	1970 1990	 23%	1970 1990	27% 27%
Percentage houses with inside piped water[c]	1970 1990	39% 50%	1970 1990	54% 64%	1970 1990	60% 64%
Percentage houses connected to main drainage[c]	1970 1990	42% 52%	1970 1990	61% 69%	1970 1990	74% 87%
Percentage houses with electricity[c]	1970 1990	59% 88%	1970 1990	81% 95%	1970 1990	90% 99%

a. Here "total urban" includes all localities with more than 2,500 inhabitants. Figures are calculated from the Banco de México surveys on household incomes and expenditure using consistent methodology. Households without any current monetary income, predominantly rural, are excluded from average on both years. Current peso are values converted to 1980 values using national consumer price index, then converted to US dollars using the 1980 average rate of 23.26 pesos per dollar.

SOURCE: Secretaría de Programación y Presupuesto (1977), *Encuesta Nacional de Ingresos y Gastos de los Hogares*; also Instituto Nacional de Estadística, Geografía e Informática (1992), *Encuesta Nacional de Ingresos y Gastos de los Hogares*, Cuadro 2, page 39 and *Encuesta de Ingresos y Gastos de los Hogares del A.N.C.M.*, Cuadro 2.4, page 19.
b. National Population Census, 1970 and 1990.
c. For 1970: COPLAMAR (1982) *La Vivienda en México. Situación Actual y Perspectivas al Año 2000*, México, Presidencia de la República, p. 78; Mexico City: National Population Census 1970. For 1990: National Population Census 1990.

rybody began to notice Mexico City's wealth related environmental deterioration, particularly traffic congestion and atmospheric pollution which, by then, had reached critical levels.

That Mexico City, in particular, was becoming not such a good place to live is reflected in recent migration patterns. Between 1987 and 1992, there was net negative in-migration of 180,000 for the whole metropolitan area[9] and, having disappeared as a factor in population growth, migration is not seen now as a major issue in urban development. Behind the net migration figures, however, mobility is higher than ever. Millions of people are flowing in and out of the city but they are not similar people. Although data on migration is scarce, there is strong evidence to suggest that, unlike 20 or 30 years ago, today's newcomers are poorer and less educated. Those leaving the city, on the other hand, tend to be more qualified and they are leaving not only to find better jobs but also to avoid the pollution.[10] The devastat-

9. Estimates by Consejo Nacional de la Población (1997), based on a comparison between their 1987 and 1992 surveys.

10. For a quantitative assessment of recent migration patterns see Luque, R. and R. Corona (1992), "El perfil de la migración en la ZMCM" in *La Zona Metropolitana de la Ciudad de México:*

problemática actual y perspectivas demográficas y urbanas, Consejo Nacional de la Población, Mexico DF. For a more qualitative appreciation of the same tendencies and for evidence that middle-class emigration out of Mexico City could be influenced by the deteriorating environment, see Izazola, H., C. Martínez and C. Marquette (1998), "Environmental perceptions, social class and demographic change: a comparative approach", *Environment and Urbanization* Vol.10, No.1, April, pages 107-118.

11. It was widely predicted that, by 1990, Mexico City would be the second largest city in the world, after Tokyo-Yokohama, with 20 million inhabitants, reaching almost 28 million in 2000. The 1990 census showed 14.7 million, causing a general downscaling of predictions. By 2010, Mexico City will scarcely make the UN top ten league of the world's biggest cities (see United Nations (1991), *Urbanization Outlook*; also United Nations (1995), *Informe Mundial de Asentamientos Humanos*, New York. Regarding overestimation in other Third World cities, see Satterthwaite, D. (1996), *The Scale and Nature of Urban Change in the South*, research paper, IIED, London; also Gilbert, A. (1993), "Third world cities: the changing national settlement system", *Urban Studies* Vol.30, Nos.4-5. On Mexico City's polarization reversal, see Rowland, A. and P. Gordon (1996), "Mexico City: No longer a Leviathan?" in Alan Gilbert (editor), *The Mega-City in Latin America*, United Nations University Press, Tokyo. In many other recent publications, Mexico City is still cited as the largest city in the world with over 30 million inhabitants by the year 2010 (see, for example, reference 4, Potter and Lloyd Evans (1998), pages 16 and 132).

12. What follows diametrically opposes Rowland and Gordon's conclusions, which consider that the slowing down of Mexico City's ing earthquake of 1985, an extreme example of one of Mexico City's environmental hazards, was also a contributing factor to the exodus in the late 1980s.

As a result of these changing migration patterns, together with an above average decline in fertility rates, the demographic projections for Mexico City in 1990 proved to be drastically overestimated, as indeed were those for practically all other Latin American and many other Third World cities.[11] The population growth rate of Mexico City's metropolitan area has now levelled out at slightly less than the national average of 1.9 per cent per annum.

Yet, having five or six million fewer people than expected did not make for much improvement in environmental conditions; quite the contrary.[12] One reason why the 1990 census came as a surprise to many was that, during the 1980s, Mexico City had been visibly growing, spreading dust and cement over ever-widening swathes of the surrounding hills and valleys. Two important factors have contributed to this disproportionate spatial expansion. The first is linked to the demographic transition itself. The reduction of the fertility rate from over 5 to 2.2 between 1970 and 1995,[13] and the corresponding decrease in average household size and dependency ratios have implied a disproportionate increase in housing; (not to mention a radical change in most women's lives[14]. Adults require more space than children: to live in, to travel in, to work in. They also eat and drink more, consume more energy and create more rubbish. In short, for the "predict and provide" mentality, the demographic transition has its ecological downside. To put it another way: demographic projections are not the best way to estimate future environmental impacts; more imaginative predictions are required for more imaginative solutions.

The other major factor behind disproportionately extensive urban sprawl is the housing provision system. In spite of explicit policies favouring public subsidies over rebuilding housing within the city centre,[15] financial resources for housing development within the city are extremely limited in relation to needs. This has been exacerbated by World Bank inspired policies aimed at making the housing market financially more efficient but whose principal effect has been to inflate land prices and create thousands of unpayable mortgages in the middle-income sector.[16] Lower income families' only option is to rent in the intermediate areas at increasing expense or build their own house on unserviced sites on the ever-expanding edge of the city. As a result, the central areas which already have services and infrastructure are losing population.[17]

The negative implications of population redistribution from already built-up areas towards the urban fringes are made worse by the fact that Mexico City is administratively divided into two separate political entities (see Figure 1 and Table 3). Roughly half the population lives in the Federal District (DF), the country's capital. The head of the DF government used to be a ministerial post appointed by the country's president and the budget controlled directly by the national congress. The lack of any kind of elected government has gradually been replaced by a

Figure 1: The Two Mexico Cities

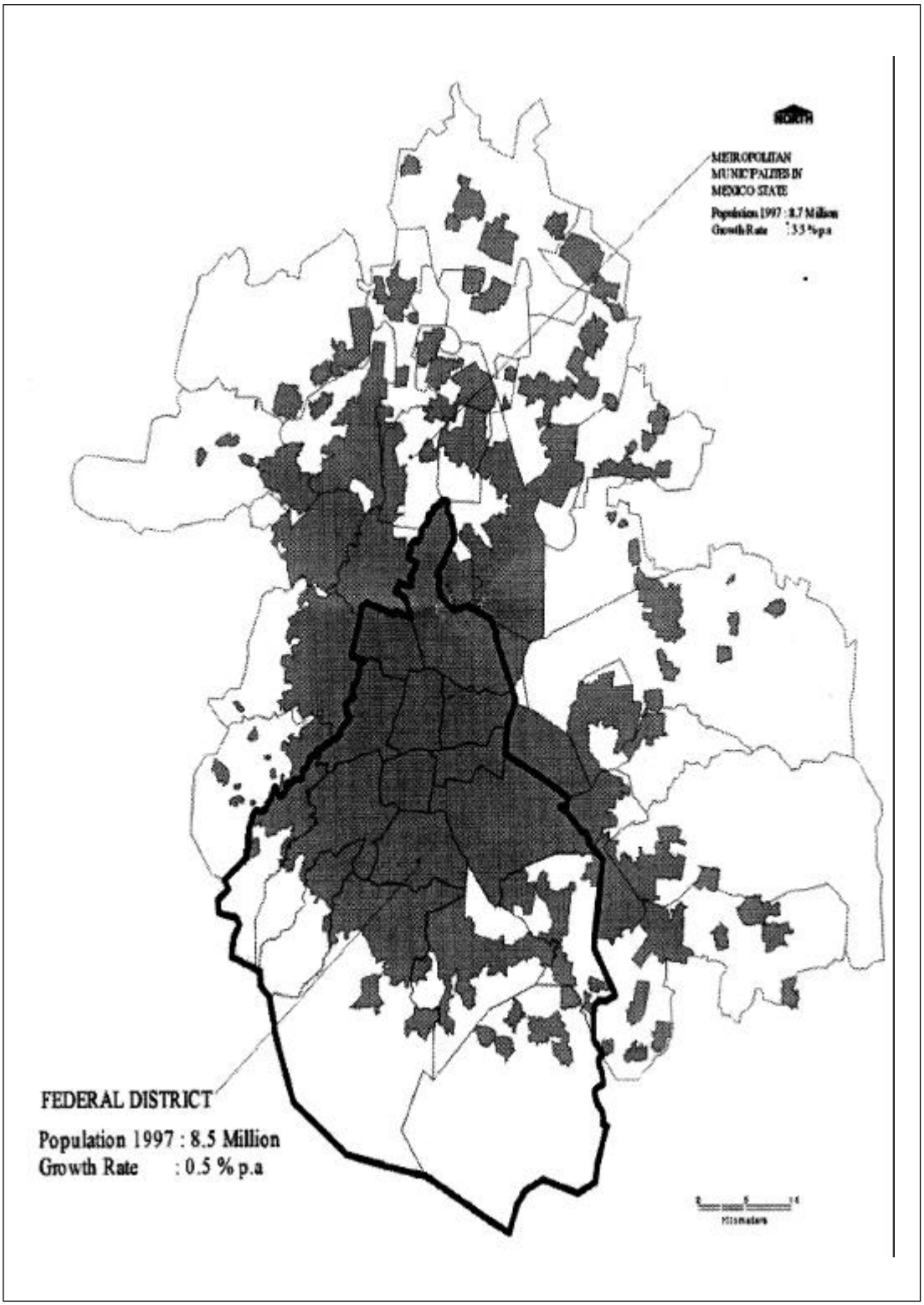


Table 3: The Two Mexico Cities

	Federal District	Mexico state
Population 1997	8.5 million	8.7 million
Mean annual growth rate 1990-5[a]	0.5%	3.3%
Percentage houses without inside running water[b]	28%	45%
Water provision[c]	35.4 litres per sec.	25.3 litres per sec.
1992 local government budget[d]	c. US$ 5,500 million	c. US$ 1,300 million
	DDF	State + ZM municipalities
Annual investment in public transport 1992[d]	c. US$ 1,000 million	US$ 80 million

SOURCES:
a. Porras, M. (1997), "El distrito federal en la dinámica demográfica megalopolitana en el cambio de siglo"' in Eibenschutz, R. (editor) (1997), *Bases para la Planeación del Desarrollo Urbano en la Ciudad de México. Tomo 1: Economía y Sociedad en la Metrópoli*, Miguel Ángel Porrúa/Universidad Autónoma Metropolitana-Xochimilco, Mexico, page 39; also 1990 population census.
b. Castañeda, V. (1997), "Gestión integral de los recursos hidráulicos" in Eibenschutz, R. (editor) (1997), *Bases para la Planeación del Desarrollo Urbano en la Ciudad de México. Tomo 2. Estructura de la Ciudad y su Región*, Miguel Ángel Porrúa/Universidad Autónoma Metropolitana-Xochimilco, Mexico, page 76.
c. Duhau, E. (1997), "Las finanzas locales en la zona metropolitana de la Ciudad de México 1988-1994" in Coulomb, R. and E. Duhau (editors) (1997), *Dinámica Urbana y Procesos Socio-Políticos 2. Investigaciones Recientes sobre la Ciudad de México*, Centro de la Vivienda y Estudios Urbanos, Mexico.
d. Instituto Nacional de Estadística, Geografía e Informática (1994), *Censos Económicos 1993*, Mexico.

growth, by avoiding the "doomsday scenario" of "...housing, infrastructure and services falling further behind the rapidly growing population" has given "...the authorities a chance to catch up with the problems." Thus, "...in terms of settlement patterns, the effects of economic liberalization are mostly benign" (see reference 11, Rowland and Gordon (1996), pages 198-9). An opposing view, by someone who understands that solving cities' environmental problems is not just a question of "authorities catching up" is put forward by Satterthwaite, who states "There is also evidence that the scale of urban poverty grew considerabley in most countries during the 1980s when they experienced serious economic problems and were also facing a slowdown in the rate of growth of their urban populations" (see reference 11, Satterthwaite (1996), page 19).

13. Average number of live births per woman at the end of her reproductive life in the Zona Metropolitana de la Ciudad de México (Centro de la Vivienda y Estudios Urbanos (1996), *Escenarios Demográficos y Urbanos de la Zona Metropolitana de la Ciudad de México 1995 a 2010*, unpublished study

series of reforms introducing both an elected local assembly and, from December 1997, an elected mayor, the first elections having been won by the opposition left-of-centre Party of the Democratic Revolution (PRD). There are still no lower-level elected municipal governments. Where the Federal District has lacked in democracy, however, it has gained in budgetary resources. The accumulated economic concentration and corresponding fiscal base means that the Federal District government has a per capita budget roughly double the average for the other Mexican states, and somewhat more than the combined income of all the country's municipalities. It has also had federal backing for its public debt. Needless to say, the more central and older parts of Mexico City, which are losing population, are located within the Federal District, whose total population growth is scarcely 0.2 per cent per annum.

The other half of Mexico City's population, and most of the growth, is, therefore, now accommodated outside the Federal District in an indeterminate and increasing number of municipalities in the neighbouring state of Mexico. Although a relatively rich state, and considering the combined resources of state and municipal governments, total local government expenditure in this part of Mexico City is only half that of the Federal District.[18] Furthermore, unlike the Federal District, where funds are centralized and distributed between the sub-jurisdictions approximately in proportion to their respective populations, the municipalities have widely differing budgets, depending on each one's fiscal base.[19] Thus, the poorer municipalities which are receiving most of Mexico City's low-income population growth are wholly unable to make the necessary investments in urban infrastructure even with the help of social investment programmes financed from state or federal government coffers. Without these investments, increasing numbers of Mexico City's inhabitants will suffer from insufficient housing, water and sani-

for Consejo Nacional de la Población (CONAPO)). Recent CONAPO publications state that the national fertility rate dropped from more than seven in 1975 to 2.6 in 1995.

14. The tremendous impact of falling fertility rates all around the world on practically all aspects of human existence, particularly on women's lives, does not seem to have been fully taken on board in debates on human settlements. For a good account of the way in which fertility rates are connected to economic crisis, migration and urbanization see Matthews, G. and L.N. Tellier (1993), "La transition démographique au Maghreb et l'evolution du systeme urbanine Marocain", *Cahier/Discussion Paper No.3-93, Villes et Développement*, Groupe interuniversitaire de Montréal.

15. These programmes started with the post-earthquake reconstruction project of the late 1980s which, by providing 44,000 dwellings in central areas, had a considerable impact on retaining population in the affected areas. Since 1988, the Federal District government has been developing new low-cost housing units in central areas in the order of 600 per year.

16. This was examined in Connolly, P. (1998), "El financiamiento de vivienda en México" in Herrrasti, M.E. and J. Villavicencio (1998), *La Política habitacional en América Latina: balance y perspectivas*, Centro de la Vivienda y Estudios Urbanos/Universidad Autónoma Metropolitana-Azcapotzalco, México DF.

17. Between 1970 and 1995, the four inner-city jurisdictions lost 1.1 million inhabitants, equivalent to 62 per cent of their combined 1995 population of 1.7 million. Since 1980, four more centrally located jurisdictions have also begun to lose population. (Population data from Porras, A. (1997), "El distrito federal en la dinámica

tation. Clearly, this deprivation owes more to the administrative and spatial organization of the city than to an overall lack of resources.

III. WATER: TOO MUCH AND TOO LITTLE

WHILE INSUFFICIENT AND, especially, uneven funding for urban infrastructure still creates poverty related environmental deprivation, providing land, water and drainage is, in itself, the cause of Mexico City's major ecological disaster: its paradoxical hydraulic cycle. Extreme environmental degradation is in fact inimical to this city, whose natural destiny is to be a lake, situated as it is in a closed basin with an average of 1,000 millimetres rainfall every year between May and September. Human beings, however, would have it otherwise and have thought it a good place to live and rule from even before the Aztecs founded Tenochtitlán in the early fourteenth century. Successive drainage of the Mexico City valley and the consequent need for external water supplies have been achieved through a series of increasingly ambitious engineering feats over five centuries (see Box 1). Throughout most of this time, efforts were geared towards saving the city from flooding during the rainy season, a not infrequent occurrence. The elimination of human waste was a secondary consideration but was also associated with river flows.[20] So by the late nineteenth century, when the need for sewage disposal was recognized as an essential component of a modern city, the only solution envisaged was to combine waste and storm water drainage. To drain the valley by means of a 40-kilometre "*Gran Canal*" and a tunnel bored through the mountainside for discharge into a lower-lying river had been in the imagination of successive city administrations for nearly three centuries. The definitive solution was at last achieved in 1900, at great cost and with the help of British contractors. The subsequent introduction of a public drainage system and, to wash it through, a vastly increased potable water supply meant that water was continuously flowing out of the valley, and not only after heavy rainfall as originally envisaged.[21] Increased volumes of water meant additional drainage capacity: a second tunnel, followed by the construction of an aqueduct bringing water from the Lerma Valley, 60 kilometres away; new main outfalls and the deep drainage system which takes over from the *Gran Canal* during heavy rains; and, finally, the Cutzamala aqueduct which brings water up by nearly one kilometre from a distance of 150 kilometres.

This absurd hydraulic system, whereby practically all waste and storm water is pumped out of the valley while drinking water must be brought up over increasing distances poses a serious threat to Mexico City's future viability,[22] perhaps even more so than atmospheric pollution. It also has disastrous and far-reaching effects on the river systems, which both supply the water and receive the effluent, not to mention the national-scale ecological and economic implications of the energy required for moving so much water in and out of the valley.[23] In this re-

Box 1: Mexico City's Hydraulic Infrastructure

1324	**The Mexica or Aztecs founded their capital on the island of Tenochtitlán.**
C14-C16	**The system of *chinampas* ("floating gardens") used by the Aztecs to reclaim land for urbanization and agriculture. The city was protected from seasonal flooding and the salinity of Lake Texcoco was controlled by a complex system of dykes and causeways; potable water brought in by aqueducts.**
C16	**After the conquest of Tenochtitlán in 1520, the Spaniards adopted and reinforced the Aztec system of hydraulic defences.**
C17-C18	**The first channel which drained the north-western part of the valley (the *Tajo de Nochistongo*) was excavated by forced Indian labour under the colonial administration during the seventeenth and eighteenth centuries. Aqueducts were built to bring in water from springs to the west of the city.**
C19	**Definitive project to drain the city to north-east by excavating the 40-kilometre long *Gran Canal* and Tequisquiac tunnel.**
1900	**Drainage canal inaugurated, drying up most of Lake Texcoco.**
1903	**First sewerage system inaugurated.**
1913	**Aqueduct supplying Mexico City with water from Xochimilco finished.**
1925	**Drainage system was found to be dysfunctional due to sinking of the city.**
1928-38	**System of dams and reservoirs built to prevent flooding from west of the city.**
1930	**Xochimilco water supply insufficient.**
1933-35	**New main sewers built to service expanding city.**
1937	**Severe floods. Work begun on second tunnel out of valley.**
1938	**Second Tequisquiac tunnel finished.**
1941/42/43	**Floods.**
1942-51	**Construction of aqueduct bringing water from River Lerma 80 kilometres away.**
1943-60	**Mexico City's main rivers covered over.**
1939-50	**Main sewers built to accommodate further city growth.**
1954	**Severe flooding. Central Mexico City under water for days.**
1955	**Pumping stations built to raise sewage from main collectors to *Gran Canal*.**
1947-52	**Construction of at least 99 artesian wells inside valley.**
1950s	**More main sewers built for growing city.**
1957-1968	**Extension of Lerma aqueduct to take water from higher up the river.**
1959-64	**Two main outfalls built to the west of the city to relieve pressure on *Gran Canal* during rainy season. Need for a second outlet out of valley recognized.**
1967	**Work on deep-drainage canal to north-west begun.**
1975	**First stage deep-drainage canal inaugurated.**
1975-82	**First stage of the Cutzamala aqueduct built, bringing water from 150 kilometres away.**
1970s/80s	**Deep-drainage system extended with many ramifications.**
On-going	**Continuation of Cutzamala aqueduct.**
On-going	**Construction of second deep-drainage outfall to north-west.**

megalopolitana en el cambio del siglo" in Eibenshutz, R. (editor) (1997), *Bases para la Planeación del Desarrollo de la Ciudad de México. Tomo 1: Economía y Sociedad en la Metropoli*, Miguel Angel Porrúa/Universidad Autónoma Metropolitana, Xochimilco, Table 1.

18. Duhau, E. (1997), "Las finanzas públicas locales en la zona metropolitana de la ciudad de México" in Coulomb, R. and E. Duhau (editors), *Dinámica Urbana y Procesos Socio-Políticos: Investigaciones Recientes sobre la Ciudad de México*, Centro de la Vivienda y Estudios Urbanos AC, México, page 105.

19. See reference 18, pages 103-4.

20. The belief that the free circulation of water and air was an essential condition for health has been widely accepted in Mexico since the eighteenth century and has inspired public urban design. Even today, there is the widespread practice in Mexico of throwing rubbish down creeks and into rivers, presumably in the hope that some of it will be washed away in the next rainy season.

21. The major drainage works that were effected at the end of the nineteenth century were based on the project designed by Don Francisco de Garay in 1856 which included not only the canal and tunnel, to be used only during emergency flooding, but also a series of secondary canals for retaining water inside the valley, to be used for irrigation, transport and recreational purposes. The urgent need for sewage disposal combined with economic limitations eliminated these additional elements from the final project.

22. For a very good account of Mexico City's hydraulic problem, see Academia de la Investigación Científica (1995), *El Agua y la Ciudad de México*, México DF; also Castañeda, V. (1997),

spect, Mexico City clearly has a greater water problem than other Mexican cities. If, however, water could be retained and recycled within the valley to a much greater extent than at present,[24] Mexico City might be at some advantage over other *altiplano* cities, which have less rainfall and fewer subterranean water sources.

The growth of the city itself has other environmental implications within the valley. As grassland and trees give way to concrete and tarmac, the rainfall goes straight into the drainage system and is pumped out of the valley instead of permeating into the subsoil. Also, in spite of the expensive aqueducts, 60 per cent of the city's water supply is still provided by local wells. The subsequent depletion of the aquifer has caused the subsoil and the city itself to sink drastically and unevenly. This fractures the drains and makes them change gradient thus contaminating the ground water. Because of the way in which Mexico City's hydraulic system has evolved, storm water, industrial effluent and sewage all go down the same drain. Given the contours of the valley and the permeable nature of the subsoil, leakage from the drainage system combined with direct discharge into the soil and creeks creates another major pollution problem.

The uneven sinking of the subsoil also damages the water pipes. This both contaminates the drinking water and causes up to a 38 per cent loss of supply through leakage. It has been suggested that eliminating half the leaks in the system plus substituting all 16-litre capacity toilets with 6-litre ones (which work just as well) would save 8.13 cubic metres/second: enough water to supply a city of half a million people or to provide for all industrial needs in Mexico City or to substitute 80 per cent of the water at present provided by the Cutzamala aqueduct.[25] The recently elected DF government has adopted this kind of reasoning and is promising to mend the pipes.[26] Until now, however, there has been no effective policy to increase the efficiency of the existing system or to limit demand by modifying consumption habits beyond reducing the capacity of new toilet cisterns. Perhaps the fact that building aqueducts at public expense is more profitable and politically more impressive may explain this, and no one questions the need to provide for predicted water consumption.

Another effect of the desiccation process has been the loss of vegetation and subsequent land erosion which has been observed since the beginning of the sixteenth century.[27] This was greatly accelerated when the last remaining lake was drained in 1900, exposing thousands of acres of salt flats which turn into a dust bowl in the dry season. The prevailing north-easterly winds stir this up and distribute it all over the eastern part of the city. As the inhospitable ex-lake bed became extensively urbanized from the 1950s onwards by irregular settlements, initially without sanitation, all this resulted in severe atmospheric pollution from suspended particles of dust and faecal matter. The paving over of these and similar settlements located in the surrounding hills has, in fact, improved the problem over the last decades in some areas, while it is constantly repro-

"Gestión integral de los recursos hidráulico" in Eibenshutz, see reference 17.

23. It has been estimated that the total energy costs for pumping water through Mexico City's hydraulic system is US$ 0.20 per cubic metre or approximately US$ 1 million per year; see Ezcurra, E. (1990), *De las Chinampas a la Megalópolis: El Medio Ambiente en la Cuenca de la Ciudad de México*, SEP/ CONACYT, México.

24. In spite of costly water treatment plants financed by foreign loans, only 11.3 per cent of Mexico City's combined sewage and storm water is treated. Of this, scarcely 1.2 per cent is used for irrigation and a miniscule 0.4 per cent is filtered to recharge the aquifer. (Statement by Gustavo Rodríguez of the Federal District Department of Hydraulic Construction and Operation during the seminar entitled *Hacia un Desarrollo Sustentable del Habitat Construido*, Mexico DF, 26-29 October 1998. Cited in *Semanario de la UAM,* Universidad Autónoma Metropolitana, 3 November, 1998.)

25. Castañeda, V. (1997), "Gestión integral de los recursos hidráulicos" in R. Eibenshutz (editor), *Bases para la Planeación del Desarrollo en la Ciudad de México. Tomo II: Estructura de la Ciudad y su Región*, Miguel Angel Porrúa/ Universidad Autónoma Metropolitana-Xochimilco.

26. Cárdenas, Cuauhtémoc (1998), *Primer informe de Gobierno*, September.

27. The environmental degradation caused after the Spanish conquest as a result of the destruction of the Aztec city and its hydraulic defences, plus the overexploitation of forests, the introduction of livestock, etc., all in relation to the city floods, was astutely observed by the architect of the *Tajo de Nochistongo*, Enrico Martínez (1606), duced in an ever-expanding circle as new settlements are formed on the outskirts. Pollution from wind-borne topsoil particles has also been tackled by a public investment policy which includes the regeneration of the vestiges of the lakes (Texcoco and Xochimilco) as well as intensive tree-planting in and around Mexico City, financed by Japanese loans.[28] Information about the environmental impact of these measures is scarce; in 1994, it was estimated that particulates from "natural" and organic sources contributed about 12 per cent by weight to Mexico City's renowned atmospheric pollution,[29] compared to 15 per cent in 1989, although this percentage would rise to as much as 30 per cent in terms of toxicity.[30]

IV. AIR POLLUTION AND THE ENERGY-MATTER CYCLE

IT IS, OF course, the smog which has become Mexico City's hallmark. Concern about air quality has dominated both private concern and public policy regarding the environment, perhaps to the detriment of other aspects. Before looking in more detail at the air pollution problem, it is worth remembering that this is just one facet of complex chains of relationships involving both the physical transformation of matter and socio-spatial realities. Atmospheric pollution is not the only environmental hazard caused by emissions, perhaps not even the most important. Water-borne emissions, which contaminate the water supply, and solid wastes are also dangerous, and recent declarations by the ex-director of the National Ecology Institute suggest that toxic waste is a major problem of industrial pollution.[31] The problem is not, however, specific to Mexico City and, more importantly, does not pose a major threat to the city's inhabitants themselves and, therefore, does not transcend into the local political arena.

In all events, emissions are the other side of the coin to the consumption of resources, most importantly of energy resources. Like industrial waste, energy is not seen as a big issue in relation to Mexico City's environmental problems. Neither is energy conservation much of a national concern.[32] Although there is a national programme for energy conservation, this has maintained a fairly low profile since its creation in 1980. There are no specific programmes nor campaigns for energy conservation in Mexico City and relatively little effort has gone into identifying areas for improved energy efficiency and alternative sources. As a result, two-thirds of national energy needs are met by oil products,[33] hardly surprising in an oil-producing nation. Historically, Mexico's industrialization has been based on increasingly inefficient energy consumption; in 1988, mean energy input per unit product was 0.67, compared to 0.44 in the United States and 0.26 in Japan.[34] On the other hand, Mexico City turns out to be 50 per cent more energy efficient than the country as a whole.[35]

Low prices combined with the benign climate make for carefree attitudes towards energy. Electricity, which is produced and

Repertorio de los Tiempos e Historia Natural desde Nueva España, Edición Facsimile, Centro de Estudios de Historia de México, CONDUMEX (1981). Later observers of Mexico City's environmental degradation include Alexander Von Humboldt (1815), Spanish version entitled "Ensayo político sobre el reino de la nueva España" in *Sepan Cuantos* No.39, Editorial Porrúa, Mexico DF (1981); also Fanny Calderón de la Barca (1843), *Life in Mexico*, Facsimile edition, Century Hutchinson, London (1987).

28. This programme, the *Programa Integral de Recuperación de Bosques y Areas Verdes del Distrito Federal*, proposes to plant over 10 million trees in rural areas of the Federal District and 2 million within the city.

distributed by nationalized companies, is subsidized, (costing US cents 3.94, 4.32 and 10.59 per kilowatt hour for industrial, domestic and commercial uses, respectively, in 1999). In fact, it is sometimes free to very low-income households who illegally connect up when there is no regular supply. Domestic water-heating and cooking, and a large part of smaller industrial and commercial needs are met by liquid petroleum gas (LPG) composed of 70 per cent propane mixed with butane, isobutane, propylene and butylene, and distributed to individual households either in 20 and 30 kilogram cylinders at US$ 0.40 a kilogram, or from tankers which refill 80 to 200 kilogram roof tanks at a cheaper rate of US$ 0.18 per litre. These prices imply a government subsidy of 55 per cent. At present, the consumption of piped natural gas is limited to industrial uses in particular areas and to the main thermoelectric station, recently converted from fuel oil. Concessions to British and North American companies for installing and distributing piped domestic natural gas are currently being negotiated.

The greater part of Mexico City's fuel energy consumption is gasoline, diesel and LPG by commercial transport and, to a lesser extent, natural gas by industry (see Table 4). In addition to the local energy consumption described in this table, the greater part of the city's electricity is provided by external sources, including hydroelectric and nuclear power.

Table 4: Distribution of Energy Consumption in Mexico City Metropolitan Area by Type of Fuel, 1993-1994

	Transport	Thermoelectric power	Industry and services	Others	Total
Gasoline	41%				41%
Diesel	12%		n.s.		12%
Fuel oils			2%		2%
Liquid petroleum gas	3%		7%	10%	20%
Natural gas		9%	15%	1%	25%
Total	**56%**	**9%**	**25%**	**11%**	**100%**

SOURCE: Instituto Nacional de Ecología (1994), *Informe de la Situación General en Materia de Equilibrio Ecológico y Protección al Ambiente 1993-1994.* Cited in Programa para Mejorar la Calidad del Aire en el Valle de México, 1995-2000, México, 1996, page 72.

29. Mexico (1996), *Programa para Mejorar la Calidad del Aire en el Valle de México*, page 74.

30. Lacy, R. (1993), *La Calidad del Aire en el Valle de México*, El Colegio de México, Mexico DF, page 48.

31. Gabriel Quadri, at the presentation of the book *Residuos Industriales en México, una Torre de Babel Ecológica*, suggested

Public debate on the environmental significance of energy consumption is, however, mostly limited to the impact of fuel consumption on Mexico City's atmospheric pollution. Unlike most areas of environmental concern, reliable and publicly accessible information on this issue has been provided since 1988 by a network of 32 automatic monitoring stations. Although there is still a need to improve the present system, atmospheric monitoring in Mexico City is far superior to that in any other Mexican city.[36] Before 1988, measurements had been built up over a number of years from early manual systems initiated in 1967. Data from these are patchy and inconsistent but provide a clear picture of rapid deterioration throughout the 1980s, particu-

that industrial waste is "out of control". Two million metric tonnes are adequately disposed of; 70 or 80 metric tonnes are exported to the USA, the UK, France, Finland and Holland every year at a cost of about US$ 100 million and it is not known where the other 6 million remaining tonnes of toxic

larly concerning pollution from carbon monoxide, sulphur dioxide and hydrocarbons.[37] Lead was present in unacceptable quantities at the beginning of the decade but improved after 1986 due to the progressive elimination of lead from gasoline. This was the first of a series of measures to control vehicle and industrial emissions, culminating in a full-blown metropolitan anti-pollution policy implemented from the early 1990s onwards (see Box 2).

Box 2: Mexico City's Clean Air Policy

1982	**First Federal Environmental Legislation (*Ley General de Equilibrio Ecológico y Protección al Medio Ambiente*) established some norms for industrial emissions. Inspections undertaken selectively by the Ministry for Health (*Secretaría de Salubridad y Assistencia*) but to little effect.**
1986	**The above legislation reformed into the *Ley General de Equilibrio Ecológico y Protección al Ambiente* (LEGEEPA). The Ministry for Urban Development and Ecology now in charge of inspections. About 6,000 industrial inspections carried out between 1986 and 1992.**
1986	**Introduction of new petrol with added detergent to reduce lead emissions.**
1989	**Introduction of unleaded gasoline.**
	Introduction of "*HOY NO CIRCULA*" banning all cars from the road in the Mexico City metropolitan area once a week, and twice weekly and at weekends when pollution reaches dangerous levels.
1990	**Introduction of yearly emissions-testing for vehicles in Mexico City.**
1990	**First Integral Progamme against Atmospheric Pollution in Mexico City Metropolitan Area (*Programa Integral Contra la Contaminación Atmosférica en la ZMCM* (PICCA)). The main measures arising out of this have been:**
1991	**Closure of oil refinery situated in central Mexico City.**
1991	**Obligatory catalytic converters in all new cars.**
1991	**Improvement of gasolines by PEMEX (on-going).**
1991	**Prevention of vapours in gasoline stations (on-going).**
1991	**Substitution of diesel by natural gas for industry including main power station. By 1997, 84 per cent of industry converted to natural gas.**
1992	**Creation of the Federal Prosecutor for the Environment (*Procurador Federal de Protección al Ambiente* (PROFEPA)). This is now in charge of inspecting industrial emissions, among other things, and prosecuting where necessary. The number of inspections between 1992 and 1997 increased to 69,076, 43 per cent of which were in Mexico City's Federal District, resulting in 2,340 total or partial closures and 54,261 fines.**
1992- 98	**Conversion of commercial cargo vehicles to LPG. (In 1998, about 30,000 commercial vehicles were powered by privately distributed propane gas.)**
1994	**Stricter emissions controls on all new vehicles.**
1994	**Frequency of obligatory vehicle emissions-testing increased to six-monthly.**
1994	**Revised and stricter industrial emissions norms.**
1996	**Programme to Improve Air Quality in the Mexico Valley 1995-2000 (*Programa para Mejorar la Calidad del Aire en el Valle de México* (PROAIRE)).**

Major resulting measures:

1996 **Stricter emissions-testing with three qualification levels:**
• vehicles subjected to normal once-a-week ban plus three times a week in times of pollution emergency;
• vehicles only subjected to normal once-a-week ban;
• vehicles exempt from any restrictions (post-1993 models only).

1996 **LEGEEPA reformed, widening federal jurisdiction in industrial regulation and imposing stricter fuel and emissions standards for industry and services, especially for nitrogen oxides and volatile carbon compounds.**

1998 **Programme to Reinforce Actions to Improve Air Quality in the Mexico Valley (*Programa para Fortalecer las Acciones de Mejoramiento de la Calidad del Aire en el Valle de México*).**

Implications for 1999:

• Stricter vehicle emissions standards (<300 ppm Hydrocarbons and <3 per cent CO) aimed at eliminating pre-1985 models which constitute 50 per cent of all vehicles in circulation but contribute 80 per cent of the pollution).
• Exemption from six-monthly emissions-testing for two years for 1999 models which fulfill <0.25 grams NO compounds per kilometre travelled.
• Stricter emissions standards for industry and revision of the industrial register.
Criteria for declaring pollution emergencies changed to:
• when ozone exceeds 2.4 times the acceptable norm; or
• when PMIO exceed 1.75 the acceptable norm; or
• when ozone exceeds 2.25 and PMIO exceed 1.25 their acceptable norms.

residues end up. Reported in *Reforma*, 22 September, 1998, 1-A, 3-A.

32. The control of Mexico's energy resources, which are still nationalized, and their future development is a national concern.

33. Sixty-six per cent of Mexico's national net electricity generation in 1997 was oil or gas powered thermo-electric, 16 per cent hydro-electric, 10 per cent coal powered thermo-electric, 5 per cent nuclear, 3 per cent geothermal and an insignificant amount eolo-electric. (Data from Secretaría de Energía, in Zedillo, E., (1998), *IV Informe de Gobierno*, annexe, page 175.)

34. López, R. and E. Ordaz (1994), "Desarrollo industrial, consumo de energía y contaminación", *Ciudades* No.21, January-March, page 50; also Pedrero R. (1994), "Visión

As a result, atmospheric contamination from industry in Mexico City was cut by 65 per cent between 1992 and 1997, the greatest improvements coming from reductions in sulphur dioxide, particulates and nitrogen oxides.[38] At the same time, vehicle emissions controls, circulation restrictions and emergency contingency measures have brought carbon monoxide to acceptable levels and have also virtually eliminated the high peaks of occasional extreme pollution from ozone and particulates. Yet, the average levels of pollution by both of these are increasingly high: 1.7 times the acceptable limit for ozone during 1997 and, on 90 per cent of days, the air quality is unacceptable by Mexico's current norms.[39] The norms, which provide the basis for the "Mexican atmospheric pollution index" (IMECA from its Spanish initials), were drawn up in 1980 and are constantly revised to bring them in line with international standards (see Table 5).

Mexico City's atmospheric pollution is aggravated by its geographical conditions, precisely those which make it such a good place to live. Atmospheric stability, due to its location at the heart of a great land mass and to the protected nature of the valley with mountain barriers on all sides except from the direction of the prevailing wind, prevent natural dispersion of pollutants. The combination of high altitude (2,240 metres above sea level) and tropical latitude makes for temperate sunny daytime weather and cool nights: perfect for ozone creation and thermal

Table 5: Mexican Norms for Acceptable Levels of Atmospheric Pollutants

	Upper limit		
Pollutant	**Acute exposure**		**Chronic exposure**
	Concentration and average exposure time	Maximum acceptable frequency	
Ozone	0.11 ppm (1 hr.)	Once every 3 yrs.	-
Sulphur dioxide	0.13 ppm (24 hrs.)	Once a year	0.03 ppm (yearly mean)
Nitrogen dioxide	0.21 ppm (1 hr.)	Once a year	-
Carbon monoxide	11 ppm (8 hrs.)	Once a year	-
Total suspended particulates	269µg/m^3 (24 hrs.)	Once a year	75 µg/m^3 (yearly mean)
PM_{10}: Respirable particulates	150µg/m^3 (24 hrs.)	Once a year	50 µg/m^3 (yearly mean)
Lead	-	-	1.5 µg/m^3 (3 monthly mean)

The pollution index (IMECA) is expressed as a percentage of the acceptable norm. When the IMECA for ozone exceeds 240, when PM10 exceed 175 or when ozone exceeds 225 and PM10 exceed 125, a phase I pollution contingency is declared and emergency measures implemented.

SOURCES: Programa para Mejorar la Calidad del Aire en el Valle de México 1995-2000 and Programa para Fortalecer las Acciones de Mejoramiento de la Calidad del Aire en el Valle de México.

económica del sector eléctrico" in Resendiz, D. (editor), *El Sector Eléctrico de México*, Comisión Federal de Electricidad-Fondo de Cultura Económica, México, page 357.

35. The Federal District contributes 27 per cent to the national GDP while consuming 18.5 per cent of total energy consumption. The Federal District and the state of Mexico together generate 43 per cent of total industrial GDP and consume 28.5 per cent of total industrial energy consumption (see reference 34, López and Ordaz (1994)).

36. Outside Mexico City, information on atmospheric pollution is available only for Monterrey, Guadalajara, Toluca and Ciudad Juárez. Declaration by Julia Carabias, Minister for the Environment, Natural Resources and Fisheries Secretary, *La Jornada* (1998), 25 June.

37. Legorreta, J. (1995), *Transporte y Contaminación en la Ciudad de México*, Centro de Ecología y Desarrollo, México

inversions. The lower oxygen content of the air, due to the altitude, also means that internal combustion engines are 23 per cent less efficient than at sea level, with a corresponding effect on emissions. For these reasons, it can be argued, Mexico City is particularly unsuitable for urban development; but then, many of the above-mentioned characteristics are shared by other Mexican cities on the *altiplano*, while the urban centres at lower altitudes need air-conditioned spaces, at least for many administrative and commercial developments. Properly designed buildings in Mexico City should need neither heating nor cooling throughout the year.

The sources of atmospheric pollution coincide closely with the distribution of energy consumption (see Table 6); again, transport is the main culprit. However, if the pollutants are weighted by toxicity, industrial atmospheric emissions gain relevance, as do particulates from topsoil (faecal matter in dust). Table 6 does not consider the pollutant effects of LPG escaping from the often leaky domestic gas connections, the butane components of which may de responsible for 20 to 30 per cent of ozone formation. Furthermore, it should be remembered that these figures, based on the 1994 emissions inventory, do not portray the highly dynamic atmospheric pollution problem. For instance, they do not include the occasional high risk contingencies, such as the forest fires of spring 1998, nor do they reflect the increased production of ozone precursors (nitric oxide, nitrogen dioxide, unburned hydrocarbons and volatile organic compounds) due to the growth of car ownership, or diesel engines.[40] These are the same figures, however, as those on which current environmental policy is based.

Table 6: Mexico City: Airborne Pollutants by Source, 1994 and by Toxicity, 1989

	Percentage distribution by weight				Total ('000s metric tonnes/year tonnes/year)
	Energy and industry	Services	Transport	Vegetation and topsoil	
Particulates	1.4%	0.2%	4.2%	94.2%	452
Sulphur dioxide	57.3%	15.9%	26.8%	-	46
Carbon monoxide	0.4%	O.1%	99.5%	-	2,358
Nitrogen oxides	24.5%	4.2%	71.3%	-	126
Unburned hydrocarbons	3.2%	38.9%	54.1%	3.8%	1,026
Total	**3%**	**10%**	**75%**	**12%**	**4,010**
Total weighted by toxicity 1989	27.7%		42.4%	29.9%	4,356

SOURCE: Inventario de Emisiones (1994), Programa para Mejorar la Calidad del Aire en el Valle de México 1995-2000, México, 1996, pages 74-75; also Lacy, L. (compiler) (1993), *La Calidad del Aire en el Valle de México*, El Colegio de México, page 48.

gives a very good account of the early monitoring policy.

38. Procuraduría Federal de Protección al Ambiente (1998), *Informe Trianual 1995-1997*, page 44.

39. Centro de Estudios del Sector Privado para el Desarrollo Sustentable (1998), *Ciudad de México: respirando el futuro. Evaluación del Programa para Mejorar la Calidad del Aire de la Zona Metropolitana de la Ciudad de México 1995-2000*, page 49.

40. A recent study points out the urgent need to update this emissions inventory, elaborated in 1994, on which pollution control policy is still based, see Centro de Estudios del Sector Privado para el Desarrollo Sustentable (1998), *Normatividad Ambiental y Emisiones Vehiculares en México*, page 69.

41. But this is nothing compared to the sulphur dioxide occasionally released into the atmosphere of Mexico City, Puebla and other nearby towns and cities by the Popocatepetl volcano .

A further breakdown of the 1994 emissions inventory reveals that the greater part is generated by a few identifiable sources. Industries producing non-metallic minerals emit over a quarter of total sulphur dioxide emissions,[41] while combustion for commercial uses (such as public baths) contributes 13 per cent. The thermoelectric plant is the major non-transport generator of nitrogen oxides (14 per cent) while the commercial distribution of LPG generates a quarter of unburned hydrocarbons. (How much more comes from all those makeshift gas connections on the roof tops, one might ask?) None of these sources, however, especially if recent improvements in industrial emissions are taken into account, compare to transport as the major cause of pollution.

V. TRANSPORT AND THE MOTOR CAR

WHEN THE 1994 emissions inventory is broken down, not surprisingly it is passenger transport, specifically private cars and taxis, which is responsible for most of the pollution (see Table 7).

This table should be immediately compared to Figures 2 and 3 which show, respectively, the distribution of daily journeys within Mexico City by mode of transport for 1994, and the evolution of this modal split from 1986 to 1992. Both require some comment on what they do and do not show.

The 1994 modal split pie chart is based on an official household origin-destination survey carried out that year. It therefore excludes transport within the city by non-residents but includes commuting out of the city by residents. It also excludes preschool children and, amazingly, trips on foot. This omission reflects the mentality of those who commissioned the survey, whose manifest objective was to establish “demand corridors” for pub-

Table 7: Mexico City: Airborne Pollutants by Transport Source (percentage by weight), 1994

	Private car[a]	Taxi	Minibus[b]	Bus	Freight and other[c]
Particulates	2.5%	0.1%	0.1%	0.9%	0.5%
Sulphur dioxide	14.1%	6.8%%	3.3%	1.9%	0.8%
Carbon monoxide	47.4%	22.5%	15.2%	2.8%	11.8%
Nitrogen oxides	26.9%	12.4%	11.1%	9.2%	11.7%
Unburnt hydrocarbons	26.6%	12.3%	9.9%	0.5%	4.7%
Total	**44.5%**	**22.3%**	**15.8%**	**6.2%**	**11.2%**

a. Includes pick-up trucks
b. 25 and 15-passenger microbuses, and 10-12 passenger Combis
c. Trucks and LGVs, rail and airport

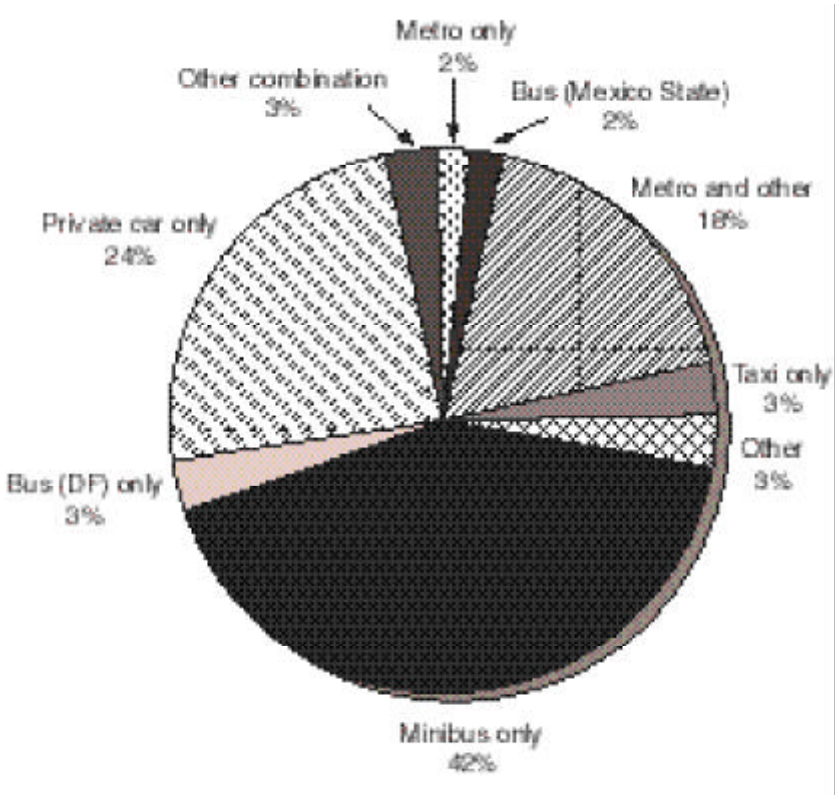
SOURCE: Inventario de Emisiones (1994), Programa para Mejorar la Calidad del Aire en el Valle de México 1995-2000, México, 1996, pages 74-75 and 86.

lic transport and roads, and thus justify investment in infrastructure, rather than to understand travel behaviour.[42] This extremely narrow "predict and provide" approach is further evidenced by the fact that the survey has been processed in such a way that paired trips are undifferentiated; the outward journey from home to another destination is indistinguishable from the homeward journey. So we know, for example, that the average journey time is 46 minutes (35 by car and 50 by public transport) but we do not know how much time people spend travelling a day (presumably a mean of at least one hour and a half) nor how much time is spent walking. The 1994 survey is also completely incompatible with a previous origin-destination study of 1983, as it uses different criteria for trip and zone definition. The time-series data shown in Figure 3 refer to unlinked trips, that is, parts of journeys on one mode of transport. Data for the publicly controlled modes, namely, metro, trolley buses, light rail, and the now privatized bus routes are based on ticket sales and turnstile registers. The use of the other modes of transport are estimates based on the number of vehicles in circulation and estimated occupancy rates, and are therefore likely to contain a high degree of error.

With these limitations in mind, what is clear is the absolute preponderance of public transport - more than 70 per cent of total trips - achieved mainly by privately run franchised or concessioned transport. As much as 42 per cent of the sample used exclusively the "minibus", a form of collective taxi which is either a 25-seater chassis on a 2.5 tonne pick-up truck or a 10-12 seat passenger van, most usually a Volkswagen "combi". Although these vehicles are neither energy efficient nor clean, the percentage of passengers carried was far greater than the minibuses's contribution to total atmospheric pollution measured the same year. The meteoric rise in this form of transport between 1989 and 1991 may be explained by policies implemented both in the Federal District and in the state of Mexico to help

42. Departamento del Distrito Federal, Gobierno del Estado de México, Instituto Nacional de Estadística, Geografía e Informática (1994), "Origen y destino"; also Departamento del Distrito Federal, Secretaría de Transportes y Vialidad (1996), *Programa Integral del Transporte y Vialidad 1995-2000 (Versión Actualizada)*.

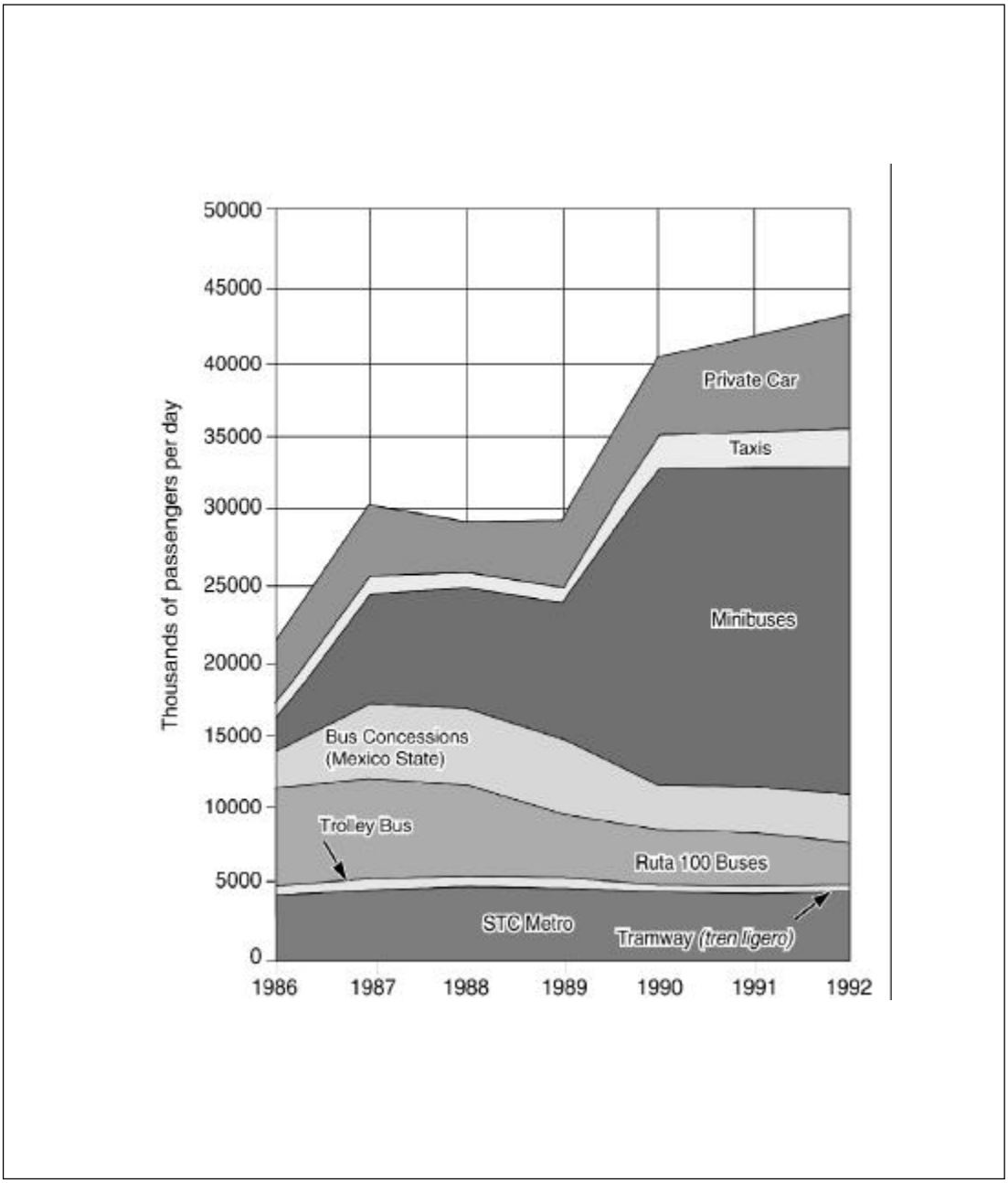
Figure 2: Mexico City: Distribution of Linked Journeys by Transport Mode June-July 1994



Mean journey time:	All - 46 minutes Car only - 35 minutes Public transport only - 50 minutes Car and public transport - 79 minutes
Mean total of linked journeys:	20.57 million
Mean total of unlinked journeys:	29.24 million

NOTES AND SOURCE: The pie-chart excludes journeys by foot, children under 6 and non residents. Based on DDF, DGPPTV e INEGI (1994), *Origen y Destino 1994*, Tables 1, 15, 16 and 38.

Figure 3: Mexico City: Distribution of Average Daily Passenger Trips by Mode of Transport, 1986-1992



concessionaires modernize their fleets. With the help of soft loans subsidized by the government, the traditional five-passenger *peseros*, or collective taxis, were substituted by much higher-capacity vehicles using the new unleaded gasoline, without significantly increasing the number of franchised vehicles. The minibus operators range from individual owner-drivers to entrepreneurs with large fleets. All operators are affiliated to the organization of their particular route and these organizations are effectively controlled by a handful of very powerful cartels which demand political allegiance and economic contributions from their affiliates.[43] The cartels also control relations with the government: a pyramidal clientelistic system which has characterized much of Mexican urban politics throughout the century. Policy regarding minibuses therefore, like that of other types of franchised transport, namely taxis and buses, owes more to political expediency than to any technical objectives of a transport policy. Collective taxis have traditionally dominated suburban public transport, for which they are arguably efficient and provide the necessary flexibility. However, in recent years, the overgrown minibuses have invaded the central areas, successfully competing with the less polluting, higher-capacity buses, trolley buses and the metro. It is now generally agreed that the political power of the minibus cartels represents a serious obstacle to rationally planning the public transport system.

43. See reference 37, Legorreta (1995), pages 154-80 for the best account of this

In a similar way, taxis have grown in importance as a means of transport in recent years, and also for political reasons. From 1988 to 1992, the Federal District government increased the number of taxi permits from 20,000 to 80,000, mostly to individual concessionaires,[44] this being one way to re-muster failing political support for the official party. After the issuing of further permits stopped in 1992, an estimated additional 10-12,000 taxis began to operate illegally with forged papers. Fewer than 10 per cent of all taxis operate from a base; the rest roam

44. Departamento del Distrito Federal, Secretaría de Transporte y Vialidad (1998), *Distribución del Parque Vehicular del Transporte Concesionado, 1996*, Mexico DF; also Pastrana, D. (1998), "Circulan en el distrito federal cerca de 12 mil taxis piratas", *La Jornada*, 12 July.

Box 3: Mexico City Buses: The Politicization of Transport

1923	**The bus syndicate *Alianza de Camioneros* was established, initially to organize concessionaires and independent drivers, but it would later evolve into a monopolistic bus cartel with strong corporativist political clout.**
1974	**Conflicts between the City Authorities (DDF) and the Ruta-100 line along one of Mexico City's major thoroughfares led to the municipalization of this route.**
1981	**After conflicts between the bus companies and the city authorities over investments, fares and the reorganization of bus routes, all the bus routes in the Federal District were municipalized and amalgamated into the single public company Ruta-100. (The buses had ceased to be profitable and the concept of transport as a public service prevailed.)**
1982	**Creation of the Ruta-100 workers' union called "SUTAUR-100".**
1982-88	**Ruta-100 bus routes were reorganized on a grid layout and connected with metro and trolley bus terminals. The number of buses in operation increased from 2,800 to 6,100 and the average number of passengers**

	per day from 4.9 million to a 6.9 million peak in 1988. Fares were kept low and were highly subsidized by the federal government. SUTAUR-100 achieved good labour conditions and its membership increased from 18,000 in 1982 to 24,000 in 1988.
1985	**Formal creation of the Independent Proletariat Movement (MPI), a left-wing political organization to which SUTAUR-100 was affiliated.**
1988-94	**Lack of investment in renewal and maintenance of fleet; subsidies went mainly to labour costs and SUTAUR-100 was blamed for this. The number of buses in operation dropped from 4,546 in 1988 to 2,488 in 1993. Daily passenger numbers decreased from 5.5 to 2.6 million. Federal government finance for Ruta-100 phased out completely between 1990 and 1994. During this time, many of Mexico's state owned companies were privatized. (The oil and electricity companies are important exceptions.) Ruta-100 is anathema to prevailing economic policy. Relations between SUTAUR-100 and Mexico City's (DF) mayor were fairly good, after a deal in 1989 whereby the number of workers was cut by half to 12,000 in exchange for future financial guarantees.**
1993	**The mayor of Mexico City (DF) resigned after having been passed over as a future presidential candidate. A new mayor appointed.**
1994	**Zapatista uprising in January; presumed support for Zapatistas by MPI and SUTAUR-100. Presidential changeover in December meant a new Mexico City (DF) government.**
1995	**January-March, various SUTAUR-100 members charged with "terrorism, delinquent association, abuse of confidence, etc." Federal District high court magistrate, Abraham Polo Uscanga, refused to ratify the order for arrest on these charges, on the grounds that there was no crime to prosecute.** **April 6: the newly appointed transport secretary of the Federal District government was found mysteriously dead having been twice shot through the heart, after auditing the financial state of affairs of the Ruta-100 bus company. Verdict: suicide.** **April 8: the Ruta-100 bus company declared bankrupt and the workers fired.** **April 9-10: six of the SUTAUR-100 leaders arrested for abuse of confidence.** **April 27: Magistrate Polo Uscanga kidnapped, tortured and released alive.** **June 18: SUTAUR-100 offices broken into and ransacked.** **June 18: Coordinator of fiscal prosecution against SUTAUR-100 assasinated.** **June 20: Magistrate Polo Uscanga found murdered near SUTAUR-100 offices. None of these assassinations have been clarified.**
1995-96	**Extended conflict over settlement with the ex Ruta-100 unionized workers (SUTAUR-100 members). Meanwhile, buses run by a syndicate set up to temporarily provide the service while the Ruta-100 company being wound up. New franchises to operate existing bus routes being divided up between new concessionaires. These include some bus producers and some minibus cartels, thus vertically integrating the system. SUTAUR-100 achieves the concession for two routes as part of lay-off settlement.**
1997- 98	**Some routes begin to operate, mostly with renovated vehicles previously belonging to Ruta-100.**

the streets, often without passengers. For the most part, they are highly contaminating VW beetle saloons although the more recent ones have catalytic converters. Taxis are, therefore, the most polluting of all forms of transport in relation to the proportion of journeys they cater for.

One reason for the success of minibuses and taxis has been the demise of the buses, also for political reasons. The story told in Box 3 gives some idea of the difficulties facing efficient transport investment and management. Once the major form of urban transport, the buses were municipalized in the early 1980s in the Federal District and partially in the state of Mexico. The routes were reorganized and, initially, some investment in modernizing the fleet took place. However, the necessarily high subsidies and, especially, conflicts with the left-wing labour union led to disinvestment in the Federal District buses and, following a series of unsolved political assassinations, their re-privatization in 1996. The new franchises have not been successful[45] and are currently under radical revision.

More surprising is the relative demise of Mexico City's subway, the metro, which now handles less than 20 per cent of total trips. The metro was built from the late 1960s onwards with the help of French finance and technology combined with Mexican civil engineering expertise. With 178 kilometres (20 more to be opened in 1999) and 4 million passengers per day, the Mexican metro now ranks as sixth longest in the world, third in terms of number of passengers and first in terms of average number of passengers per kilometre.[46] It is also the cheapest in the world where, in January 1999, a ticket costing the equivalent of US 15 cents was valid for one trip throughout the whole network, a price which bears a subsidy of 50 per cent of running costs. Capital costs, of course, have been extremely high and have been financed partly by tied loans, mostly under protocol agreements with the French government and the participation of the *Banque Nationale du Pays*. During the 1980s, the Federal District department's foreign debt, almost all due to the metro, provoked a severe financial crisis requiring the federal government to take over all Mexico City's debt service. More recent metro construction has attempted to economize, especially on civil engineering costs, involving more suburban ground level routes. Use of the metro peaked in 1989, at 4.7 million passengers per day, since when it has fallen in spite of an additional 37 kilometres having been added to the network.

There are various possible explanations for decreasing metro use. The falling population in central areas is one, increased car ownership and the rapid growth of the more flexible minibuses is another. The new ground-level style metro, which solves problems of road junctions by building bridges and tunnels, invites competition from cars, buses, minibuses and taxis which take advantage of the subsequently improved roads. Another alarming indicator is that the first three lines to be built, representing a quarter of the network, carry three-quarters of all metro passengers. This might raise some questions about the viability of continued investment in what is still an extremely expensive urban transport solution, especially in suburban situations

45. In January 1998, it was found that seven out of the ten companies that had won concessions to operate the newly privatized bus routes the previous year had not acquired a single bus (reported in *El Universal,* 28 January, 1998).

46. Calculated from *Janes Urban Transport Systems* (1998).

where alternative and cheaper means, such as high-capacity exclusive lane buses, could be envisaged.

None of these issues is debated publicly. Mexico City is rightly proud of its metro and no one questions the policy of extending the network, either in general or in relation to building particular lines. The only opposition has come from neighbourhood organizations who have tried to prevent metro stations being built in their vicinities, in anticipation of the street vendors who tend to agglomerate around such places. The metro policy is effectively determined by those who build it: the major civil engineering contractor and the French team of technical experts. The unchallenged objective is to build as much as possible, the only constraint being the availability of finance and approval from the federal treasury.

It should be clear from the above discussion concerning minibuses, buses and metro that Mexico City has no overall public transport policy. Although lip service is regularly paid to such a policy, each mode is determined separately by its own economic logic and political actors. Policies for promoting public transport only envisage investment in improving bus services or extending the metro. The fundamental issue of travel behaviour is not addressed. Thus, planning and building legislation, including the provision of parking, are in no way related to transport, even less to the environmental problem. The question of gasoline and public transport prices, taxes and subsidies are debated purely in terms of their financial implications, never as a potential tool for modifying transport behaviour and, ultimately, reducing pollution.[47] As a result, individual transport in cars and taxis has been allowed to dominate Mexico City unchecked and, in many ways, actively supported by government policy.

The number of cars registered in the Federal District and metropolitan municipalities in Mexico City has grown much faster than the population, almost doubling from 1.3 million in 1986 to 2.4 million a decade later. This is an average of about 0.15 cars per inhabitant, compared to about 0.35 in the UK and 0.56 in the USA. According to the 1994 origin-destination survey, 37 per cent of all households in Mexico City have at least one car, comparable to the situation in the UK in the mid-1960s. The private car is undoubtedly the most convenient way to move around Mexico City with average journey times of only 35 minutes compared to 50 minutes total average on all modes. (There is no information on the average distances travelled.)

Although cars' overwhelming contribution to pollution is recognized, there have been virtually no attempts to curb car ownership and use, except as emergency measures when pollution levels become intolerable. For instance, in the 1996 revision of the Federal District's 160-page "Integral Road and Transport Programme 1995-2000", car travel takes up precisely 11 lines, concluding with "...a reduction in the use of the private car requires sufficient and efficient public transport".[48] That a reduction in car use might mean something more than that has not been contemplated by anyone, not even in academic debates or critical political fora, and certainly not in government policy. In Mexico, as in most countries, the policy towards pri-

47. Demand for transport in Mexico City is so inelastic that using prices as an incentive to change transport patterns would probably have to be so extreme as to be totally unfeasible.

48. Departamento del Distrito Federal, Secretaría de Transportes y Vialidad (1996), *Programa Integral de Vialidad y Transporte. Revisión 1995-2000*, Mexico DF.

vate cars has been to encourage them to be less polluting[49] while providing the necessary infrastructure for their apparently inexorable increase.

The only exception to this was possibly the short-term effects of the first ban on the use of 20 per cent of all cars for one day a week, first implemented in 1989. This obliged car users to travel by public transport that day, thus becoming familiar with its possibilities, or to resort to car-sharing or other strategies. Soon, however, as the one day a week restriction stopped being an emergency measure and became institutionalized, those who could afford to do so acquired a second or third car, often older and more polluting models than their main car. Others reorganized their timetable so as travel more on the days when they were able to use their cars.

Whereas the early anti-pollution legislation put most of the onus on car owners to keep their vehicles tuned and serviced (see Box 2), subsequent legislation, which raised the emissions standards on new models while exempting those which met standards from the one day a week ban, has had a radically different effect. Those who can afford new cars are simply not affected by the anti-pollution policy. This then becomes merely a matter of negotiation between the government, the nationalized oil company and the auto industry. Nonetheless, for the lower-income car user, both the need to pass the emissions standards twice a year (to be able to circulate at all) and the once a week ban (twice a week when pollution exceeds the specified limit) reduce the advantages of car ownership to some degree.

Against that, a whole array of public and private investment patterns enforces car dependency. New and wider roads pave the way for more cars. Traffic congestion continues to be dealt with by road-widening schemes and the construction of overpasses. This is even justified on environmental grounds by the argument that vehicles pollute more when moving slowly, thus congestion is the major problem. Car parking is widely and cheaply available at a maximum cost of about US$ 1.0 an hour, usually much less. Parking near supermarkets and other commercial centres is often free. New buildings, including most housing, require parking spaces throughout the city and recent policies have actively promoted the construction of new down-town subterranean car parks, for which the government has provided land and other indirect subsidies. Empty lots are routinely authorized for use as car parks. Like roads, car park provision is justified on environmental grounds in that on-street parking - especially in double or triple rows - causes traffic congestion, which is depicted as the ultimate pollution generator. Car-owning Mexicans are not usually prepared to walk more than half a block to their final destination and they do not usually have to.

Recent trends in real-estate development further enhance the advantages of car mobility. Shopping malls combined with restaurants and multi-cinemas, first introduced for the upper echelons of the market, are now multiplying all over the city and cater essentially to the car. Pedestrian access to these is often complicated and unpleasant. Car dependence is inculcated early on, as those who own cars tend to drive their children to school.

49. The question of safety, either for the motorist or for pedestrians, is not an area of major public concern in spite of the extremely high accident rates. According to Arturo Lomelí (president of the Mexican Association for Studies on Consumer Defence) 2,000 people are killed and 90,000 injured every year in road accidents in Mexico City, which also implies costs of around 270 million pesos (*Excelsior*, 21 April 1998).

Those that can afford to do so buy their seventeen-year olds their own car, motivated by concerns of personal safety as much as convenience. Politicians, policy advisors, academic researchers and ecological activists generally fit into this kind of income bracket; the population that is supposed to abandon their cars in favour of some potentially improved public transport system is always someone else. No one who has a car at present seriously envisages a future without one. But it is not only the car-owning population that is hooked on their automobiles. The country's economy as a whole is highly car dependent. At the top end, as much as 30 per cent of manufactured exports, or 12.4 per cent of direct foreign investment, is related to the automobile industry.[50] At the opposite extreme, there is a thriving trade in the export of stolen cars to Central and South America. In between, tens of thousands of people make their living servicing motor vehicles. In all, too many people have a stake in cars.

50. Gitli, E. and J. Rocha (1988), *La Inversión Extranjera Directa y el Modelo Exportador Mexicano de los Ochenta*, Universidad Autónoma Metropolitana-Azcapotzalco, México DF; also recent data supplied by the Secretaría de Comercio y Fomento Industrial (1998).

VI. CONCLUSION

THE PRECEDING PAGES have tried to show that the environmental problems facing Mexico City are both complex and dynamic. In some important ways, the issues are similar to those in all big cities and their outcome will be highly dependent on what happens elsewhere. For example, the future of the car in Mexico will be largely determined by the fate of the car in the United States. Foreign investment, technology and expertise will all have an important role to play in producing and reducing ecological degradation. But at the same time, many aspects of the problems are Mexico City's own to solve. This city's particular physical geography requires specific solutions of great imagination. Many of these solutions will perhaps be derived from measures which are not directly associated with environmental policy: most importantly, housing and land provision but also education, health and retailing. The implementation of other policies more commonly recognized as environmentally improving, such as transport, may also be strongly dependent on wider political and economic events. The franchised public transport sectors (or the street vendors or car parking attendants, to name a few) cannot be reorganized until political reform has made considerably more headway against traditional clientelistic systems and criminal impunity. If mere survival becomes more difficult for an increasing number of the city's inhabitants, as it has done over the past two decades, then taking care of the environment will, necessarily, be postponed until the economy improves. It is these kinds of issues that will determine Mexico City's environmental future, not the number of people who happen to be counted in the 2000 census.