TOWARDS ENVIRONMENTAL SUSTAINABILITY IN THE METROPOLITAN ZONE OF MEXICO CITY: INDICATORS AND PROJECTIONS TO 2030

by

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SUMMARY

This thesis develops quantitative indicators of environmental sustainability for Mexico City and its metropolitan zone of influence (MCMZ). These indicators of sustainability were developed by taking into account seven key variables for the urban environment: the water supply situation, air pollution, transportation and roads, energy, solid wastes, the housing supply and green areas. Based on these indicators and the history of the city's physical evolution since it was founded seven centuries ago, a desirable type of urban form is proposed, one in which there is a "decentralized concentration" which would allow Mexico City to approach sustainability in a time frame that concludes in or about the year 2030. Accordingly, the thesis proposes urban policy measures that, while addressing issues of sustainability, permit Mexico City to face the challenges of globalisation, which would entail transforming it into a "global city" within a worldwide network of great cities. The urban policy and environmental measures that are recommended anticipate the largest economic, demographic and technological changes that will affect Mexico City, but are above all in harmony with the natural ecosystems of the elevated endorheic basin in which it lies. They do no call for a break with or the alteration of the city's natural landscape or its already constructed historical patrimony and, when possible, they presuppose a new sustainable hydraulic model, capable of restoring lakes and recharging the underground aquifer. Finally, a great deal of emphasis is placed on the recuperation of green areas in accordance with the basin's original natural vegetation.

Key Terms: Mexico City, urban sustainability, sustainability indicators, metropolitan zone, urban greenery, megalopolis, global cities, urban ecosystems, digital revolution, urban form.

NA OMGEWINGS-VOLHOUBAARHEID IN DIE METROPOLITAANSE SONE VAN MEKSIKO STAD: AANWYSERS EN PROJEKSIES TO 2030

Deur ; CASSIO LUISELLI FERNÁNDEZ

Graad; DLITT ET PHIL

Onderwerp ; GEOGRAFIE

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OPSOMMING

Hierdie proefskrif ontwikkel kwantitatiewe aanwysers vir omgewings-volhoubaarheid vir Mexico Stad en sy metropolitaanse invloedsone (MCMZ). Die aanwysers is ontwikkel in terme van die sewe sleutel-veranderlikes van die stedelike omgewing naamlik die waterbalans, lugbesoedeling, vervoerinfrastruktuur en paaie, energie, soliede afval, die verskaffling van behuising en groensones. Gebaseer op hierdie aanwysers en die geskiedenis van die stad se fisiese evolusie sedert sy stigting ongeveer sewe eeue gelede, word `n wenslike tipe stedelike vorm voorgestel van "gedesentraliseerde konsentrasie" wat sal toelaat dat na hierdie volhoubaarheid beweeg word binne ´n tydskaal wat sal eindig in 2030. Gevolglik stel die proefskrif stedelike beleidsmaatreëls voor wat, terwyl die kwessie van volhoubaarheid aangespreek word, toe sal laat dat Mexico Stad die uitdagings van globalisasie konfronteer, wat die transformasie daarvan in ´n "globale stad" impliseer binne ´n wereldwye netwerk van groot stede. Die stedelike beleids- en omgewingsmaatreëls wat voorgestel word antisipeer die grootse ekonomieses-, demografiese en tegnologiese veranderings wat Mexico Stad kan affekteer, maar is bo alles in harmonie met die natuurlike ekosisteme van die verhewe endorhiese kom waarbinne die stad geleë is. Dit veronderstel geen breuk met of 'n verandering in die stad se landskap, of sy historiese patrimonium nie, waar veronderstel waar moontlik, 'n nuwe volhoubare hidroliese model, wat die vermoë het om mere te herstel en die ondergrondse watertafel aan te vul. Ten slotte word daar groot klem gele op die herwinnning van groensones met die Kom se oorspronklike natuurlike plantegroei.

Sleutelbegrippe: Meksiko Stad, Stedelike volhoubaarheid, Metropolitaanse gebied, Stedelike groen, Megastad, Wêreldstede,Stedelike ekosisteme, Digitale rewolusie, Stedelike vorm

CHAPTER 1

INTRODUCTION

Mexico City: Its Historical Significance and Main Challenges

SIGNIFICANCE

Mexico City is the only pre-Columbian urban centre that, after seven centuries, has maintained its predominance and importance in the large area in which it is situated. There is no other city in the entire Western Hemisphere that has functioned as the political, economic and spiritual capital of its territory of influence as long as Mexico City. It was first the centre of the Aztec empire, which ruled the entire region of Mesoamerica for almost two centuries; then it was the powerful capital of the large Viceroyalty of New Spain. For almost two hundred years, it has been the proud Capital of Mexico.

For more than seven centuries, the city has also been one of the most populated places on the planet, and throughout its history, its rich and complex environment has been an enormous and continuous challenge for its inhabitants. Not only is it the single most populous human settlement that the world had ever seen, but it is also the spiritual heart of the Mexican nation, serving as the centre of its political and economic powers for more than seven hundred years.

Mexico City is what it is today as a result of the epic clash that forever merged two major civilisations: The Spanish and the Aztec empires. The mestizo (Creole) Mexico was born out of this very difficult encounter and, both culturally and linguistically, it is by far the most influential and largest Hispanic city on earth. Nowadays, Mexico City is the democratic head of the country's renovated political system. Its economic importance is ostensible as well. For example, the Gross Regional Product of the Metropolitan Zone of Mexico City is almost twice as large as that of South Africa. If it were a separate economy,

it would take third place in Latin America, behind only Brazil and Mexico itself.

Its unique location at more than 2,000 metres above sea level contributes to its singularity and great ecological richness -- as well as its high level of biodiversity derived from its location at the borderline of the Neartic and Neotropical bio-geographic realms – which are today threatened as urban growth causes its still abundant forests to disappear at an alarming rate. A huge amount of resources – in the form of food, water and energy – are taken from distant places and then converted into waste, which is usually disposed of without being cleaned or recycled.

Today's Mexico City faces the risk of losing its pivotal role in Mexico and the world. After decades of mismanagement and decay, it must recover its grandeur. But to achieve this, it must face the formidable twin challenges of transforming itself into an environmentally sustainable urban centre as well as a node, or a important player in an ever more globalized world.

PROBLEM STATEMENT AND DESCRIPTION

The most serious problem in Mexico City is its increasing environmental unsustainability. For more than five centuries, the city has been losing the battle against its environment. Since the years of the Spanish Conquest, it has deforested, impoverished and contaminated its soil and artificially drained its water out of its own basin. As a consequence, it is also experiencing severe and dangerous sinking (subsidence) in its most populated areas. Over the last 50 years, on top of these centuries-old problems, one can add the problems of perhaps excessive economic growth and massive and chaotic urban expansion. This exacerbates old problems and creates new ones, such as severe air and water pollution, the accumulation of waste, traffic jams and associated economic and social problems.

Because it is situated at an altitude of more than 2,000 metres above sea level and because of its condition as a closed, endorheic basin, these environmental problems are magnified. Today, it is an enormous city of more than 18 million inhabitants with thousands of

industrial establishments and almost 4 million vehicles passing through its streets every day. With these conditions, the air is continually polluted and remains trapped in the closed basin. Furthermore, thermal inversions are common in winter and the problem of ozone contamination is a constant threat. The same can be said of water-related issues. The basin receives abundant rainfall in the summer, giving rise to numerous small rivers on the high volcanoes and mountains, which naturally tend to renew large underground aquifers and feed the five original lakes of the basin. However, this natural water cycle has been completely disrupted and now the city brings water from distant locations, which is quickly polluted and discharged to the north without reuse or treatment. The amount of water the city extracts from its aquifers is always less than that brought in from outside the basin; the water from the aquifers, in turn, becomes more and more polluted. Green areas are being sacrificed at an accelerated rate in the face of intense and disorderly urbanisation. But the problems are interrelated: less greenery, lower capacity of soil retention, less and less renewal of aquifers and blockage.

If the current dynamics persist, all the environmental variables that affect Mexico City will move the city towards growing unsustainability. The situation, however, is even more serious because these variables tend to reinforce each other in the perverse dynamics of a vicious circle. Thus, issues of water balance, air pollution, transportation and roads, energy consumption, solid waste, housing conditions and increasingly reduced greenery --all of which will be studied in this work in depth-- are interconnected and together they create a dismal scenario in environmental terms for the future of the city and its metropolitan zone.

Furthermore, Mexico City is losing ground in the face of the technological and economic changes that are brought about by economic globalization. Although the city is still by far the principal economic centre of Mexico and still retains importance worldwide, its relative economic weight has gradually declined over the last two decades. While it is true that its economy has been restructured in a suitable direction with more services and fewer contaminating industries, Mexico City still lacks many attributes that would allow it to position itself firmly as a "World City" of the 21st century. Namely, the city still lacks a reasonably large, diversified, modern financial system, advanced information services,

digital networks, a rapid means of communication and an efficient public transportation system, advanced Technopoles, a large airport and modern and attractive installations for the transit of huge numbers of people. Of course, the economic problem is compounded precisely by the extremely poor situation of the environment, as described above. In short, Mexico City has the size of a "World City," but lacks its attributes.

SUB-PROBLEMS

From the general series of questions described above, a few sub-problems can be derived whose individual analysis will serve both to clarify the MCMZ's problems as a whole and to better understand the methodology used in the research of this thesis. In general, two sets of sub-problems can be identified: the first of these relates to questions having to do strictly with the city's environment and physical medium; the second has more to do with socioeconomic topics, which also involve the challenges that globalization imposes on Mexico City. We can look at each problem separately:

The sub-problems of an environmental nature have to do with the soil and the principle bio-geochemical cycles that occur in the environment of the Mexico Basin (as seen in sections 4.7 and 6.1). The following are the most notable:

In first place, without a doubt, is the problem of the hydrological cycle and the grave fact that not only is the cycle interrupted in the territory of the basin, but also --without corrective measures-- it represents a seriously unsustainable tendency. This affects, first of all, the water supply of the metropolis, as well as the possibilities of increasing green areas in the city and allowing for the survival of the few remaining green forests (section 6.1.2) and wash away soils; by not recharging the subterranean aquifer, the subsistence of the urbanized zone grows. The city's progressive water shortage also has a negative affect on the climate, which is increasingly dry and hot, and this, in turn, worsens atmospheric pollution. These reasons make the water issue one of the greatest sub-problems in the basin, if not the greatest. The problem impacts numerous variables and is vital to the everyday life of the entire population. Issues of water access are becoming increasingly urgent and

political. Thus, the water sustainability indicator is developed extensively (see section 6.1.1). It is concerning that the solution that continue to be applied to this problem are very short sighted; it consists of taking water from external, increasingly distant locations with ever greater opposition from rural inhabitants who end up losing their supply, and carrying it hundreds of kilometres to Mexico City. The quantitative indicator is useful for demonstrating issues of increasing scarcity and the unsustainability of the current hydraulic model applied in the MCMZ.

Also of importance are the sub-problems related to the city's serious atmospheric pollution which has to do with the emissions of more than four million vehicles and thousands of industries trapped in a closed ecological basin such as that of the MCMZ. The indicator developed for this sub-problem (section 6.1.4) takes into account the principle sources of emissions and the pollutants themselves, although it also relates to the change in the climate and other factors such as the city's industrial structure, congestion and traffic, as well as energy sources and consumption, which has a section dedicated to its analysis (section 6.1.7). All these issues are amply analysed in this thesis. The question of soil contamination is addressed in the indicator related to solid waste management (section 6.1.5), in which it is shown that the model of trash generation, disposal and treatment is unsustainable and affects, all to the same degree, air, soil and --due to infiltration-- water.

The second set of sub-problems refers more to demographic or socioeconomic issues that affect the MCMZ and the challenges presented by globalization. Primarily, these have to do with the city's demographic dynamic, which was analysed, among other things, in terms of the demographic transition, and which showed a clear tendency toward the stability of the population and its consequent aging. They also relate to the city's economic structure and economic tendencies. Here the "urban rings analysis" is used, and, clearly, the economy of the city is headed in a direction that should be supported: as a service-provider with environmentally cleaner, more high-tech industries. The tendency is favourable, but the public policies that support it are insufficient and should be more and more "globalization conforming" (sections 4.1 and 4.2-4.6). These questions are closely related to transport, infrastructure and housing needs, from which quantitative indicators are developed

(sections 6.1.3 and 6.1.6). Also of importance in this sense are considerations about rapid changes in information technology and transport and the infrastructure that they will inevitably require.

Clearly, the two sets of sub-problems occur territorially and in a unified manner, and therefore Chapter 7 deals above all with looking at policy prescription as a whole. Thus, we carried out extensive analysis of what the most appropriate urban form would be for a sustainable MCMA. From there, the compact city vis-à-vis other possible urban forms was analysed. The choice of a polycentric urban form, or "concentrated decentralization," is not arbitrary: it comes empirically from the wealth of information provided by an "urban rings analysis" and the survey of state-of-the-art analysis of sustainable urban forms that minimize environmental stress and damage (see sections 4.2-4.3 and 6.1-6.2).

But the questions of sustainability and globalization are an integral part of this thesis. Both are related in that it is hard to imagine a Mexico City able to conform positively to globalization without first having achieved for its citizens an acceptable level of environmental sustainability. A city that is cleaner and greener, with better housing and transport, will attract investments and create jobs and wealth. There is an evident synergy then between sustainability and globalization lying at the core of this work.

METHODOLOGICAL ASPECTS

All this points to the need to use different methodological tools in order to arrive at our desired end of proposing a determinate urban form that supports the achievement of sustainability and that makes it possible to face the challenges and access the benefits of globalization (and minimize its risks). The principle methodological questions of this thesis are, of course, addressed --in Chapters 4 and 7. However, in this introductory chapter, it will be useful to visualize in a successive manner the different methodologies that allowed us to reach the objective of the thesis:

First of all, this requires an analytical description of the Mexico Basin's peculiar ecology and the history of the population that finally shaped the enormous Mexico City of today. This is why so much emphasis is placed on the basin's original ecological conditions and its urban history. The reader will notice, however, that this history will systematically emphasize the environment, particularly water, transport, and the physical aspect of the city's expansion. The idea then is to re-establish, to the greatest extent possible, the natural conditions of the basin's ecosystem, which is now highly degraded by gigantic, chaotic urban sprawl. A detailed analysis of the MCMZ's environmental crisis is made in section 4.7.

In the second place, after reviewing the most relevant literature and carrying out a solid analysis of the history and evolution of the city from its remote origins to the year 2000, projections are made based on a few well established trends of key urban phenomena. These include the evolution of the demographic transition and how it is reflected in the MCMZ. A ring analysis is carried out on this and the MCMZ's economic dynamics, as well as on the historic tendency toward expansion and urban sprawl and its impact on the environment, which can be visualized with different highly elaborated maps. In the same fashion, analysis is undertaken of the phenomenon of economic globalization and how Mexico City is conforming to it.

Thirdly, we describe and analyse in detail the principle aspects of the ongoing information technology and communications revolutions and their probable impact on the MCMZ's urban form and economy. Particular attention is paid to the Internet and the probable evolution of the automobile, both of which greatly and immediately affect sustainability and urban form. To this end, numerous projections were made relating to the use of the Internet, and, in a related manner, estimates were made of the level of automobile use at the present time, as well as projections for the year 2030.

In the forth place, and through the use of this abundant information, a solid empirical foundation was attained, allowing for the construction of seven quantitative indicators of sustainability (and another of a methodological order which allows one to visualize the sum

of the previous seven), all of which will be mentioned further on. Additionally, a "globality indicator" was generated. These indicators are developed diagnostically in section 4.7, and quantitatively and with policy recommendations in section 7.1. The indicators are measured indexes with projections until the year 2030, made with the help of a spread sheet. They will allow us tackle each of the sub-problems mentioned above, although what will still be lacking is an integral vision that takes into account these problems as a whole.

To this end, and in the fifth place, all variables --including both environmental sub-problems and those of a socio-economic nature related to globalization-- had to be adapted territorially, although in a hierarchal order based on the integrated analysis of the desirable or ideal urban form of the MCMZ (this analysis is carried out in Chapter 7). In this case it was very important that, before a recapitulation, certain broad recommendations concerning territorial policy be made using each of the seven indicators. Therefore, based on the ideal urban form, we make broad proposals on environmental reordering (lake restoration, a new hydraulic model, a low environmental impact ring around the MCMZ, green corridors, urban renewal policies for each of the five sub-centres and certain key communications, road and airport infrastructure). These are, in turn, linked with the more specific proposals emanating from each indicator. This is, in reality, a brief summary of the central thrust of the thesis.

OBJECTIVES OF THE STUDY

The main purpose of this thesis is to help find a solution to the serious environmental problems facing Mexico City and its Metropolitan Zone (MCMZ) through the development of seven quantitative indicators. This can only be done by increasing our understanding of the city's most basic problems, which, as mentioned above, involve the loss of sustainability and the challenges of the continued globalization of one of the world's largest cities.

Therefore, an attempt is made to carry out a detailed analysis of the city's problems of sustainability, although this is done, firstly, through an analytical description of seven

centuries of the city's environmental and urban history, with an emphasis on the environment. The thesis attempts to offer both a path toward sustainability and an integrated spatial strategy for a new urban form, also aimed at bringing about sustainability.

The seven indicators of environmental sustainability are based on the city's history and a detailed diagnosis of its environmental situation. They also represent quantitative instruments which we use to make recommendations on how to overcome the MCMZ's problems of sustainability and economic modernisation in the face of globalization. The seven indicators of sustainability are: water balance, air pollution, transportation and road infrastructure, energy, solid waste, housing and green areas. As mentioned above, an additional general indicator is developed based on the previous seven, and yet another is generated regarding the city's position in the face of economic globalization. We believe that only through this process can general, yet valid, recommendations be made on to how to make the great Mexican metropolis more sustainable and how to end its fight against its natural environment, allowing the city to strike a balance with its rich and diverse natural environment, as in the times of the Aztec Empire, and at same time to transform itself into one of the main players in the increasingly globalized world that will basically function as a dense network of primary, secondary and tertiary cities.

As will be made apparent in the sixth and last chapter, this study is also prescriptive and offers an overview of a possible sustainable and global future for Mexico City. While these considerations are important, they are not the ultimate or sole objective of this thesis. They are simply and clearly drawn from an "urban rings analysis" and the sustainability indicators, as well as from questions related to globalization, all of which are, in truth, the central elements at the core of this study.

Lastly, and to avoid any confusion, it is important to also indicate aspects that are not essential to the objective of this thesis. As important as they may be, detailed economic and production issues, labour problems, informal employment, poverty and social inequality are not considered to be key to our investigation. Likewise, we do not deal with the topics of urban finances or aspects of administration, planning or politics. To a greater or lesser

degree, all of these points are mentioned, but only in terms of our analysis of the topics of urban sustainability or in the context of the economic diagnosis surrounding the challenges of globalization. It is important to stress that this is a study of environmental sustainability and the challenges of globalization that the Mexican metropolis faces as it begins the 21st century.

OVERVIEW OF CHAPTERS

This thesis is organised into seven chapters. It has numerous maps, tables and graphs. Additionally, it has a lengthy General Bibliography that the reader might find useful and fitting.

After the first chapter, which is this introduction, the second describes and analyses the basic geography and ecology of the Mexico Basin. The importance of this chapter cannot be stressed enough. These complex and peculiar geographic and ecological conditions set the foundations for our main tasks. First of all, it establishes the Mexico Basin and not the urban "city limits" as our unit of analysis. Secondly, the basic data in this chapter is used as the basis for the sustainability diagnosis and the development of the indicators.

The third chapter outlines the long and fascinating history of the population processes and the transformation of the basin's natural environment by continuous human encroachment. It describes and analyses the basin's population patterns since pre-Mexica (or Aztec) times. The great pre-Columbian city of Teotihuacan is given especial consideration, not only because of its intrinsic greatness, but because its abrupt demise might have had a catastrophic environmental cause.

But of course, the main role of what today is Mexico City within the lacustrine ecosystem is given foremost attention. The city of Tenochtitlan, the Capital of the Aztec Empire, is analysed in terms of its superb management of water and its intensive food production methods with low environmental impact, due to the "chinampas" or cultivation "gardens". Then we describe the Spanish Conquest as what it was in reality: a major environmental

disaster. Later, we establish a crucial nexus between the Aztec capital and the newly created Spanish capital atop its ruins: a similar urban form. However, at the same time it represented a radical departure as far as water and transportation were concerned. From that point and throughout the chapter, we follow water issues as well as the evolution of the urban form.

Afterwards, the long period of the city as the Capital of colonial or, more properly, the Viceroyalty of New Spain is discussed. The problematic and protracted process of lake desiccation and water diversion from the basin is given a great deal of attention since it was the cause of the main environmental transformation (and disasters) of that era and affected the city environment and urban form decisively. Then, the Capital of independent Mexico is analysed. The booming years of the "Porfiriato" were of particular importance as was the onset of the Metropolis, between 1910 and 1940.

Lastly, the later years of enormous demographic growth and economic boom are discussed in detail along the successive presidential administrations. This era of almost unmanageable growth was of enormous importance. A true Megalopolis emerged, with its "crown" of secondary cities, and it set the stage for the later environmental (as well as social and economical) debacle of Mexico City, which is described in the final section. This historical chapter may seem too long and detailed, but we think that it is absolutely essential to fully understand Mexico City's past so as to solidly project it into the future. It is important not to forget that one of the main ideas of the thesis is to propose the restoration of the complex link of the city with its lacustrine vocation. But history is covered unconventionally, rather like a string that carefully threads the beads of the city's history of its formidable expansion, its urban form and environmental impact on water, forests and greenery as well as housing and transportation.

The fourth chapter focuses on the future and tries to discern what established trends will allow us to understand, project and face the challenges of the future: the population and its transition to a scenario of maturity and slow growth (actually, the demographic transition is mirrored in "urban transition") and a moderate but sustained rate of economic growth,

which is consistent with the city's long-term economic performance. Only from these firm, established trends can quantitative alternative scenarios be constructed for the future without falling prey to excessive speculation or simplifications of minor relevance. Only after this kind of analysis will there be a sense of an unavoidably speculative exercise to understand and incorporate the predictable impact of new technologies on the urban dynamic of the MCMZ, which we attempt in the following chapter. In any case, the last section of Chapter Four describes with some detail the major components of the present environmental crisis of Mexico City (or the MCMZ or its Metropolitan Zone, terms which are used interchangeably throughout the entire thesis). This is a crisis of unsustainability and the main components are water, air, energy, transportation, greenery, housing and waste. That information will be the basic ingredient for the construction of the seven sustainable indicators in the next chapter, as well as their prescriptive policy towards long-term sustainability (2030).

The fifth chapter analyses the scope and importance of the two main challenges that the 21st Century will pose to Mexico City: to be both global and sustainable. It starts with the conceptual issues of globalization, but with specific reference to cities and their roles as nodes in the network of globalization. It establishes Mexico City (the entire MCMZ) as a possible candidate for a truly global role. The chapter closes with a long discussion on the impact of the Internet and the digital revolution as well as the impact of the new technologies on the city's urban form and performance, the chapter moves on to a key section about the challenges of environmental sustainability in an urban context. This section is both innovative and very relevant for the entire thesis.

Then, the Chapter 6 deals with the seven indicators which are constructed and presented with a set of policy recommendations to change their dynamics into a sustainable long-term path (2030). The recommendations focus on water balances and a new hydraulic model, public green areas and land use, new road infrastructure and a transportation model, air pollution, solid waste management, housing supply and energy use and transition. They are followed by a very useful general indicator that combines all of them (in fact, a weighed sum of all seven) and could be used to measure the degree of sustainability at any given

time. To complement these sustainability indicators, there is an index or indicator of globalization at the end of the chapter.

The seventh and final chapter of the thesis has to do with the path to sustainability for the city and its dealings with globalization within a time frame of about 30 years (most mathematical projections are calculated to the year 2030) but it offers a hitherto unprecedented, unified and coherent spatial view of what a sustainable and "global" MCMZ might be and, more intriguingly, how it might look on a detailed map. For this reason, a desired "polycentric" urban form ("plurinuclear" or more precisely, one of "concentrated decentralisation" and a very detailed set of proposals and maps were also developed. But again, this prescriptive chapter, albeit important and illustrative, is but a complimentary part of the main thrust of the thesis, which is sustainability indicators in a world dominated by the forces of globalization.

On entering the third millennium, the time may have come for the great Mexico City to begin to do things differently and contrary to what has been done over the last 500 years: to work in harmony with its own history and nature, and not against them.

CHAPTER 2

GEOGRAPHY AND ECOLOGY OF THE MEXICO BASIN

2.1 Geographic Location of the Mexico Basin

Mexico City and its metropolitan area lie in the central part of the Mexico Basin and have for centuries constituted the geographic and spiritual heart of the Mexican nation. Long before the arrival of the Mexicas and the Spanish conquest, the basin was home to advanced urban cultures that were unparalleled in the western hemisphere.

The Mexico Basin is located in the south eastern part of the vast elevated plateau that lies on the Transversal Volcanic Axis[1] at 2,359 metres above sea level (see Map 2.1). Surrounded by mountain ranges and volcanoes, it forms a lacustrine plain that has seen not only multiple population centres along its shores, but at least three great urban centres: Cuicuilco in the south, the city of Teotihuacan in the northeast and the Toltec capital of Tula at the far northern end. In the basin's central, lacustrine portion, laid the Capital of the Mexica or Aztec Empire, Tenochtitlán (1325), and, on that same spot, the Spanish conquerors erected the Capital of the Viceroyalty of New Spain, Mexico-Tenochtitlán (1521), today's Mexico City (see Map 2.2). The basin's temperate weather, its geography and its water resources made it particularly suitable for the emergence of agriculture and the establishment of human settlements.

[1]Within the Mexico Basin, Mexico City and its surrounding metropolitan area are located precisely between the parallels 19°01'18" and 20°09'12" latitude north and the meridians 98°31'58" longitude west of Greenwich. The total surface area of the basin is between 7,500 and 9,560 square kilometres, depending on the different assumptions about where its borders lie in the mountains and plateaus of the northernmost end. Only a fraction of this area, some 1,800 square kilometres, is urbanized, forming part of Mexico City or the metropolitan area. Five federal territorial divisions converge within the basin, the largest of which is the State of Mexico, which takes up almost half of its area, principally to the north and east, followed by the Federal District, taking up 14%, or 1,320 square kilometres (which include Mexico City as well as non-urbanized areas). Smaller shares are held by the states of Hidalgo (north) with 26%, Tlaxcala (northeast) with 9% and Puebla (east) with 1%.

Map 2.1. Neovolcanic Axis and Mexico Basin Location.
Source: Atlas Mundial encarta 99.

Map 2.2. The Basin of Mexico in the XV Century.
Source: Arqueología mexicana.

2.2 The Formation of the Basin and its Geography

The magnificent and rugged geography of Mexico is the product of the orogenic revolution of the Cenozoic era, especially the Miocene and Pliocene. It was in the later part of the Tertiary when the surface of what is now Mexico emerged from a shallow tropical sea. The central plateau upon which the basin lies is the highest in the country, and this fact, along with its latitude near the northernmost meridian of the tropic of Cancer, accounts for its great biological diversity.

To be exact, the Mexico Basin is a closed endorheic entity, and not a valley, as it is often mistakenly described. This fact is a result of the basin's tectonic origin –the Cocos and North American plates—which led to intense volcanic activity that began more than 50 million years ago (high Eocene) and which produced, at a much later date, 20 million years ago, the great geological fault of the Transversal Volcanic Axis.[2] It was this important fault, which is considered one of the 11-morph tectonic realms of Mexico, that gave the Mexico Basin its geography, shape and hydrology, and thus it largely explains its great biodiversity.

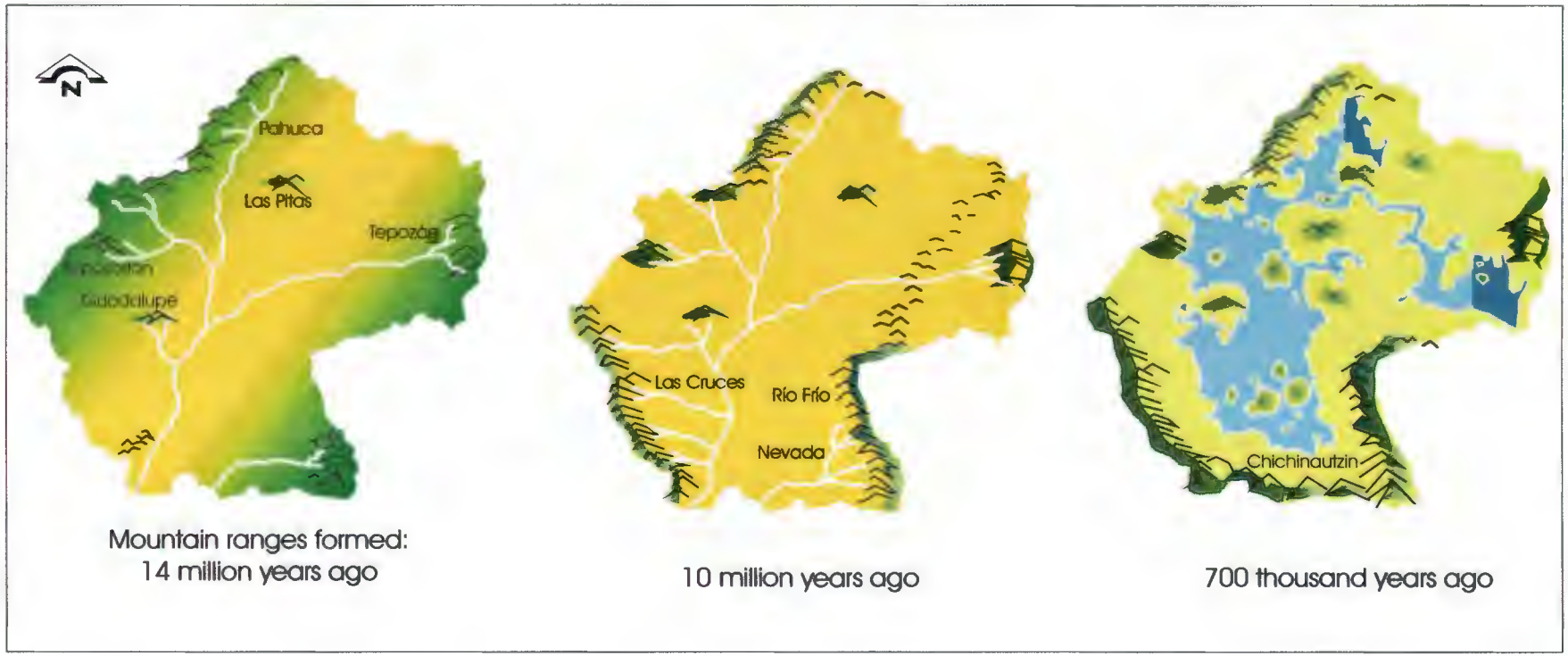
The formation of the basin itself ended after three catastrophic volcanic episodes.[3] At the end of the Miocene, 15 million years ago, the low-lying, now eroded mountains of the north of the basin --the ranges of Pachuca, Guadalupe and Tepozotlán-- were the first to arise. Before the Pliocene, some ten million years ago, the Sierra de las Cruces and the southern section of the Eastern Mountains emerged on the east side of the basin. Towards the south, tectonic pressure led progressively to the closure of the plain, resulting in the formation of the Sierra de Chichinautzin, from which emerged the imposing Ajusco volcano (3,952 m). This not only sealed the basin on its southern end, but also isolated the neighbouring valley to the west, known as the Toluca Valley, thereby blocking water drainage into the south and to the westward-flowing Lerma River. The ensuing emergence

[2]R. López Recéndez, Geomorfología, *Atlas de la Ciudad de México,* G. Garza (comp). México: Departamento del Distrito Federal, El Colegio de México, Centro de Estudios Demográficos y de Desarrollo Urbano, 1987, p. 30; A. Guillermo Aguilar, Localización Geográfica de la Cuenca de México, *La Ciudad de México en el fin del segundo milenio,* México: Departamento del Distrito Federal, El Colegio de México, 2001, pp.31-33; F. Mooser Hawtree, Estructura Geológica, *La Ciudad de México en el fin del segundo milenio...*,pp. 39-43.
[3]Mesmer in *Atlas de la Ciudad de México,* México: Departamento del Distrito Federal, El Colegio de México, 1987.

of lakes in the central area was the result of the lack of natural drainage, something that was to become the most defining and problematic characteristic of the basin, and which continues to explain its dynamics and ecology today. Later, during the Quaternary, this series of violent volcanic episodes gave birth, in the east, to the towering Sierra Nevada, crowned by the imposing, perennially snow-capped volcanoes, Popocatépetl (5,450 m) and Iztaccíhuatl (5,326 m). With this episode, the formation of the Mexico Basin was basically complete (see Map 2.3).

Due to these volcanic cataclysms of tectonic origin,[4] the basin would always be highly prone to seismic activity.[5] Some of the basin's numerous volcanic cones are dangerously young and active; some are only one thousand years old. This condition also contributes to the heterogeneity and diversity of the basin. Different climates as well as patterns of rain, humidity and soil are to be found at the basin's many levels of elevation. As we will see later, detailed studies have identified at least nine ecological zones or realms within the basin itself.

[4] F. Mooser Hawtree, Estructura Geológica, *La ciudad de México en el fin del segundo milenio,* México: Departamento del Distrito Federal, El Colegio de México, 2001, pp. 39-45.
[5] *Ibid.*



Map 2.3. Mexico Basin Formation.
Source: Own elaboration based on Carrillo Trueba, p. 26-27.

Having described the manner in which the Mexico Basin was formed, we should now take a more detailed look at its geomorphology, for which the research of López Recéndez is useful.[6]

Besides the four groups of mountains of tectonic and volcanic origin which surround the Mexico Basin, which we described above, are complemented by their piedmonts or slopes with a wealth of varied and important vegetation and fauna, which connect the sierras with the plains, especially in the east and west.

The Mexico Basin in its totality can be divided up into secondary sub-basins, which were formed much more recently, at the end of the Pleistocene. These sub-basins tend to be flat and interconnected, and can be explained by the accumulative effect of the hydrology of the lakes. The highest of these is the Plain of Pachuca (2,400 m) in the north, followed by the Mexico depression (2,240 m) in the central area. Another sub-basin lies in Xochimilco in the south. The sub-basins of the southern and central areas are divided by the Sierra Volcánica de Santa Catarina, a range that emerged in the Quaternary, which runs from east to west and represents an important part of the basin's landscape. It is also worth to mention the series of high plains found along the north eastern edge of the basin, especially the farthest of these, known as the plains of Apam.

2.3 Basic Ecology of the Mexico Basin

2.3.1 General Features

But to describe and understand the basin, it is fundamental to discuss its lacustrine character and lake system. Originally, there were a series of five shallow lakes (one to three metres deep), connected from north to south. Two salt lakes in the north, Zumpango and Xaltocan, drained into the saltwater lake of Texcoco, the largest of them all. Located at the

[6]R. López Recéndez, Geomorfología, *Atlas de la Ciudad de México*, G. Garza comp., México: Departamento del Distrito Federal, El Colegio de México, Centro de Estudios Demográficos y de Desarrollo Urbano, 1987, pp. 29-32; F. Mooawe Hawtree, Estructura Geológica, *La Ciudad de México en el fin del segundo milenio...*, pp. 39-46.

lowest point of the basin, Texcoco receives the drainage of all the basin's rivers. Finally, two fresh-water lakes in the south lie three metres above Texcoco: Xochimilco (which partially subsists) and Chalco (extinct). During the rainy season, the lakes expanded and joined together, while in the dry season they shrunk and separated from one another. At the time of the arrival of the Spanish in Mexico, the surface area of the lake system totalled 1,500 square kilometres, or one-fifth of the basin's surface.

The dynamics of this geomorphic structure influenced by tecto-volcanic forces, along with many centuries of intense urban and agricultural activity, have dramatically transformed the basin. The complex interaction of these elements –which have yet to be thoroughly understood—provides explanations for the basin's current landscape, structure and ecosystem.

As befits an endorheic hydraulic basin, there are no important rivers crossing through the area, only some smaller rivers and streams that come down from the mountains and flow into the lake basins. Those deserving mention are the east-west rivers Magdalena, Piedad (now underground), Los Remedios and Cuautitlán, although there are number of other rivers of lesser importance. Besides, the runoff caused by the intense summer rains, these rivers also receive water from the periodic melting of snow on the highest volcanoes. There are also a number of springs, especially in the foothills of the southern mountains, although many of these are disappearing due to the depletion of aquifers, resulting from the imbalance of extraction over replacement. It is particularly important to mention Chapultepec Hill, which originally stood beside a lakeshore, and where a considerable number of springs were responsible for abundant vegetation and served as a strategic source of drinking water for both the former Tenochtitlán, and for Mexico City well into the twentieth century.

From an ecological point of view, the most severe alteration to have taken place has been to the hydraulic complex of sierras and volcanoes whose runoff drains into the lakebeds, eventually ending up in Lake Texcoco. The lake's extreme salinity is the result of the salt and minerals that drain into its waters, followed by an evaporation process. This salinity

also accounts for the complex ecological interaction with the rest of the basin and its other bodies of water.

The gradual disappearance of the lakes began in the Aztec era, but accelerated during the Conquest. The Aztecs had reduced the surface perimeter to plant corn and some indigenous groups continued this practice during the Colonial era. The lakes had beneficial effects on the climate: but, as we will see, during the Viceroyalty era these bodies of water were reduced, leading to the rapid destruction of almost all the rich local agriculture (mainly known as *chinampas*) and affecting the climate. Lake Texcoco, which was almost completely drained, had by the beginning of the 20th century lost its agricultural-economic function except for the production of salt and extraction of protein-rich *espirulina* algae and caustic soda.

Since the 1970s, efforts have been made to recuperate soil and some bodies of water in what was formerly Lake Texcoco. The planting of salt-resistant grass has helped diminish dust storms.[7] The other lakes of the northern part of the basin: Xaltocan and Zumpango, are practically dry and pools of water form only during the rainy season. The lake of Chalco survived much longer although it was highly altered. Beginning in 1945, the lake was drained to make way for agriculture and practically disappeared. It should be mentioned that since the 1980s a new water surface has emerged in Chalco due to the sinking of the basin. Overall, the Lake of Xochimilco is the most preserved due to its location in a zone of chinampas where efforts are made to maintain a production zone of flowers and horticulture. Since 1990 the area has been involved in an interesting ecological recovery project.[8]

Of course, the basin is now drained artificially, and water has to be imported from other distant basins. Water is also obtained from a number of wells within the Mexico Basin, although an extensive covering of asphalt impedes the replenishment of aquifers, in what represents a serious environmental and even geological threat since this phenomenon

[7]G. Cruickshank, *Proyecto Lago de Texcoco: Rescate hidroecológico,* México: Cruickshank editor, 1998.
[8]M. C. Serra- Puche & E. S. Otto, Rescate Integral: El Parque Ecológico de Xochimilco, en Serra- Puche *Xochimilco Arqueológico*, México: 1994.

contributes to the substantial subsidence (sinking) of the central urbanized area, which currently totals ten metres.

The soil found in the basin is the combined result of its volcanic origin, climate, the mountain slopes and its drainage. Generally, young soil predominates. Badly drained soil high in salt is present in the area around Lake Texcoco, while a rich type derived from volcanic ash is to be found in the mountains and foothills. There is much rich soil that is badly drained; *Humaquept* is the most common soil type in the basin. A great amount of earth has undergone intense, prolonged erosion (especially in the north). The majority of the basin's soil falls into an order known as *inceptisols*.[9]

The weather in the basin can be defined as benign and temperate, and is considered to be tropical or high-elevation subtropical. The altitude and the intense summer rains generally make for milder weather; the average temperature of 15°C varies by 8°C in summer and winter. Night time frosts are common in winter. The macroclimate consists of two well-defined seasons. The first is the dry season, a period from November to April of typically clear skies and occasional cold fronts that are part of North American weather patterns. Similarly, there are winds from the west know as dust storms or *tolvaneras* which until a few years ago caused dust storms over the city, an effect that has now subsided thanks to soil regeneration projects carried out in the Texcoco lake basin. Following this period is the rainy season, which goes from May to October. When temperatures rise in North America, weather activity coming from the north lessens and a tropical influence takes over. Summer brings intense "monsoon" type rains to the basin that fall from June to September and tail off abruptly in October. During this season, the basin receives 80% of its average annual precipitation, which ranges between 400 mm in the north and 800 mm in the south. There are parts of the southern mountains, however, that can see as much as 1,500 mm of rain in a year.

[9] J. F. Cervantes Borja & G. Alfaro Sánchez, Características de los suelos, *La ciudad de México en el fin del segundo milenio...*, pp. 47-54.

The part of the basin in which Mexico City lies –in its southern and central portion-- can be described more or less in the same manner as above. It rains much less on the north side and the Texcoco lakebed, making these areas much drier than the central and southern areas. The weather is greatly affected by atmospheric pollution and urban sprawl, which produce a localized "greenhouse effect." Thus, intense "heat pockets" occur in the most urbanized areas as the result of the concentration of asphalt, automobiles and air pollution.[10]

2.3.2 Basic Vegetation of the Mexico Basin

It is a proven fact that, at least until the arrival of the Spanish, the Mexico Basin, then dominated by its lakes, was densely forested along its perimeter. Its ecosystem was rich and diverse and included dense forests, pastures, lakes and varied wild life. After more than seven centuries of urban growth and four thousand years of agriculture, it is clear that vegetation has been altered greatly and forests reduced dramatically. Still, many original species of vegetation can be found in the basin that was present during the early settler era.[11]

Lying exactly upon the south eastern part of the Transversal Volcanic Axis, the Mexico Basin is located in a very important ecological area: it is there that the western hemisphere's two basic bio-geographic provinces or realms meet, a fact explained by the lithosphere's tectonic dynamics. The first of these is the Neo-tropical realm, which extends toward the south, and the second is the Neartic realm, which stretches to the north. This position along the Transversal Volcanic Axis, as well as the abrupt changes in weather at different points along its mountain slopes, account for the great biotic wealth and endemic species that make Mexico in its entirety one of the world's four great realms of biodiversity.[12] The Mexico Basin's position, exactly upon this dividing line, is the cause for its varied, singular flora and fauna. It is therefore, not uncommon to find animal and plant

[10] E. Jáuregui, Clima, *La ciudad de México en el fin del segundo milenio...*, pp. 69-75.
[11] M. C. Serra- Puche & Erwin Stephan Otto, Rescate Integral: El Parque Ecológico de Xochimilco en Serra-Puche *Xochimilco Arqueológico*.
[12] *Biological Diversity of Mexico. Origins and Distribution,* edited by T. P. Ramamoorthy, R. Bye, A. Lot , J. Fa, New York, Oxford: Oxford University Press, 1993.

species belonging to either bio-geographic realm: wolves, bears, pine trees, palm trees, monkeys and parrots. The Transversal Volcanic Axis is one of the areas of greatest vegetal endemism, and this accounts for the abundance of ecological zones and species. The original lakes found in the basin, however, made for even greater biodiversity. The area's biotic wealth also accounts for its early emergence as a centre of human settlements.

At the same time that Mexico's biodiversity is considered to be of world importance, it is also home to around 10% of all vascular plant species and native plants of fundamental dietary value to humans. This is a result of Mexico's position within the "genetic belt," the strip of land that encircles the globe at the latitude of the tropics, where the seeds of great agricultural revolutions were sown. The combination of these two characteristics sets Mexico apart from those countries that are also rich in biodiversity. As it is well known, corn (*Zea mays*) is native to Mexico, or, to be more exact, to the Tehuacan Valley, a high-elevation valley near the Mexico Basin in the eastern state of Puebla. But also native to Mexico are beans (*phaseolus*), avocadoes (*Persea americana*), tomatoes and an infinite number of chilli peppers, to mention just a few, [13] all of which have long been present in the Mexico Basin.

The basic vegetal pattern of the basin has been deeply disturbed and diminished by a long-time human presence, and especially by recent, massive urbanization. However, it can still be validly described as the rich transitional area between the temperate deciduous forests of the south which gradually transforms itself into scrub xerophytes in the north. The vegetation around the lakes, now almost completely extinct, consisted of halophytes, which lent the basin greater biotic uniqueness.

Along with its condition as a closed basin (without any natural drainage), altitude also plays an important role in biotic distribution. In general, between elevations of 2,500 and 4,000 metres, conifer forests continue to be the dominant type of vegetation, despite the fact that their area of influence is shrinking into smaller and smaller parts of the higher reaches of

[13] *Biological Diversity of Mexico. Origins and Distribution,* edited by T. P. Ramamoorthy, R. Bye, A. Lot , J. Fa, New York, Oxford: Oxford University Press, 1993, pp. xxxi-xxxiii.

the mountains. Tundra can be found at elevations above 4,000 metres, and there are even some "fiord" formations of snow on the summits of the highest volcanoes. Corn has been extensively cultivated for more than 4,000 years, and, along with other domesticated prehispanic plants (including *huatli amaranto*); it led to the disruption of prehistoric flora.

There are a number of important, detailed studies on the basin's ecology, vegetation and fauna. The now classic work of Sanders, Parsons and Stanley[14] carried out fundamental work on occupation patterns and prehispanic ecology, defining nine ecological zones within the basin's interior, each with its vegetation and fauna. It is important to mention these researchers due to the fact that their work has been the basis of other studies; they should be considered in any ecological recuperation study or project carried out on the city or basin. The zones they defined can be thought of as a succession of rings or contour lines that encircle the basin's flat central area, once dominated by lakes, and go as far up as the highest sierras:

1) The Lake System, which is described above with the basic five lakes, is today basically extinct. It was formerly the habitat of at least five species of fish, batrachians, some freshwater molluscs and crustaceans, turtles and a number of edible insects. Algae (the still existent espirulina is a one variety of these) was present, as well as rushes and bushes along the lakeshores. Of special importance is the fact that, in fall and winter especially, the lakes served as termini for migratory birds, the majority of which were ducks, which flew down from western Canada.

2) The Saline Lakeshore, which surrounded the three saltwater lakes of the north, was wide, measuring between 500 metres and a kilometre. They formerly served to produce salt (and are now dry, highly eroded land). On the freshwater shores, on the other hand, halophyllous vegetation grew in abundance. Particularly noteworthy is the fact that varieties of grass that were naturally resistant to a high degree of salinity, such as *Sporobolus plumbens, Distichlis prostrat* and *D. spicata*, as well as different types of cattails (*Typha*), grew in the

[14]*The Basin of Mexico. Ecological Processes in the Evolution of a Civilization*, W. T. Sanders, J. R. Parsons, R. S. Stanley editors, New York: Academic Press, 1979, p. 81-85.

existent Texcoco Lake.

3) Deep-Soil Alluvium forms a band several kilometres wide around the lakes, at an elevation of between 2,240 to 2,300 metres. The original flora --now practically non-existent due to millennia of agriculture—included sedges, swamp cypresses, sweet acacia (*Cyperaceae, Taxodium mucronatum*, *Acacia*) and reed beds. The fauna consisted of rodents and different varieties of rabbits (*Sylvilagus, Lepus callotis*), birds and reptiles, and in more humid areas, the white-tailed deer (*Odocoileus virginianus*).

4) Thin-Soil Alluvium is especially predominant in the northern part of the basin. Despite its advantageous sandy texture, the lack of depth of this soil makes the cultivation of most crops impossible. This zone is relatively dry, which is why one only continues to find short grasses and magueys (*Agave spp.*) growing there.

5) The Highlands on the Transversal Volcanic Axis lie on an elevated plateau (2,450 a 2,600 metres) on the south and southwest sides of the basin, close to Amecameca. They consist of sedimentary deposits made up of brittle soil. The area sees considerable rainfall of about one metre per year, and few frosts. The Ameca River runs through the area, which is now an important area for its agricultural production, although originally oak trees (*Quercus sp.*), along with pines, alders, *madrones* and cedars, grew at higher elevations. In the lowest-lying areas in the north of this sub-region, *huizachales* were to be found. Due to the predominance of cedars, the existence of a numerous population of white-tailed deer is assured.

6) The Lower Piedmont is a wide, gently sloping band located at elevations of less than 2,350 metres, found along with the alluvial soil of the base of the basin. Its sandy soil, although suitable for corn, is now highly eroded, especially in the north, and in some cases the subsoil or *tepetate* is now exposed. The original vegetation practically no longer exists, but it is presumed –especially in the south—that oaks trees covered the area. In lower-lying areas, to the degree that the vegetation encountered the bottom of the basin, it mixed with bushes and different types of grass. It is likely that the fauna was similar to that described in

the previous zone, with the predominance of the white-tailed deer.

7) The Middle Piedmont is a band of generally gentle slopes between 2,350 and 2,500 metres that has a variety of soil types similar to those of the previous zone. Due to its higher elevation, its original vegetation of relatively dense forests of broadleaf oak trees is more or less intact. The dominant herbivore is the white-tailed deer.

8) The Upper Piedmont has steeper slopes and is located between 2,500 and 2,700 metres above sea level. It constitutes a transition ecosystem before the higher sierras. Its soil is shallow, muddy and very eroded; a number of canyons crisscross the area. Due to frequent frosts, only highly resistant corn can be grown. Before erosion was so widespread, there was a mixture of conifers and deciduous trees, including oak trees, pine trees (*Pinus leiophylla*), cypresses (*Cupressus lidleyi*), alders (*Alnus spp.*), butterfly bush (*Buddleia spp.*), madrones (*Arbutus xalapensis*) *ahuejotes* or bonpland willows (*Salix bonplandiana*) and junipers, along with a number of bushes and grasses. This zone probably marks the end of the white-tailed deer's habitat.

9) The Sierras, located at an elevation of 2,700 to 5,800 metres, have steep slopes, especially in the eastern and southern parts of the basin. Little land is used for agriculture, and even today this zone is mostly forested. As is logical, the sierra is covered with conifers, with an abundance of oaks, *ahiles* and large extensions of pines, with three dominant species: *Pinus patula* and *Pinus Montezumae*, which grow up till 3,500 metres, and *Pinus Hartwegii*, which can be found until 4,000 metres. Also present in great numbers is the *oyamel* fir tree (*Abies religiosa*) revered by the Aztecs, the juniper (*Junniperus deppeana*), as well as the varieties of grass known as *zacatones*. Up until 50 years ago, small mammals and a few deer were to be found in this zone. Those remaining include *zacatuches* or volcano rabbits. Pasturing livestock have been introduced, and, unfortunately, forest fires are frequent, threatening different species of pines, the juniper and other trees in the area.

According to Melo Gallegos and Oropeza Orozco,[15] this stratum of trees lies on an area of 216,798 hectares, bushes and scrub on 88,531, plantations and exotic species on just 2,120 and agricultural crops on the largest area of 541,623 hectares.

Rzedowski's[16] important contributions to the study of the basin's vegetation greatly complement the information discussed above, although his work should be considered separately. At the same time, his work provides the basis for new, more recent, and more detailed studies.[17] At this point, we can enumerate his observations, including complementary information where possible.[18] Rzedowski recognizes ten types of vegetation in the basin:

1) Aquatic and Subaquatic Vegetation (see the lake system above, 1):
In the past, aquatic vegetation dominated the basin's vast plain and was central to the diet of the Aztecs and other peoples living on the lakeshores. It is important not to forget that it was only shortly after the Conquest that the basin's predominant physiognomy of lakes was irremissibly lost. In Texcoco and Zumpago, there are still cattails (*Typha latifolia* and *Scirpus validus*), plants that are rich in fibre and useful for construction, as well as reeds, sedges and duckweed (*Lemma sp.*) Ezcurra indicates that water lilies (*Eichornia crassipes*) which are native to South America, have now invaded the few remaining bodies of water with very negative effects on the original flora and ecosystem.

2) Halophyllous Vegetation (see above the lake system and the saline lakeshore, 1 and 2):
This vegetation is saline and, even today, it predominates in the low-lying parts of the basin, in what were once the old lake beds, especially that of Texcoco. The Texcoco Plan

[15]C. Melo Gallegos & O. Oropeza Orozco, Vegetación, en *Atlas de la Ciudad de México*, G. Garza comp., México: Departamento del Distrito Federal, El Colegio de México, Centro de Estudios Demográficos y de Desarrollo Urbano, 1987, pp. 33-35.
[16]J. Rzedowski, Diversity and Origins of the Phanerogamic Flora of Mexico, in *Biological Diversity of Mexico. Origins and Distribution*, edited by T.P. Ramamoorthy, R. Bye, A. Lot, J. Fa, New York, Oxford: Oxford University Press, 1993, pp. 129-144.
[17] A. G. Aguilar, *et. al.*, The Basin of Mexico, in *Regions at Risk: Comparisons of Threatened Environments*, edited by J. X. Kasperson, R. E. Kasperon, B.L. Turner II, Tokyo: United Nations University Press, 1995, pp. 304-366.
[18]E. Ezcurra, *De las chinampas a la Megalópolis. El medio ambiente en la cuenca de México*, 2ª reimpresión, México: Secretaría de Educación Pública, Fondo de Cultura Económica, 1995, pp. 15-22.

rightly proposes to reincorporate this type of vegetation.[19] Excurra explains that the physiognomy of these areas is of "short, dense grasslands" where one finds gramineous plants (*Distichlis spicata* and *Eragrostis obtusiflora*), as well as saltbushes (*Atriplex sp.*) and the still very popular and edible *romerito* (*Suaeda nigra*).

3) Xerophyllous Scrub (see above deep-soil and thin-soil alluvium, 3 and 4, among others): This type of vegetation consists of bushes, which are still very abundant today in different relatively low-lying areas in the basin. Xerophyllous scrub predominates, for example, in the vegetal landscape of the Pedregal de San Ángel, where there are a great deal of *palo loco* bushes (*Senecio praecox*), locust-trees (*Bursera spp.*), butterfly bush (*Buddleja spp.*), California pepper trees (*Schinus molle*) and a number of other plants endemic to the Pedregal. In the north of the basin one finds fields of cactus paddles (*Opuntia streptacantha*), the magnificent yucca plant (*Yucca flifera*), the cat-claw vine (*Mimosa biuncífera*) and the *cenicilla* (*Zaluzania augusta*), while at higher elevations the *guapilla* (*Hechtia podantha*) and the very common *lechuguilla* (*Agave lechuguilla*) are present, among other plants.

Ezcurra reports that in the Sierra de Guadalupe the *palo dulce* bush (*Eisenhardtia polystachya*) subsists, although it is rapidly disappearing.

4) Grasslands (present in different zones, especially in those with alluvial soil):
Pastures are scattered throughout a number of zones in the basin such as the plains in the central and northern areas, as well as in severely disrupted areas between 2,300 and 2,700 metres, where annual gramineous plants grow (*Aristida adscencionis* and *Bouteloua simplex*). Grasslands are found on the piedmont slopes of the Sierra Nevada and in the north of the basin, where *Hilaria cenchroides* predominates. At higher elevations, between 2,900 and 3,500 metres, oyamel fir trees grow, along with valleys and plains of attractive creeping *sínfito* plants (*Potentilla candicans*) and other sedges and gramineous plants. At the highest elevations, those above 4,000 metres, which lie above pine forests, are steep alpine-like grasslands (*Muhlenbergia y Festuca*).

[19] See foot note 7 above.

5) Scrub Oak Forest (see, above all, the lower piedmont, 6):
This type of vegetation is abundant in the semi-arid (700-900 millimetres of annual precipitation) northeastern part of the basin. The scrub oak (*Quercus microphylla*) could be a community induced by human intervention, especially fires, in an area where it is almost certain that pines and oak trees grew. This vegetation forms thickets no higher than 80 centimetres, and tends to grow alongside the *palmita* (*Nolina parviflora*) and the sotol (*Dasylirion arcotriche*). This zone is very prone to erosion, which makes the propagation of its plant covering advantageous.

6) Juniper Forest (see, above all, the upper piedmont, 8):
The trees in this zone are someone small, reaching a height of no more that six metres; they form a sparse forest and grow alongside abundant herbaceous vegetation. Semi-arid slopes or plains are common above all else. The juniper, *juntero* or *sabino* (*Juniperus deppeana*) could have replaced communities of pines that disappeared due to human intervention (fires).

7) Oak Forests (see above the middle and upper piedmont, 7 and 8):
Oak groves are commonly found in the Mexico Basin. They occur at elevations between 2,300 and 3,000 metres and receive rainfall of between 700 and 1,200 millimetres annually. They grow alongside pines. Ezcurra indicates that there are a wide variety of oaks in the basin, associated with the different altitudes where they occur. They form dense forests and are more or less short, measuring between five and 12 metres, to reach just below the tops of pine trees. A noteworthy example of an oak forest (especially of *Quercus rugosa*) is the one found in the Pedregal de San Ángel, now almost entirely extinct.

8) Pine Forests (see, above all, the sierras, 9):
This zone takes up about 5% of the basin's surface area, following the oyamel fir tree forests; it is the most important native arboreal species in the basin.

Pine trees constitute the natural landscape of the highlands of the Mexico Basin (from 2,350 to 4,000 metres), especially in its southern portion; they occur in areas that receive

rainfall that is average for the basin, between 700 and 1,200 millimetres. The smallest pine trees are the *Pinus leiophylla*, which are associated with oaks; the next largest is the very Mexican Montezuma pine or *Pinus Montezumae*. In the north, where it is drier, the *Pinus rudi* can be found. At the highest elevations, above 3,000 metres, the *Pinus hartwegii* grows on almost 5,000 hectares (in second place in terms of the total area of the basin). This type of pine is found alongside highland grasses or zacatones, and is at high risk from fires, the intrusion of sheep and other exogenous activities.

9) Cloud Forests (see the upper piedmont, 8):
This is a small vegetal community that occupies a small part of the basin. According to Ezcurra, it lies mostly "in the protected canyons and mountainside of the lower slopes of Iztaccíhuatl and the Sierra de las Cruces" (2,500 to 3,000 metres). In this habitat there are abundant *alifitas* such as mosses and ferns, as well as climbing plants, which make their way up tree trunks. Of the trees found in this zone, Ezcurra makes special mention of the *tlecuáhutl* (*Clethra mexicana*), the *limoncillo* (*Ilex tolucana*) and the oak.

10) Fir Forests (see the upper piedmont and the sierras, 8 and 9):
This is the basin's largest area to still be forested and more or less preserved (80,572 hectares, or 8.48 % of the total area, according to Melo, Gallegos and Oropeza Orozco). These are shady, dense, perennial forests with trees measuring between 20 and 40 metres. They occur between 2,700 and 3,500 metres, especially in the south and the east where there is more humidity, as well as deep, rich, well-drained soil. These fir trees stand beside pines, ahiles (*Alnus firmifolia*), white cedars and oaks. Also to be found are willows (*Salix oxylepis*), *romerillos* (*Pseudotsuga macrolepsis*) and *capulines* (*Prunus serotina sp. Capuli*). The undergrowth consists of mosses.

Of course, a large number of exotic species are growing on a large portion of the basin, especially in its urbanized area. Melo Gallegos and Oropeza Orozco[20] define "exotic plantations" as the trees used for reforestation that were introduced relatively recently, mostly eucalyptus, casuarinas, pitules, estoraques, poplars and willows, all of which have

[20]M. Gallegos & O. Orozco, Vegetación, en *Atlas de la Ciudad de México....*, pp. 33-35.

adapted well and grown rapidly despite the difficult conditions present in the basin. They have been grown in the National Parks, the foothills of the main sierras and even in the Bosque de Chapultepec and other parks within the city.

As we mentioned before, another foreign addition to the basin's natural flora are, or course, agricultural crops, which lie on the largest portion of land, more than a half-million hectares as of the 80s, according to the authors previously cited here. The crops grown in the basin include corn, fodder, a number of gramineous plants, legumes and tomatoes (*Physalis sp.*), and of particular interest, the bean, the *huautli* or amaranto (a nutritious grain, complementary of corn, that provides much vegetal protein), and squash. Many of these crops overflow from the flat areas suitable for agriculture and invade higher areas, to the detriment of forests, and with a negative impact on the basin's ecology.

Since Mexica times, the basin's inhabitants have eaten herbs and plantlets of high nutritional value that crop up as undergrowth (quelites) associated with corn, including wormseed or *epazote*, *pápalo*, purslane, marigolds and romeritos. Ezcurra, quoting Niederberger,[21] mentions 15 species of quelites (*quenopodiáceas*, *amarantáceas*, *portulacáceas*, *oxalidáceas*, *escrofularéaceas*, *solanáceas*, *poligonáceas*, *ninfeáceas* and *umbelíferas*).

[21]E. Ezcurra, *De las chinampas a la Megalópolis. El medio ambiente en la cuenca de México...*, pp. 32-33.

2.3.3 Fauna of the Mexico Basin

Perhaps even to an even larger extent than the flora, the basin's fauna has gone through different periods of extinction and adaptation. There is archaeological evidence that the first inhabitants of the basin were, during at the first ten-thousand years, nomad hunter-collectors of the abundant fauna of the Pleistocene, such as mastodons, mammoths, bison, and at least one species of came lids and glyptodonts, as well as a larger type of deer (*Odocoileus halli*), now extinct. All these species, in fact, are now extinct in the basin, as they are in the rest of the world.

Cristina Niedeberger[22] compiled a comprehensive list –based on historic and archaeological evidence-- of the species present in the basin before the Conquest, and Ezcurra compared that list to another much more recent one compiled by Ceballos and Galindo.[23] A total of 87 species were identified, for the most part bats (*Chirotera*, 26 species) and rodents (35 species such as gophers, squirrels and mice), although there were also 12 species of carnivores, felines (the puma, the lynx and the extinct ocelot), canids (the coyote and the grey fox), procyons (ringtails and raccoons), and volpes (weasels, foxes, and badgers). The pronghorn antelope, a species of the *antilocapridae Ungulates*, is now extinct. The whitetail deer (*Odocoileus virginianus*) continues to exist, whereas the mule deer (*Odocoileus hemionus*) has died out, probably along with other cervids. There were also five species of insectivores, such as the shrew, six types of logomorphs, such as hares and rabbits, armadillos (teethed) and even marsupials, such as the opossum-like *tlacuache*. Ezcurra rightly observes the near absence of large herbivores. The ungulates (deer) were most likely hunted to extinction in the 17th century, along with the wild turkey (*Meleagris gallopavo*).

[22]E. Ezcurra, *Ibid...*, p.25.
[23]Ceballos y Galindo, in E. Ezcurra, *De las chinampas a la Megalópolis. El medio ambiente en la cuenca de México.*

Within the lacustrine area, there was a rich, varied fauna that was an integral part of the diet of the lakeshore peoples. Among these animals were ducks and other birds, including migratory species, many of which are still present; there were also amphibians, crustaceans, and other aquatic invertebrate crustaceans. Many reptiles and insects valued by humans were present in large numbers. A few authors cited by Ezcurra[24] pointed to the existence of "22 species of ducks, geese and swans; three species of pelicans and cormorants, ten species of herons and storks, four species of grebes, 19 of plovers and *chichicuilotes*, nine species of cranes, *gallaretas* and *gallinitas de agua*, and eight of puddle ducks (*Anas spp.*). Niederberger[25] describes five species of frogs and toads, four of the highly valued *axolote*, seven of water snakes and three of turtles. There were also a great number of freshwater fish (which were caught with nets), especially the *aterínido* or white fish, known as *iztacmichin* in náhuatl. Also present were *ciprínidos* and *goodeidos*. She mentions crustaceans such as *acolies*, arthropods, algae and fish eggs, as well as edible insects such as *ahuautli* and the larva of dragonflies, water beetles and flies.

[24]E. Ezcurra, *De las chinampas a la Megalópolis. El medio ambiente en la cuenca de México...*, p. 25.
[25]E. Escurra, *Ibid.*, p. 23.

CHAPTER 3

HISTORY AND URBAN FORM OF MEXICO CITY

3.1 The Original Peoples and the Ancient Cultures of the Mexico Basin

We know with certainty that man arrived to the American Continent in relatively recent times, having come from Asia across the Bering Strait in Alaska, when the Wisconsinian glaciation allowed for the passage of groups of humans, in the late Pleistocene.[1] The exact date this took place is still the subject of academic debate, as the well-known Clovis Horizon seems to move farther and farther away. However, it now seems reasonable to place the crossing between 30,000 and 25,000 years ago. With respect to the Mexico Basin, evidence suggests a human presence around 20,000 years ago, on the archaeological horizon, on the then island of Tlapacoya in Chalco Lake, in the south.[2] The evidence – remains found in the sandy soil of what were the beaches of the lakes—of possible first settlements is located near Chalco and in Chimalhuacán and other sites on the south eastern side of the basin. These primitive inhabitants were nomad hunter-collectors and used rudimentary instruments made of obsidian and stone to hunt animals such as the great mammals described previously, which are now totally extinct.

3.1.1 First Inhabitants

Evidence of groups of humans in the basin becomes more frequent and plentiful dating back around 7,000 years, at which time the fundamental transition between a nomadic and sedentary existence began to take place. As in so many other parts of the world at about the same time, this period marked the advent of the agricultural revolution. It is likely that numerous stable human communities began to form along the shores of the freshwater lakes, and, by the period known as the *Horizonte Playa*, around 5,000 BC, there is evidence of sedentary proto-agricultural settlements, possibly associated with the introduction of

[1] J. L. Lorenzo, in *Historia General de México*, México: El Colegio de México, 1978.
[2] *Ibid.*

teosinte (*Zea mexicana*), the close relative of corn, which began to be cultivated at that time in the valleys near Puebla and Tehuacán.

Later, toward the end of 300 BC, during the Zohapilco Cultural Horizon, there is evidence of notable agricultural progress such as the cultivation of corn, amaranto and squash, as well as the use of better tools made of stone; even a small anthropomorphic figure made of clay, the oldest in the area, has been attributed to this period.

Thus, the Mexico Basin began to consolidate its position as the founding nucleus of the important cultural-civilizing region known as Mesoamerica.[3] The area's borders were clearly defined, stopping short of the semi-arid Mexican high plateau to the north, the Lerma River to the west, and the Nicoya Peninsula in what is now Costa Rica to the south. The Mexico Basin emerged as the fundamental location of the unfolding of events in Mesoamerica, which would culminate in the political and cultural occupation of the Aztec Empire, a territory that saw numerous technological and cultural advances. The empire not only would spread throughout Mesoamerica, but also would come to represent the point where other cultures met and assimilated. The first cities in America emerged along with their grand ceremonial centres; here all technological systems known as Mesoamerican agriculture[4] were to be found: the "groove" technique used on lower, semi-forested slopes, seasonal planting that took advantage of the rainy period, crop rotation and the construction of terraces on alluvial slopes. Later, other technologies included the use of canals for irrigation and chinampas, the highly productive method of growing crops in swampy areas and lakes. The progressive intensification of Mesoamerican agriculture allows us to discuss more precisely the formation of urban cultures and consequent demographic pressure.

3.1.2 Ancient Cultures: Cuicuilco, Teotihuacan, Tula

Around 1300 BC, the Olmec Horizon consolidated itself in the basin and later throughout

[3]The following is a description of the principle cultural traits of the Mesoamerican peoples. Their basic food source was corn, which they planted with a planting staff or *coa*. Also cultivated was the Mesoamerican triad of beans, squash and chili peppers. Corn was mixed with lime to produce a shapeable mass (***nixtamal***). They polished obsidian, constructed multi-level pyramids, and had two types of calendars, one ritual and the other solar. Forms of sacrifice and self-sacrifice existed. They had markets and domesticated animals such as dogs and turkeys.

[4]A. Palerm & E. Wolf, *Mesoamérica*, México: SepSetentas, 1973.

Mesoamerica. At this time, evolution and agricultural and cultural life revolved around corn, which expanded to all of Mesoamerica consolidating itself as the most important crop and adapting to a great number of ecosystems. (The American man was not successful at domesticating large animals; after millenniums of hunting, the problem of the progressive extinction of many species of herbivores had to be faced. There was a much stronger focus on the development of agriculture, with corn as the foundation). This was a period of great demographic expansion in the basin, where ten important human settlements were coming into existence, the most significant of which were Tlatilco and Tlapacoya. Other noteworthy population centres were Tetelpan, Aztahuacán, Tulyehualco, Cuauhtlapan, Coatepec, Xalostoc and Tepetlaoztoc, many of which continue to exist today, as poor neighbourhoods within the metropolitan area.

The now-classic work of Sanders[5] on demographic processes and settlement of the basin, shows that the area's population started to grow significatively around 1500 BC, albeit with ups and downs and oscillations; thus, it might be apt to term this first era one of "pulsating growth." Periods of population expansion and formation of clusters of important, high-density settlements were followed by periods of relative population loss and/or movement to new population centres. This type of demographic expansion intuitively seems to follow the model set forth by the Danish economist Ester Boserup on the exhaustion of the "carrying capacity" of given ecosystems.[6] However, population growth was quite stable at the time of the Aztec's arrival to the basin, as we will see later on.

At around 600 BC, a significant expansion of commercial and cultural activities (agricultural growth, ceramics) took place, coinciding with the formation of large population centres in the basin. It was a period of growth especially in the south of the basin, around the lakes of Chalco and Xochimilco. Additionally, the population grew in what can be considered a corridor that ran along the piedmonts around Lake Texcoco (which at that time covered a very large area) and, farther to the north, along the

[5]W. T. Sanders, The Population of the Central Mexican Symbiotic Region, the Basin of Mexico and the Teotihuacán Valley in the Sixteenth Century. In *The Native Population of the Americas in 1492*, edited by W. M. Denevan, WI: University of Wisconsin Press, 1978.
[6]E. Boserup, *The Conditions of Agricultural Growth: the Economics of Agrarian Change Under Population Pressure*, with a foreword by N. Kaldor, Chicago, Ill.: Aldine Publications Company, [1966, c. 1965], 124 p.

Teotihuacan River. There were also considerably large population centres in Atzcapozalco and, to the east, in the area surrounding the Sierra de Guadalupe.

CUICUILCO

Nonetheless, it was certainly in the south eastern part of the basin where the first truly significant human settlement came into existence: the great ceremonial centre of Cuicuilco (around 500-300 BC). Cuicuilco may have had as many as 20,000 inhabitants settled on an area of some 1,000 hectares. Its urban architectural layout was sophisticated. In its centre lay a unique, round, semi-pyramidal construction whose base was 135 metres wide. Well-designed roads connected the city with its pyramidal centre. Its ceramics were elaborate and its corn-based agriculture was sophisticated. The city traded actively with other settlements, especially with Ecatepec in the northern part of the basin.

Cuicuilco was destroyed by the violent eruption of the Xitle Volcano, which covered with lava the city as well as fertile agricultural land.

Around 300 BC, the southern portion of the basin continued to be the most populated, with at least 15 "nuclear" population centres. There is also evidence from this period that indicates that the population was moving from the lakeshores to the lower piedmonts, especially those of the Sierra Nevada and the south. The population in the eastern Texcoco area continued to be large and the corridor mentioned previously still existed.

At this time the presence of humans in the Teotihuacan Valley –the driest part of the basin located in the north eastern corner—was still relatively minimal. However, there were some small settlements with populations of no more than 200 to 500 inhabitants living in clusters of around 25 houses.

The period from 200-100 BC saw even greater regional variation and population diversification. Two proto-urban regions clearly emerged in opposite corners of the basin. In the northeast there was Teotihuacan, which quickly reached a population of perhaps

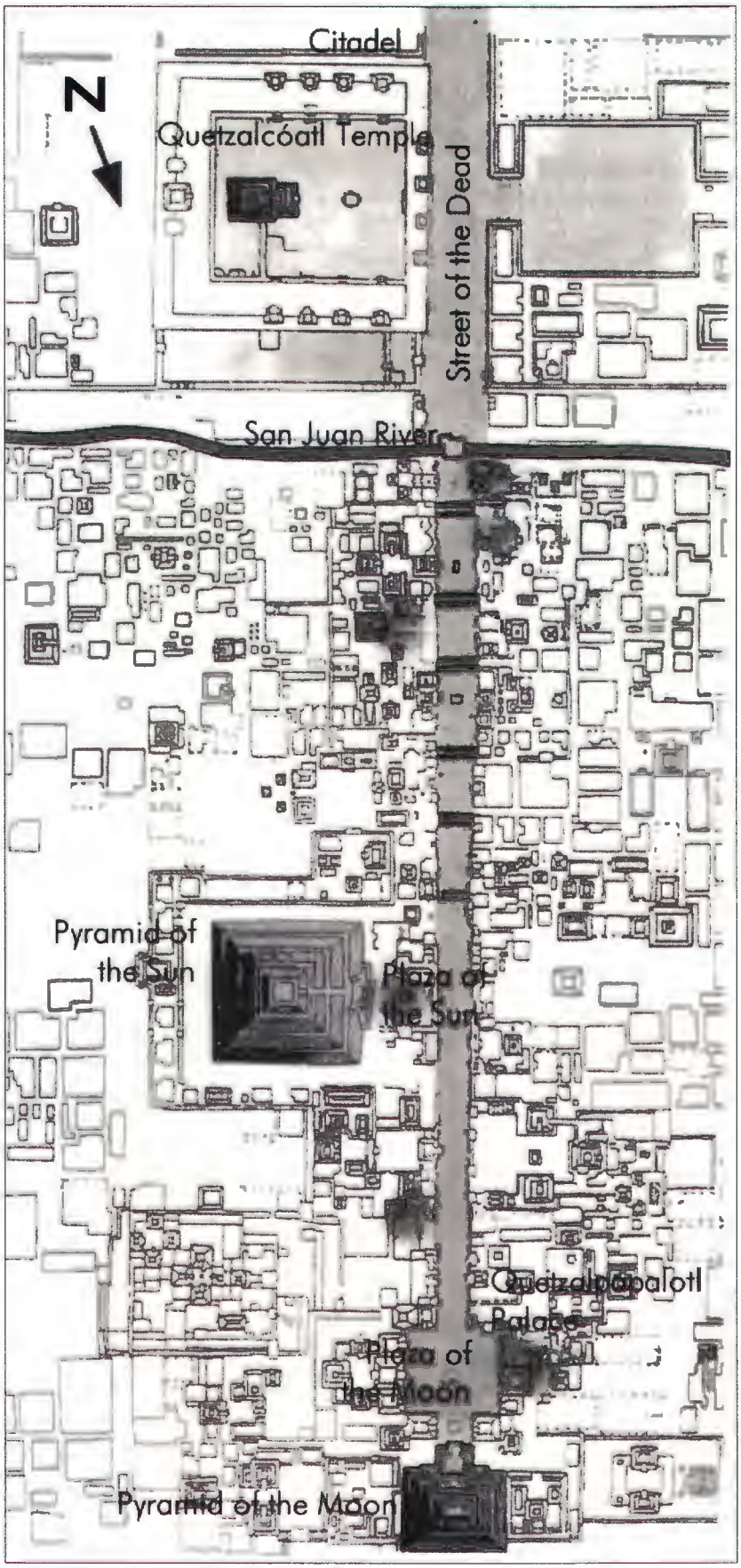
10,000 and an area of 600 hectares, while another population centre, about which little is known, developed in the southeastern area where Cuicuilco one stood. The two settlements may have been about the same size and were located within 60 kilometres of each other. There were also at least five nuclear population centres around the southern and eastern shores of Lake Chalco, as well as other modest settlements on the opposite, outer reaches of the basin in Amecameca and in the semi-arid northwest, around Lake Zumpango. Another population centre was located on the peninsula of Ixtapalapa.

THE TEOTIHUACAN ERA

At the beginning of the first century, up until the year 400 AD, a true urban revolution took place in the northeastern and central areas of the basin, with Teotihuacan becoming the first great urban centre in the western hemisphere. Lying on an area of 20 square kilometres, Teotihuacan reached a population of 30,000 to 50,000. By the middle of the 6th century, the number of inhabitants probably exceeded 100,000. The city was located in a drier valley where there was less of a chance of being overtaken by lakes as in the mid-to-lower parts of the basin. On the other hand, the conditions for growing corn were less favourable compared to the southern and eastern piedmonts.[7] Nonetheless, the city became a centre for the production of cactus textiles, salt and the highly valued obsidian stone that to a large extent served the same function as metal.

With the exception of the north western corner of the basin (Zumpango), a certain demographic depression occurred during these years in the area south of the Teotihuacan Valley. More precisely, a depression took hold of the rural areas in favour of the great urban centre of Teotihuacan, leading to the migration of the inhabitants of many smaller settlements and even from neighbouring Texcoco on the eastern border of the basin. It is important to note, on the other hand, that Teotihuacan's predominance can also be explained by Cuicuilco's abrupt decline after the eruption the Xitle Volcano.

[7]It should be mentioned that during Teotihuacán's boom, other cultures flourished such as the great Zapotec city located in the Valley of Oaxaca, Montealbán.



Map 3.1. The Trace of Teotihuacan.
Source: Own elaboration based on Sabloff.

In order to explain the basin's urban development, it would at this point be useful to briefly discuss the urban design of Teotihuacan, which, it must be recalled, probably grew to be larger than Tenochtitlán (see Map 3.1). During its apogee, Paris and London were small, insignificant villages.

The City of Teotihuacan was an amazingly well planned urban settlement, its design conceived of to please the local gods. Its monumentality has been matched in few other places in any era. The city was laid out around the straight, wide street, the so-called Avenue of the Dead, which ran from south to north until reaching a plaza that served as a vestibule for the beautiful Pyramid of the Moon on its northernmost end. Along the magnificent, 5 kilometre-long avenue stood a number of important constructions. The most noteworthy of these was, of course, the Pyramid of the Sun; additionally, there was a complex of public buildings at the beginning of the avenue known as the Citadel, as well as the impressive Temple of Quetzalcoátl. Extending from this urban nucleus was an enormous city made up by neighbourhoods of immigrants, not only from the basin, but from as far away as Oaxaca. The city grew to include 600 pyramids, more than 2,000 residential complexes –the majority closed quadrangular constructions built around a central area—and at least 500 workshops.

Unfortunately, however, between 700 and 900 AD Teotihuacan declined rapidly and irreversibly –perhaps because of the combination of drought and the excess of population with respect to its carrying capacity. According to Sanders and Wolf, the city's population dropped to 40,000 inhabitants. This catastrophic decline led to the abandonment of the magnificent city's central areas. Following Teotihuacan's decline, nuclear population centres began to re-emerge in the irrigated areas on the alluvial plains, exactly south of the Teotihuacan Valley and on the north western shores of Texcoco Lake. Six other nuclear population centres emerged to the south of Teotihuacan, each with an area between 100 and 400 hectares and a population of around 1,000.

TULA AND OTHER CENTRES:

It is therefore probable that Teotihuacan's disintegration led the population to again disperse towards the more productive lands in the south and east, and even to leave the basin. Beyond the basin's limits, settlements emerged in areas such as Cholula (in the state of Puebla), Xochicalco and, above all, Tula, the most important Toltec centre located on the northern fringes of the basin. Designed more or less along the lines of Teotihuacan, Tula served as the centre of the powerful Toltec people. The Aztecs would later profess to be influenced by this group and especially by their legendary god-warrior, Quetzalcoátl. Tula's apogee was around 900 AD, at which time its population reached 60,000 inhabitants and its surface area 14 square kilometres. By 1100, the city had declined. It had two notable pyramids, fields for playing a ritualistic ball game and a palace. Near its largest pyramid, stood a building upon which there were a number of columns and huge statues called "Atlantes".

Thus, from the year 900 until around 1150 AD, the population continued to disperse itself in a general process of depopulation.[8] Later, between 1200 and 1520 AD, a new era of demographic recuperation began, as well as a process of nucleation which led to the formation of a number of relatively modest urban centres such as Ixtapalapa, Chalco, Culhuacán and Xico in the south, and, in the east, Chimalhuacán, and even to some extent Teotihuacán. A short time later, Texcoco and other cities along the lakeshores emerged.

Between the 8th and 15th centuries –that is, the period before, during and even after the arrival of the Mexicas—the basin's population grew rapidly and a number of important cultural, agricultural and technological advances took place. The period also marked the arrival of new tribes outside the basin: the Chichimecas from the north who settled in Xoloc, the Alcolhuas, Tepanecas and Otomíes who established themselves in the northwestern population centres of Azcapotzalco, Tlacopan and Coyohuacan, and groups possibly of Toltec origin who migrated to Culhuacan and Chimalpa. Thus the inhabitants of

[8]E. R. Wolf, ed., *The Valley of Mexico. Studies in Pre-Hispanic Ecology and Society*, Albuquerque: University of New Mexico Press, 1976, p. 93-95.

a number of small but stable settlements came to populate the lakeshores, a process masterfully described in the *Xolotl Codex*. Agricultural advances and the construction of channels and irrigation systems led to the development of commerce and an increase in the population. It was this dynamic setting of progress which the Aztecs found upon their arrival to the basin. They later founded the city of Tenochtitlán on a small, flood-prone island, the same site upon which Mexico City would be built. Steeped in Teotihuacan's heritage, it was the last great urban centre of Mesoamerica.

By the end of the 15th century, there were more than 1.5 million people living on the basin's lakeshores and islands in more than a hundred settlements, making the basin the most dense, populated place in the world at that time. At this point we should mention a number of large urban centres such as Azcapotzalco, Coyoacán, Ixtapalapa, Tacuba, Chalco, and Xochimilco, settlements important to understanding posterior urban expansion since they were to be engulfed by the city, and exist even today within the metropolis, having acted to shape its urban composition (see Map 3.2). Only Texcoco remains outside today's urban sprawl. It was there that the wise king Nezahualcoyótl built in the nearby town of Tetzcotzingo a vast Botanical Garden, along with impressive hydraulic works. Gardeners brought planted trees from throughout the region, which had to be acclimatized. A few magnificent Montezuma Cypresses can still be seen today. Texcoco will be an integral part of this thesis reclamation project for the Mexico Basin.

Also deserving mention is the fact that, to the south, the Xochimilco and Chalco lakes were filled with chinampas, small artificial "islands" of mud and rich, highly productive soil that were maintained alongside complex irrigation systems. [9]

[9]The chinampas were also built to provide urban land and served as auxiliary orchards and gardens for families' sustenance. The real source of food for the city came from taxes levied on agricultural lands that belonged to Mexicans outside Tenochtitlán and were worked by slaves or subjugated people. A. Palerm, Urban Settlement and Residence Pattern at Tenochtitlán, quoted in S. Lombardo de Ruiz, *Desarrollo Urbano de México-Tenochtitlán según las fuentes históricas,* México: Instituto Nacional de Antropología e Historia, Departamento de Investigaciones Históricas, 1973, p. 114.

Map 3.2. Pre-Hispanic Mexico Basin.
Source: Own elaboration based on 500 planos de la Ciudad de México, p. 40, 42, 80, and Gibson, Charles, Los aztecas bajo el dominio español 1519-1810, Siglo Veintiuno, México, 1980.

By the end of the pre-Hispanic period a great web of cities had emerged on the periphery of the lakes, with the Great Tenochtitlan as their centre. Their use of the dense forests that framed the basin was limited, since they developed an economy based on the lower-lying lands close to the lakes, where they grew corn, built chinampas and wisely utilized lacustrine resources.[10]

3.2 The Great Tenochtitlan: 1325-1521

The Aztecs[11] –or more correctly, the Mexicas—arrived to the Mexico Basin from north eastern Mexico, departing from a remote and mythical place known as Aztlán.[12] They were semi-nomadic, warlike, fatalistic and religious like few others, and were one of the most successful groups in history in terms of conquest and civilization. This, in turn, contrasted with their tragic end, which came after only 200 years.

The Mexicas arrived to the Mexico Basin in 1270, settling in the west. In 1276 they briefly established themselves beside the lakes in the strategic Chapultepec hills, where they first glimpsed the basin's majestic landscape of lakes surrounded by dense forests and snowy peaks. Their view from west to east was opposite from the one that Hernán Cortés would have 200 years later. The Mexicas were promptly expelled and subjugated by Culhuacán, located on the Iztapalapa peninsula, a powerful dominion that was highly influenced by the Toltecs. From the Culhuacanos, the Mexicas received inhospitable land near Tizapán. Little by little, they came to be accepted and their luck began to improve due to their military skill, their acceptance of the Toltec influence and their mixing with other groups.

[10]C. Gibson, *Los Aztecas bajo el dominio español. 1519-1810,* fifth edition in Spanish, México: Siglo XXI, América Nuestra, 1980, p. 5.
[11]The Empire is Aztec, and its habitants are Mexicas (which is more accurate); thus, they are also known as Aztecs.
[12]According to studies carried out by Luis Suárez, Aztlán was located northwest of what is now Mexico. Its name means "land of the herons." It is also known as Tollan, which means "the navel of the world." See L. Suárez, *De Tenochtitlán a México,* México: Fondo de Cultura Económica, Archivo del Fondo 16, 1974, 111 p.

In 1325 the Mexicas established themselves on the small island, in the middle of the lake, called Tenochtitlán (the place of the prickly pears of the cactus paddle), which was held by the Tepaneca dominion of Azcapotzalco, under the powerful government of Tezozómoc. It was there that the Aztecs would worship their god Huitzchilopotzli; they would also witness the appearance of an eagle perched atop a cactus while eating a snake. In short, it was on this island that the Mexicas founded the largest city and empire in the western hemisphere until the Spanish conquest.

The Mexicas first built, beside their huts, simple shrines of mud and reeds for Huitzchilopotzli, as well as chinampas which extended their land into the lake and at the same time served for planting crops. They slowly began to use more solid materials --such as stone, wood and lime-- for their buildings and temples. Despite their progress, their status as vassal-mercenaries to the Tepanecas did not change, as was also the case on the adjacent island to the north, Tlaltelolco, which would remain a separate entity for some time.

With the election of Acamapichtli as their first governor,[13] the Mexicas began an era of progress, trade and consolidation. As a result of the beginnings of differentiation in Mexica society, the population grew and significant ceremonial buildings were erected. Although the island of Tenochtitlán served as a natural fortress and allowed for rapid intercommunication by way of the lakes, it did have certain problems which would forever influence the area's destiny: difficult access to fresh water, recurrent flooding and scarce agricultural land. In fact, records indicate that it was during Acamapichtli's reign that there was a great flood that lasted four years and destroyed numerous chinampas (vide. *Anales de Tlaltelolco*). From then on, this became a familiar theme in the economic and social life of the Mexicas. By the time of the reign of their third monarch, Izcoátl (1427-1440), the Aztecs had acquired allies: Texcoco, the dominion on the eastern side of the lake, and Tacuba, on the lakeshore to the west of the island. Finally, the Mexicas defeated

[13] The proper title was *tlatoani*, it was given by the Aztecs to their supreme ruler; he not only was the head of the government but also ruled the army, was the maximum religious authority and played a central role in the creation of laws, tribute and commerce as well.

Azcapotzalco (1428) and, with Texcoco and Tacuba, forged the so-called Triple Alliance,[14] which was soon to become the area's greatest power, achieving their dominance and empire first by conquering the lakeshore towns. Their conquests led to taxes which gave them access to the material resources needed to build their island-city as well as a vast system of hydraulic works, used not only to bring drinking water to the island (from the nearby springs in Chapultepec, and from farther south), but also to avoid the invasion of salt water from the eastern part of the lake, as well as to transport people and materials.

It was during the reign of Izcoátl's successor, Moctezuma I (1440 -1469), that the great Tenochtitlán reached its height, acquiring the monumental urban form fit for an imperial capital.[15] Despite the boom in monumental constructions during this period, Moctezuma I was faced with severe natural disasters. According to the *Ramírez Codex*, the gravest flooding of the Aztec capital took place in 1449, and not long afterwards, in 1450, frosts and then devastating droughts forced the Mexicas to live on roots, bark and other plants, mostly from the lake. It was at this time that an effort was made to resolve the serious problem that water represented. Construction on an aqueduct from Chapultepec (1466) began over the remains of a former construction that had ceased to function. The job was given to Moctezuma's cousin, the lord of Texcoco, the celebrated Nezahualcóyotl, who went on to build a monumental construction of stones and stakes 12 to 16 kilometres in length, running from south to north. The project required the labour of 20,000 peons or *macehuales*. The *tlatoani* or emperor brought in architects from Chalco, Mixtec goldsmiths from Oaxaca, and materials from the far corners of his constantly expanding empire.

[14]According to Sonia Lombardo, the Triple Alliance was made up by Tenochtitlán, Tetzcoco and Tacuba. Mexico-Tenochtitlán was the Mexico Basin's urban centre, functioning as an integrated entity that maintained a symbiotic relationship with the satellite cities. The second most important city after Tenochtitlán was Tetzcoco, whose dominion included 15 provinces that extended all the way to the coast, at Tuxpan. It is fair to say that this was the only city that gained the Mexica's recognition and consideration. There were close ties between Mexico and Tetzcoco since, besides being allies in war, they were active trading partners. Following Tetzcoco in importance was Tacuba, the third city in the Triple Alliance, which never came to be as preeminent as Tenochtitlán since its government was imposed and controlled by the latter. See S. Lombardo de Ruiz, *Desarrollo Urbano de México-Tenochtitlán según las fuentes históricas*... pp. 126, 127 y 212.

[15]Moctezuma I's reign was a period of great reconstruction of Tenochtitlán (Mexico City.) The abundant materials received as taxes and the labor provided by subjugated groups made the reconstruction of all its buildings possible. Mud was replaced with reeds and stone, or a mixture of lime and wood. S. Lombardo de Ruiz, *Desarrollo Urbano de México-Tenochtitlán según las fuentes históricas*..., p. 73.

Erected on top of the original temple built during Ixcoátl's reign, it was during this period that the definitive *Templo Mayor* or main temple, was erected in the heart of the city in the centre of its design and form. A great perimeter of masonry --the celebrated wall of snakes or Coatepantlli—surrounded the temple's patios, which were built according to strict rules that reflected the social structure and the hierarchic and stratified nature of Aztec society. Placed in perfect alignment were numerous statues (the best in Chapultepec) and houses or royal palaces, as well as the great plaza in which the market was held, in the exact spot where today's *Plaza de la Constitución* or Zócalo now lies.

By 1473, during Emperor Axayácatl's reign (1469-1481), the Mexicas were able to subjugate their island-dwelling neighbours to the north, the Tlaltelolcas, and incorporate them into their empire. The small island was joined completely with Tenochtitlán, as were other smaller ones. By the 16th century, the capital lay on an area calculated to be between 13 and 15 but some other authors put it at 18 square kilometres.[16] The city continued to prosper as the empire expanded. It grew --literally-- as more chinampas were built, and, over the period of 200 years leading up to the conquest, the area of the two original islands are thought to have doubled through a process of recuperation and addition of small, neighbouring islets.

These years produced monumental sculptures such as the *Piedra del Sol* or stone of the sun (also known as the Aztec calendar), the reconstruction of the main temples, and, above all, the hydraulic works used not only to bring in drinking water, but also to avoid flooding and the invasion of salt water which could damage the chinampas and other lands on the island. The Tlatoani Ahuizotl (1486-1503) ordered the construction of a second aqueduct to supplement the water coming from Chapultepec, this one drawing from the springs of Coyoacán. The aqueduct was said to have been badly built and caused an enormous flow of water to enter the city, causing a terrible flood in 1499. At around this time, as the empire was now consolidated, it imported more and more specialized materials from neighbouring cities. From Texcoco, which was also known for its highly skilled bricklayers, stones of varying density and hardness were acquired. From Chalco, sand, dark volcanic rock called

[16]S. Lombardo, *Atlas de la Ciudad de México, 1987.*

tezontle, planks, wooden stakes and canoes were brought in; canoes also came from Xochimilco. Lime, among other materials, was imported from southern tropical zones.

At this point urban life was completely consolidated. The density of the population was high; the society was heterogeneous and specialized. It was upon this burgeoning population that the Aztec Empire based its organization, administration and expansion.

> 'The tribal type of organization, based on clans made up by individuals bound by family relations, is considered to be related to a nomadic form of life, which evolved into a political society, organized as a State, in towns within a fixed territory, which function in an agrarian regime that relies on the distribution of land.' [17]

According to Sanders,[18] there were close to 10,000 hectares of chinampa fields to the south of the city, Xochimilco and Chalco, which were able to provide food for close to a half million people.

The last Aztec emperor, Moctezuma II (1502-1520), presided over the era of Tenochtitlán's greatest splendour, although he did not carry out significant new construction. He would have to live through the drama of the empire's final defeat.

Although the brutal destruction of the conquest destroyed practically the entire city, it is important to point out that in the great Tenochtitlán property rights were not central to its formation, or to the determination of its urban form, since these things were decided by the orders of king, without consideration of the rights of use or enjoyment of land. However, it should be pointed out that of the two types of land ownership during the final period of the Aztec Empire, the semi-communal type of the *calpullis*[19] and the official, state kind, set aside for nobility or for royal or ritual usage, the former wielded greater influence on the

[17]S. Lombardo de Ruiz, *Desarrollo Urbano de México-Tenochtitlán según las fuentes históricas...*, p. 51.
[18]W. T. Sanders, The Population of the Central Mexican Symbiotic Region, the Basin of Mexico and the Teotihuacán Valley in the Sixteenth Century. In *The Native Population of the Americas in 1492.*
[19]The true meaning of the calpulli refers to territoriality, as well as family relations, communal property, division of labor and social stratification. However, over time, the calpulli underwent an evolutionary process that gave it a multidimensional, complex nature, determined by the expansion of the empire. Besides bonds of family relationship, there were new kinds of ties based on politics and economics, in which private property was considered an important factor. See S. Lombardo de Ruiz, *Desarrollo Urbano de México-Tenochtitlán según las fuentes históricas...* p. 163.

land use and organization. The calpullis were more ore less well differentiated and organized, seeking a certain amount of special equity that had to be made function in the face of the complex hydraulic structure of the island-city. The nobility's land began to have the characteristics of private property since it could be inherited or even change hands.

The social organization of this religious and warlike people was highly hierarchal and structured, a fact reflected by the strict planning and design of their city. The Aztec's basic social structure consisted of the calpullis, that literally meant "big houses," that was applied to a community or entity of population. They were vestiges of an unusual type of clan organization that the Aztec Empire supplanted. The calpullis were small villages or hamlets located within the city with specific functions. The calpulli's land belonged to its inhabitants without private differentiation and was allotted to it members for their own use; it could not be sold or rented outside the calpulli. On the other hand, the calpullis were also military and religious units, that, over time, came to engage in administration.

Each calpulli had a supreme chief elected by the inhabitants called the *calpullec*, possessing broad powers and duties within his territory. We should note that for a highly disciplined society, which continuously organized and fought battles, and which had to undertake large agricultural and hydraulic projects, it was necessary to have stratified and well organized power structures. Operating at the highest level of power, above the calpullis, was the emperor or *tlatoani*, who was thought to have semi-divine attributes and whose power was absolute. Below him was the nobility, the military and the priest class, which wielded much influence in the Aztec world. Towards the end of the empire, merchants or *pochtecas*, who had previously been looked down upon, began to gain a better position in the social hierarchy. The great Tenochtitlán held at its centre the nobility or *pipitlin*, direct descendants of the first tlatoani Acamapichtli. Then came the priest and military castes, followed by merchants and commoners (*mecehualtin*). Also living in the city were immigrants from the empire's provinces, who lived in separate neighbourhoods, as well as a population that lived on boats, referred to as the floating population.

To understand the Mexicas, it is fundamental to look at their religion. They were an extremely fatalistic and pessimistic people that believed that a human being was created and recreated many times, since the gods destroyed people by allowing natural disasters. Man's role in the Aztec's religious universe depended less on how he lived than on how he faced death, an idea that explains the importance of sacrifice and the appreciation of warriors. The only way to pacify the gods and avoid further destruction of the world was through sacrifice, especially human sacrifice. Without it, the sun would go out irremissibly. Therefore it was necessary to sacrifice prisoners, women, children and young adults alike.

The magnitude of human sacrifice carried out by the Mexicas has no comparison in all of the history of humanity. It is said that on the occasion of the dedication of the Great Temple of Tenochtitlán in 1487, between 20,000 and 80,000 people were sacrificed. It is estimated that around 15,000 people were sacrificed in a normal year, a number which took a significant toll, demographically and socially.

The Great Tenochtitlán's urban form as of 1519, with its harmony and evident planning, was the direct result of the Aztec's social empire organization and world view. The city was built on a small island that over time incorporated small neighbouring islets, especially Nonoalco and Tlatelolco to the north. It had a semi-elliptical shape and an area of between 13 and 15 square kilometres. It measured 3.7 kilometres at its widest point along its north-south axis, and 2.9 kilometres at its narrowest axis,[20] measuring from the centre of its widest part. Towards the south, on the eastern side of the great Iztapalapa road, the land was extended to include the small island of Mixuca. The city was pleasant and clean; it was well designed and had many gardens and flowers. It was even common to find gardens on the roofs of houses, where agricultural crops were grown. Chinampas were found everywhere, representing a form of technology used not only to produce food and flowers, but to literally expand the city's area and design its urban layout.

[20]S. Lombardo de Ruiz, Orígenes y evoluciones de la ciudad de México: siglos XVI, XVII, XVIII y XIX en *Atlas de la Ciudad de México*, G. Garza comp., México: Departamento del Distrito Federal, El Colegio de México, Centro de Estudios Demográficos y de Desarrollo Urbano, 1987, pp. 45-47.

Apart from discussing the city's ordered distribution of space in its great ceremonial centre, from which four large residential districts extended, it is important to stress its condition as an island and its use of water for transport, consumption and the massive construction of the highly efficient chinampas. The island-city grew with the construction of chinampas which continuously gained land back from the lake. On the other hand, the defence of the island against flooding was also central to its design and function since it required the construction of channels and dams. Such was the case with the Nezahualcóyotl dyke, which as we will see, was built in 1449 to separate freshwater from saltwater and to avoid the flooding of Tenochtitlán, something that was achieved at least part of the time. Two main aqueducts were also built to transport drinking water, one built during Moctezuma I's reign, coming from Chapultepec in the west, and the other, built during Ahuizotl's time, coming from Coyoacán in the south. Another prominent aspect of the city's Urban design and economic life was the immense market of Tlatelolco, with its great adjacent temple, on the northernmost edge of the island. Close to 60,000 people are thought to have gone to the market on a given day, buying and selling numerous, varied products from all corners of the vast empire.

Although little substantial information about the Aztec city exists, there is iconographic information about it in the Nuremberg map of 1524, taken from *La segunda Carta de Relación* from Cortés to Carlos V. Although the images are altered by a European and utopian vision, they do show the centrality of the ceremonial, imperial centres and the secondary ordering of the four great residential districts. Incidentally, the Nuremberg map of Tenochtitlán is said to have been used as a model by Albrecht Dürer for his design of an ideal city.

The principle element of the urban form was the great ceremonial centre where the Templo Mayor was located, around which the four great original calpullis were situated.[21] These four original calpullis were established in function of the *nauhcampa* or four directions of the wind. An important principle in the Mexico Basin, this subdivision had a ritual meaning

[21]Sonia Lombardo has suggested that these four camps constituted the four ancient clans that departed from Aztlán. See S. Lombardo de Ruiz, *Desarrollo urbano de México-Tenochtitlán según las fuentes históricas...*, p. 52.

since the number four was considered sacred. These four possible directions of the wind represented different Aztec deities, at the same time that they were given certain specialized, functional roles: one for religious activities, one for politics and government, one for administration and one for agriculture. The small island of Tlalteloco, with its enormous market, became a sort of fifth calpulli.

The quadrangular area of the ceremonial centre was divided "with radial symmetry and towards the four cardinal points, the principle roads that (at the same time) defined the four huey-calpulli or 'partialities.' The streets followed the orientation imposed by the roads. Thus they formed a reticle with lines from north to south and from east to west (...)"[22] To some extent this layout was distorted due to Tenochtitlán's irregular shape as an island, its problems with flooding, its diagonal irrigation channels which came right up to the ceremonial centre, and the need to build chinampas as the city grew, always avoiding the salty waters of the east. Nonetheless, its plan was generally observed and admirably regular. Adequate urban planning was considered important and was regulated. There was even an official called the *calmimilocátl*, who was charged with the sole responsibility of urban planning, with particular emphasis on checking for the correct alignment of houses with streets. It was imperative to give an impeccable linear design to the streets and roads since streets were alternated with irrigation channels and the wide primary roads had canals in their medians, as well as pedestrian walkways.

The area of the great temple was surrounded by a wall and decorated with snakes, the celebrated Coatepantli, measuring 500 metres per side. It had four doors oriented toward the four cardinal points, from which the four roads that divided the four calpullis extended. Within the walls stood the Templo Mayor as well as a number of palaces; according to Sahagún there were a total of 78 large buildings. The temples were topped with pyramids (called "towers" by the Spanish), the largest of which measured 40 metres high, and was dedicated to Huitzilopochtli (the warrior god) and Tláloc (the god of rain). In front of these were the round Temple of Quetzalcoátl, as well as temples dedicated to the god of darkness, Tezcatlipoca, and the sun god, Tonatiuh. Also located in this area was the court

[22]S. Lombardo de Ruiz, *Desarrollo urbano de México-Tenochtitlán según las fuentes históricas...*, p.48.

for a ritual ball game, the temple of the sun, a fence made of skulls and the highly important *Calmecac*, the school for children of the nobility. Just south of the ceremonial area was the Palace of Moctezuma or New Houses (in the same spot where the National Palace now stands) and to the east was the aviary. East of these structures stood the Palace of Axayácatl and somewhat farther off in the same direction was the menagerie. Other important nuclei included Tlaltelolco[23] to the north and Tocititlán to the south; it was close to the latter where Moctezuma met Cortés.

Beyond the ceremonial area, the nobles and the more powerful citizens (members of the military, and later merchants) had well-made, tall, two-story houses with numerous patios and rooms. There were no external windows, only a door. Water drained towards the outside. The important houses were made of lime and pieces of stone. Often, there were pleasant gardens on the flat roofs. The houses were covered and decorated with painted stucco.

This central nucleus[24] was the starting point of the four roads that divided the four large calpullis, each of which had its own ceremonial centres, markets, etc.[25] To the southwest was Moyotl, to the northwest, Cuepopan, to the northeast, Atzacoalco, and to the southeast, Teopan. Tlalteloco was located to the northeast (see Map 3.3). The Spanish would later follow a similar plan, appropriating the centre (with a larger area than before) and calling the areas that were once calpullis "indigenous partialities." When designing the Spanish city, Cortés's architect, García Bravo, referred to this plan, with its ceremonial centre and the division into four large quarters, and this accounts for the contemporary city's Aztec form.

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[23]Tlaltelolco was incorporated into Tenochtitlán as another entity, with governors imposed by the Mexicans, who were able to extend their territory this way. See S. Lombardo de Ruiz, *Desarrollo urbano de México-Tenochtitlán....*, p. 82.

[24]Above all, the aforementioned nucleus was a civic and religious centre, the heart and symbol of the Mexican empire. It included the ceremonial centre, which housed the protective gods, the palace of Moctezuma, which was the seat of political, economic and military power, and, finally, the *tianguis* or market. Although the latter was not as commercially important as Tlalteloco, it was held in the plaza when large collective festivities were staged. *Ibid.*, p. 132.

[25]In Tenochtitlán, the capital of the Mexican empire, trade --along with the collection of taxes—was the basis of the economy and thus markets were fundamental urban elements. See S. Lombardo de Ruiz, *Desarrollo urbano de México-Tenochtitlán....*, p. 190.

The city's common inhabitants lived far from the central area in houses with small gardens full of flowers, which the Mexicas greatly valued. The walls of their houses were made of *adobe* and there were only one or two rooms. There was almost always a chinampa beside the house as well as a canoe; (there were an estimated 80,000 to 100,000 canoes at the time of the conquest used for transport). The indigenous home did not change much after the conquest; it continued to be made of adobe, reeds and straw roofs and other plants. They were well insulated and, most importantly, they were light and therefore did not contribute to the sinking of the humid soil. The *Códice Florentino* [26] aptly describes the types of existing houses, from palaces to the modest *xacalli* (huts). The materials used included wood, reeds from the riverbanks, straw, stone such as the useful, light and porous tezontle rock, and parts of the highly fibrous and resistant maguey cactus. They manufactured adobe bricks, binding agents like lime, mixtures of stone and vegetal resins.

Transportation within Tenochtitlán, as well as to external destinations, was centred along the shores, and carried out especially by water. There were, of course, a number of roads, as described previously, which connected the island with the land. One headed north to Tepeyac hill (now the road to Tepeyac), while another went from Tlaltelolco to Tenayuca, terminating in Azcapotzalco. Another road, which still exists, went to Tacuba in the west; it was the same road Cortés took after his first expulsion from Tenochtitlán and along the side there still stands a tree where he cried over his defeat on *noche triste* (sad night). The road to the east only went so far as the jetty for Texcoco, on the shore of the island; there was no solid ground in that direction, only the largest and most salty of the basin's lakes. The road to the south reached the Iztapalapa peninsula, where San Antonio Abad Avenue lies. This road bifurcated, one side going to Churubusco and the other to Coyoacán. These roads also served as dams (with removable bridges of wood that served both as floodgates for regulating the flow of water, and as a means of defence for the city). Their function was to regulate the water level, and, to defend the city, they built bulwarks of large almond-shaped towers located a little more than two kilometres from the entrance of the city.

[26]This manuscript by Sahagún dates back to 1569. The codex was written in two languages, and its version in náhuatl was probably moved after the copy commissioned by Sequera, known as the *Códice Florentino*. It is kept in the Biblioteca Laurenziana. See F. Esteve Barba, *Historiografía Indiana*, segunda edición revisada y aumentada, Madrid: Gredos, 1992, p. 212.

Map 3.3. The Island City of Tenochtitlan (Aztec Empire).
Source: Own elaboration based on 500 planos de la Ciudad de México, p. 22-23.

WATER AND FLOODING

Because Mexico City was built on an island both blessed and threatened by the presence of water, it cannot be understood without understanding its fearsome relationship with water.

The Aztec's very concept of the universe and the world had to do with water. The land in the middle, which is surrounded by the water, was called Cemanahuác. The universe extended from the horizon in four directions where it finally met with and became one with water. Aztlán, from whence the Mexicas departed on their long pilgrimage to the island in the south, was also an island. Tenochtitlán was nothing more than a reencounter with the insular world where water and land have to be worked with in harmony. The city was erected on water and existed as a function of water. The great sin committed by the Spanish was to conquer a world that lived between water and land; they tried unsuccessfully to expel the water from the city. This would torment the colonial city (and even now continues to cause some problems).

In his pioneering work, Ángel Palerm[27] admirably describes the integrated system used to take advantage of the lake –its network of drains and channels, dam-roads, reservoirs with floodgates, and peripheral and urban irrigation ditches—which allowed the inhabitants of both Tenochtitlán and the lakeshore cities to confront, dominate and take advantage of this hydraulic world. The model, at its most advanced stage, allowed the Mexicas to water agricultural fields and to provide drinking water to the cities and to Tenochtitlán. Excess water was contained in the rainy season (although the system did sometimes overflow) and shortages were palliated in the dry season. The system allowed for the highly efficient production of food and vegetal material with chinampas.

This vast hydraulic system required, of course, continuous and specialized work and, above all, a strong authority capable of setting priorities, giving orders and seeing that these were carried out. This was made possible by the Aztec Empire's highly centralized and hierarchic structure, a fact which has led to discussions about whether the Mexicas could be

[27]A. Palerm & E. Wolf, *Mesoamérica...*, 1973.

yet another example of "Oriental Despotism."[28] What is clear is that an entire culture developed around its contact with the lakes. Dominated and worked on in relative harmony, the lakes' area accounted for the amount of available land and how urban space was organized around irrigation channels and chinampas; lakes would be indispensable for producing a large variety of foods on dry land such as corn, beans and amaranto and, on the chinampas, corn, herbs and flowers. As we saw previously, the lakes were also home to fish, crustaceans, molluscs, amphibians, birds, ducks and lakebed alga. Reeds and hemp were even used for making roofs, baskets, clothing and furniture.

Another dimension of life on the lakes of equal importance was transportation, which involved an incredible ballet of many thousands of canoes crossing the lakes to and from Tenochtitlán, a spectacle that amazed the Spanish when they saw this world from the pass in the volcanoes. In the great Tenochtitlán, there were two main forms of transportation: one could either travel on the perfectly laid-out roads with their walkways or by way of the irrigation channels which provided an efficient means of transportation for thousands of people and tons of merchandise, requiring neither the use of fuel or the emission of pollutants. Ironically, Cortés also understood the usefulness of the latter form of transportation and he therefore built brigs with superior European technology which he used effectively to fight the Mexicas during the siege of the island. Water transport, it should be recalled, was the fundamental mode of transportation for Mexico City up until the 19th century, when the railroad to Cuernavaca took its place.

Thus, transportation on the lakes allowed for interconnectedness and ties between Tenochtitlán and other urban centres, and between the different urban centres themselves. It constituted an incipient metropolisation of almost the entire Mexico Basin. The eastern door of the central ceremonial centre, the Tezcacoac door, gave onto the only avenue which did not lead to solid ground, but instead terminated at the port that looked almost directly out on the other great city of the Triple Alliance: Texcoco. Similarly, Chalco, Coyoacán and Xochimilco were *port* cities that constituted highly dynamic poles of development. The

[28]K. A. Wittfogel, *Oriental Despotism. A Comparative Study of Total Power*, New Haven: Yale University Press, 1957, 556 p.

Aztec Empire's progress was coordinated around the lakes and had an economic system whose central node was this highly efficient, sustainable transportation on the lakes. Undoubtedly, the most serious ecological problem for the Aztec city (which still persists 600 years later) was flooding. Due to the lack of natural drainage, the northern lakes of Zumpango and Xaltocán flowed into the lowest lake, Texcoco, which, in turn, flooded the island-city.

In 1449, Tenochtitlán experienced severe flooding. In response, Texcoco's King Nezahualcoyótl was entrusted by his Mexicas allies with the construction of a dyke that ran from south to north, which served to hold back the saltwater of Texcoco Lake, not only from the island, but also from the freshwater of Xochimilco-Chalco. The dyke or Albarradón of Nezahualcóyotl was perhaps the prehispanic city's most notable feat of engineering, with its floodgates, which regulated the flow of water and permitted water transport.

ECOLOGY AND AGRICULTURE: CORN, CHINAMPAS AND NATURAL AREAS

In a broad sense, it is easy to understand that the great city of Tenochtitlán had a sustainable environment system. Although it was necessary to import external resources, and materials it never was in excess of their regenerative capacity. Although there are no records on the matter, it is obvious from archaeological and iconographic information and writings from the conquest that the forests were not destroyed beyond their regenerative capacity and that the city was sustainable in terms of its use of fuel. Problems with water (as we saw previously) had to do with supply and flooding, not with shortages or depredating importation. It was common to recycle a number of materials such as human excrement, which was used as fertilizer. Trash, which was mostly organic, was deposited on distant lakeshores within the lake perimeter and this compost later served to expand land into the lakes and to build chinampas.

As we have seen, the Mexicas truly loved trees, flowers and gardens. However, the centre of their agricultural life was corn, which, as we mentioned, had been grown in the basin for several centuries; it was the basis of the diet and culture of the Mexicas and other lakeshore peoples. Despite the economic and cultural importance of corn on the island-city, and the high productivity of the chinampas, there was undoubtedly not enough corn produced there and thus it had to be supplemented with imports from lakeshore areas, along with other valued foods that were part of the Mexica's diet. However, due to their direct impact on the economy, life, and urban form, it is important to stress that corn was also produced on chinampas.

Although there is no way of knowing the area of forest in the basin that was cleared or disrupted by the Mexicas, it is not thought to have been significant since wood was not used except for the largest temples and houses. The extraction of firewood and the construction of canoes –which are said to have totalled as many as around 100,000 in 1519—surely affected the lower forested areas. The numbers, although considerable, do not point to a particularly alarming degree of deforestation. To the contrary, testimonies by the Spanish during the period of the conquest make reference to the enormous forested area surrounding the lakes and cities of the basin.

It seems the Mexicas favoured a painstakingly careful exploitation of forests.[29] Among the most important forest-gardens was the Forest of Chapultepec, a place central to the Mexica's life and water supply used as a recreation area even before the Aztec's arrival. There was also the forest of Iztapalapa, the pools of El Peñon hill and a number of others spots such as Tetzcotzingo, Yautepec and Oaxtepec to the south and Tulancingo to the north, that, although far away, were known and frequented by the Mexicas.

[29]J. Bojorquez 1950 and Garibay 1965 in Martínez González, Mexico, 1991.

But even within Tenochtitlán, there were numerous gardens, such as the one in Moctezuma's palace or New Houses, or those found in the menagerie and aviary. Undoubtedly, we also find here the notable influence of Nezahualcóyotl, who built the first botanical garden of the Americas in a town south of his dominion in Tezcotzingo. He brought many species from far-off areas, especially the majestic swamp cypress (*Taxodium mucronatum*), which was planted to form dense, leafy groves. We also saw that houses of nobles had gardens, even on rooftops, and commoners had gardens with flowers, elements which played an important part in the ritual life of the Mexicas and other peoples in the basin, especially in Texcoco. Additionally, the use of herbs by the Aztecs and the inhabitants of Texcoco were varied and widespread. All this speaks of their advanced botanical knowledge and a deep respect for the abundant vegetal world that surrounded Mexica life.

If there is something fundamental to understanding the ecology, agriculture, demographic dynamics and urban form of the great Tenochtitlán, it would be the marvellous chinampas that are reported to have produced more than 50,000 tons of corn per year, not to mention the other crops.[30] The chinampas were not, as they are erroneously described, "floating gardens," but a type of large pot of earth or artificial island fortified with palisades, lifted up on top of the water with reeds and poles and then covered with humus and dirt until it rose above the shallow lake (see Figure 3.1). In order to consolidate the land, trees such and the bonpland willow (*salix bonplandiana*) were planted. The chinampas tended to be rectangular; although their sizes differed, they were commonly between 5 and 10 metres wide, with a variety of lengths that depended on the site and its characteristics. Humidity was always necessary. For example, a typical chinampa lot in Xochimilco varied between one and two hectares. The chinampas required a great deal of work and constant drainage and maintenance. They were perfectly *sustainable* since they used local organic material that was employed over and over in a cyclical fashion. They could be harvested several times per year thanks to the humidity and richness of the lakebed soil. On the island they served to increase the types of available food, flowers and plants, while on the lakeshore

[30]W. T. Sanders, The population of the central Mexican Symbiotic Region, the Basin of Mexico and the Teotihuacan Valley in the Sixteenth century. In *The Native Population of the Americas in 1492*, edited by W. M. Denevan, WI: University of Wisconsin Press, 1976.

they were principally used to increase food production. There were several thousand hectares of chinampas, which was undoubtedly a fundamental factor in harmonizing the basin's ecology with man's needs in such a way that the abundant forests were neither destroyed nor diminished.[31]

[31]W. T. Sanders, *A Prehispanic Irrigation System Near Santa Clara Xalostoc in the Basin of Mexico. American Antiquity*, 42(4),1997, pp. 582-588.

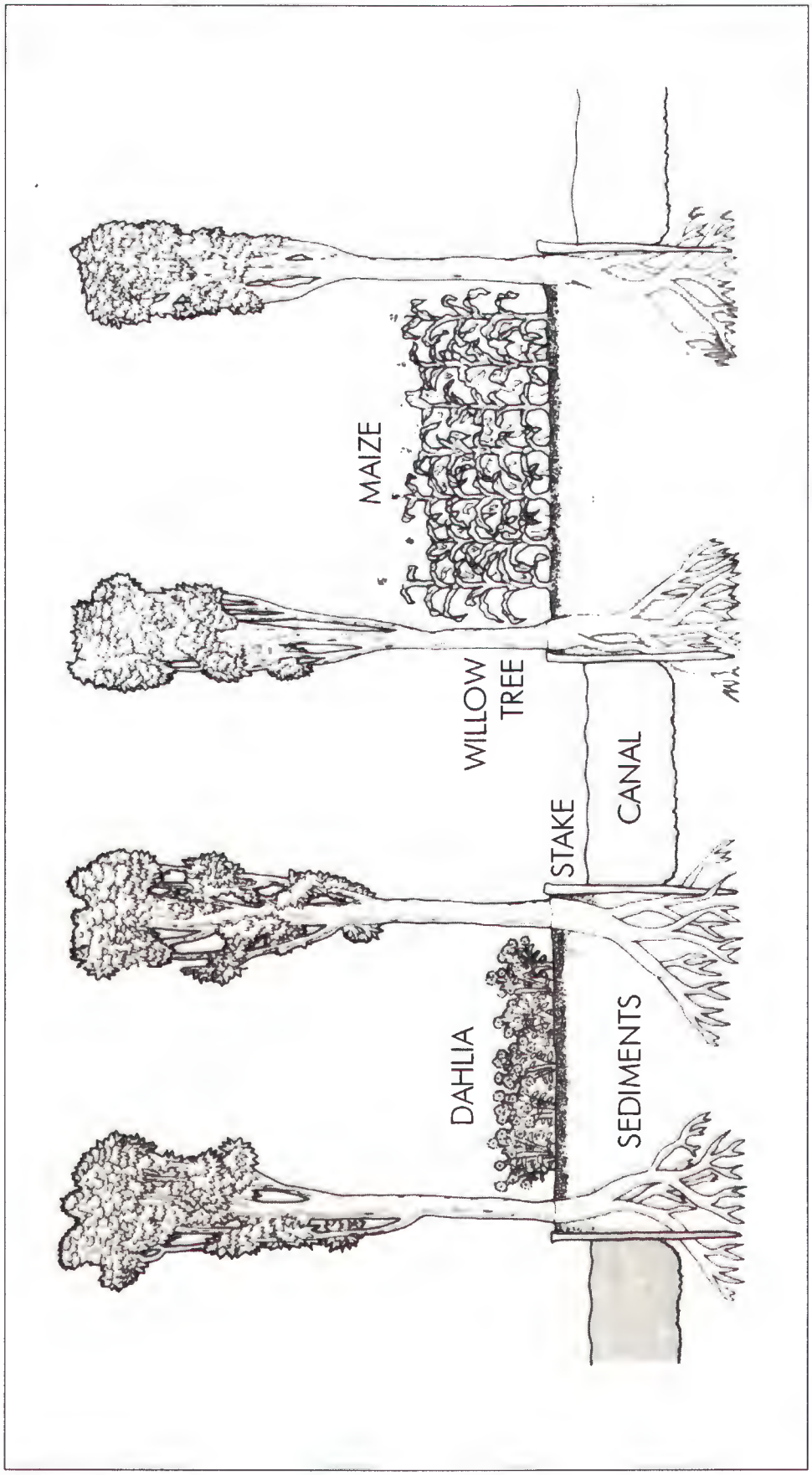

Figure 3.1. The Chinampas.
Source: Own elaboration based on Sabloff, p. 126-127.

3.3 The Spanish Conquest as an Ecological Disaster

In history, there are few greater tragedies than the Spanish Conquest of Tenochtitlán. It was a tragedy, as well as a demographic and ecological debacle. It was the abrupt, brutal end of one civilizing vector by another: Aztecs and Spanish.

The conqueror Hernán Cortés landed in Veracruz in April of 1519 (after numerous expeditions along the south eastern coast of Mexico). Here he began to come into contact and become familiar with the Mexicas first hand, since he was already in the Aztec Empire's territory and was received peacefully by a few emissaries. Cortés later subjugated and allied himself with groups that paid taxes to the Mexicas and harboured ferocious resentment towards them; he therefore made these groups his vassals and allies as part of his plan of conquest. Cortés and his indigenous allies entered the Mexico Basin from the east, using the pass between the Iztaccíhuatl and Popocatépetl volcanoes. From this elevated position, his men contemplated with stupor and fascination the view of the Mexico Basin, encircled in dense forests and high mountains, a few covered in snow. They saw the basin's lakes and glimpsed, in its centre, the splendid city of Tenochtitlán, whose buildings, especially the towering pyramids of the Templo Mayor, would have stood out. They observed the heart of ancient Mexico, as we said. From the exact opposite point as the Aztecs when they looked at the basin from the Chapultepec Hills.[32] At that time the Aztec Capital may have had a population of 200,000.[33] It was much larger than any other European city at that time (it was, in fact, one of the largest cities in the world) and its order, lushness and harmony made it incomparable. The conqueror-chronicler Bernal Díaz de Castillo gives an account of that moment in his classic *Historia Verdadera de la Conquista de la Nueva España* (True History of the Conquest of New Spain):

> '(...) When we saw all those cities and populations built on the water and other large towns erected on solid ground and the straight road on the water which went to Mexico, we felt admiration and said that it looked liked the enchanted

[32]H. Thomas, *The Conquest of Mexico*, London: Pimilco an imprint of Random House, 1994, p. 268.
[33] It is most likely that the population of the Mexico Basin was around a million and a half people; made-up of populations connected by the system of lakes, and since then has become one of the most dense and populated areas of the world.

> things they tell of in the book Amadís, because of the large towers (temples) and buildings that they had in the water and all made of lime and pieces of stone(...). I never tired of appreciating the diversity of trees and the aroma which each one gave off, and the paths full of roses and other flowers, and many fruit trees and flowering bushes and freshwater ponds(...).'[34]

On November 8, 1519, the Spanish entered the south-eastern side of the capital on the Iztapalapa road. Upon reaching the island, they were received with pomp and fanfare by Aztec dignitaries, and not much later, by the Emperor Moctezuma himself. Moctezuma II, a fatalistic, indecisive man, did not doubt Cortés' superiority –he may have even thought that he was the very same Qutezlacoátl, whose return had been prophesized. He soon renounced his divine condition and capitulated de facto before Cortés, who went on to hold Moctezuma prisoner in his own palace. The Mexicas rebelled, however, after suffering the Spaniards cruelty and the desecration of their temples and gods. Moctezuma died tragically on June 30, 1520, possibly at the hands of the Spanish or by his own rebelling people, who may have stoned him. The Spanish were about to be defeated by the Aztecs under the leadership of their new emperor, Cuitláhuác, until they beat a hasty retreat. They soon returned to definitively surround and attack the Aztecs. By then, the local population had been devastated by another European enemy: smallpox. The disease killed thousands of people, including the emperor. Thus, Cuitláhuác was succeeded by the young, fierce Cuauhtémoc. Cortés, who had formed alliances with all the surrounding towns, decided to lay siege to Tenochtitlán and in May of 1521 he cut off the water supply from Chapultepec by destroying the aqueduct. He blocked food from entering the city and he attacked the island on numerous occasions from small brigs carrying thousands of indigenous allies, hailing mostly from Tlaxcala. Aztec positions were destroyed, but fighting continued; the commanders led by Cuauhtémoc put up uncommonly fierce resistance.

[34]B. Díaz del Castillo, *Historia Verdadera de la Conquista de la Nueva España,* Madrid: Espasa Calpe, 1928, 2 vols., 537 y 629 p.

The cruel, terrible siege of Tenochtitlan lasted almost 80 days, by which time disease and the lack of food and water began to wipe out the Aztecs and destroy their moral.[35] Finally, on August 13, 1521, after a final, brutal assault like few others in history, the great Tenochtitlan fell and Cortés took Cuauhtémoc prisoner. The emperor was held in prison for four bitter years until 1525, when Cortés ordered his hanging as the result of an accusation of inciting a new rebellion. This rebellion was literally planned by the Spanish. They blocked the Mexicas from regrouping and entrenching themselves by filling in ditches and channels to allow for the use of horses, tearing down bridges and finally destroying temples, palaces and houses. This caused enormous damage to the complex, hydraulic ecology of the city. However, it is worth mentioning that the Mexicas in their defense also contributed to this destruction when they decided to burst open the *Alabarradón de Nezahualcóyotl*, causing the flooding of Iztapalapa –with salt water! Although their intention was to annihilate the Spanish offensive, they did not succeed. They also used the stones from the dams and channels to block the enemy from entering the central areas of the city. The most noteworthy act of destruction was their deliberate removal of parts of the wall of the Alabarradón de Nezahualcóyotl to allow brackish water to flood the city and to ruin the chinampas.

In the fight for Tenochtitlan, perhaps as many as 140,000 indigenous people died (70% of the population!), while probably a scant 100 Spaniards perished. The beautiful Aztec capital was totally destroyed, having been burned to the ground. Practically all the indigenous survivors were forced out and moved to the towns along the lakeshore. The Spanish set up temporarily in Coyoacán. The island was at this time inhospitable and unhealthy, since after August 13, 1521, desolation and death prevailed there. That date marked the complete disarticulation of the Aztec Empire. The chronicler Díaz del Castillo wrote:

> "(...)but today [after August 13, 1521] all that I saw then has been torn down and destroyed; nothing is left standing(...)."[36]

[35]H. Thomas, *The Conquest of Mexico...*, pp. 503 y 528.
[36]B. Díaz del Castillo, *Historia Verdadera de la Conquista de la Nueva España*

Thus the city of Tenochtitlan is and forever will be the central stage of the history of Mexico, where one civilization obliterated another. The centre of the prehispanic indigenous world and the jewel of 2,000 years of prehispanic urbanism were reduced to rubble. However, on the very same spot, the Spanish city was built --Mexico City-- and there began the colonial world that would last close to 300 years, even longer than the Aztec Empire.

Thus, the destruction of the island-city of Tenochtitlan –which depended on and was the centre of a great empire estimated to encompass a tribute excise area of over 300,000 square kilometres-- caused the irremediable disruption of the vast Mesoamerican world. After the great discontinuity of the conquest, came the lengthy colonial period which would paradoxically last 300 years, longer than the very same Aztec Empire.

3.4 The Viceroyalty Capital of New Spain: 1521-1810

Over the ruins of the city that he and his men had themselves destroyed, Cortés decided – although with some doubts and after being advised to the contrary by his captains —to build the city that, over time, would go from being called the City of Mexico-Tenochtitlan to just Mexico City.

" ....With a beautiful surrounding countryside, places to visit, recreational and comfortable areas, vegetable gardens, farms, mills, forests....tree-line streets, gardens, various species of plants and beautiful ripe fruit...this great city has streets of water which due to the people's ability, are interconnected...crossing their thousand wide streets are beautiful channels that have crystalline serpents turning around and around delightfully...'[37]

Cortés, a renaissance man, designed the most modern city at that time, taking advantage to a large degree the ample, rectangular design of the Aztec city centre. He was advised by his captains to build instead on solid ground, perhaps in what were the lakeshore towns of Coyoacán, Tacuba and even the city of Texcoco to the east, where there would be less risk of flooding, and, at the same time, water would be more accessible. But Cortés made his decision based on military considerations (the fortified island-city was a fortress) and for

[37]B. Balbuena, *Grandeza Mexicana*, México: Colección Popular, 1974, p. 81.

reasons of statehood and prestige: the Spanish, Christian city erected on the ruins of the heart of the old empire was the best possible symbol of the new, irreversible political situation of dominance. Cortés himself stated in his *Letters of Relation* that on top of the ruins of the great Aztec capital "another on an even greater scale would be rebuilt."[38]

3.4.1 The XVI Century

Basic reconstruction was carried out relatively quickly; it was said to have taken almost two years. Thanks to the efforts of indigenous workers, the new city was designed and erected with Spanish buildings standing where Aztec palaces and temples had stood not long before.

The basin's environment started to change noticeably and irreversibly from the beginning of the first years of the Colony.

> The construction of the new city, which began in 1524, consumed an enormous amount of wood for framework and piles. [Trees] were destroyed then, and continue to be destroyed on a daily basis, without planting anything new (...). The lack of vegetation leaves the soil exposed to sunlight, and the humidity that had not been lost by filtration through the light, porous basaltic rock, quickly evaporates and dissolves into the air, when not even the leaves of the trees or the density of the grass defend the soil from the influence of the sun and the dry, mid-day winds. Due to the fact that the same conditions exist throughout the valley, the abundance and circulation of water has visibly diminished therein. Lake Texcoco (...) currently receives much less water by infiltration than in the 16th century since the decomposition and destruction of the forests has the same consequences everywhere.[39]

[38]H. Thomas, *The Conquest of Mexico...*, p. 652.
[39]A. De Humboldt, *Ensayo político sobre el reino de la Nueva España*, citado en J. L. Lezama, Degradación del medio ambiente, *La Ciudad de México en el fin del segundo milenio...*, pp. 449-450.

The progressive introduction of horses and livestock from Spain (cows, sheep, goats and pigs), extensive grazing (which had already brutally eroded Castilla and other regions in Spain), and a new cultivation method (which revolved soil) to grow European crops such as wheat caused changes not only to agriculture and the natural landscape, but to transportation as well, since many of the Aztec's canals were filled in with dirt to build streets and permit the use of carriages and horses. Additionally, an enormous number of chinampas were destroyed, especially in the centre of the island. Forests were cut down to open up agricultural land for the cultivation of grains and to supply wood for the construction of the city. Not long afterwards the gradual desiccation and evaporation of the lakes began (especially to the west of the island). These measures and the obstruction of the canals disrupted the island's delicate environmental-hydraulic balance with the lakes, and had an incalculable environmental impact on the city that would last for centuries. Furthermore, the cutting down of the forests around the perimeter of the basin increased the amount of superficial runoff caused by the abrupt and abundant summer rains, worsening soil erosion on one hand, and flooding on the other. The best possible indication that the conquerors never understood the idea of the delicate environmental balance of the lake basin was their obsession with draining the basin from Zumpango in the north (since it was at a much higher elevation and had better outlets). It was not only the principle cause of public expenditure, but one of the biggest sources of grief for urban dwellers throughout the three hundred years of the colonial period.[40]

However, it is worthwhile to delve further into the subject of deforestation and other types of environmental damage to avoid the error of exaggeration or misrepresentation. The first point that should be made is that a large-scale demographic debacle immediately followed the conquest in which perhaps as much as 90% of the indigenous population was wiped out by small pox and other diseases brought from Europe and Africa by the Spanish, and to which indigenous groups had no immunity.[41] To some degree, this demographic decline

[40]It's worthwhile to consult Humboldt's classic, *Ensayo político sobre la nueva España*, which contains a good description of taxation and spending during the period. A. Humboldt, Freiherr Von, *Ensayo político sobre la Nueva España*, 2ª edición, estudio preliminar de J. A. Ortega y Medina, México: Porrúa, 1966, pp. 539-544.

[41]S. Cook & W. Borah, The rate of population change in Central Mexico, 1550-1570, *Hispanic American Historical Review*, 37(460), [S.I.]; S. Cook & W. Borah, The aboriginal population of Central Mexico on the

postponed the necessity for more land and for further destruction of forests. The second point is that there was a reciprocal adaptation of both the traditions of agriculture and livestock to Mexico's environmental conditions.[42] Even in the construction of the Spanish city, not only were the large, open spaces of the ceremonial centres preserved, but the Arab and Spanish tradition of interior patios and gardens where flowers and plants grew was harmoniously incorporated.[43]

The reconstruction of the city began in earnest in the beginning of 1522. Cortés personally decided which lands to assign and where new public buildings should be built (something for which he would later be severely criticized, since he obtained the best places for himself and those close to him, such as the palaces of Axayácatl and Moctezuma). Cortés' ideas were carried out by one of his soldiers, Alonso García Bravo, who improvised as a land surveyor, and whom Cortés asked to develop the plan or design of the city. This modest soldier from Ribera, who had arrived in 1520 to fight with Cortés, was unexpectedly made the first (and therefore inevitably) the most influential urban planner in the history of Mexico.

García Bravo's design was, of course, inspired by Spain, although with the city centre and the main streets he followed the indigenous plan. The new city's central quadrangle was reserved for the Spanish (the so-called Spanish Republic) and the peripheral areas were left for indigenous people (the Republic of the Indians). In his interesting and perceptive analysis, Manuel Sánchez de Carmona[44] challenges the idea that the inspiration for Mexico City had roots in the renaissance vision and indicates that the orthogonal form or grid comes from the old medieval tradition, in turn deriving from the Greco-Roman tradition. This may be, although the inspiration for a classic, monumental city with wide streets has undeniable renaissance origins. Carmona also confirms that the Spanish design was based

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eve of the Spanish conquest, in *Ibero-Americana*, 45(88), [S.I.]., en H. Thomas, *The Conquest of Mexico*..., p. 610.

[42]A. G. Aguilar, *et. al.*, The Basin of Mexico, in *Regions at Risk: Comparisons of Threatened Environments*...., p. 322.

[43]E. Ezcurra, *De las chinampas a la Megalópolis. El Medio ambiente en la cuenca de la Ciudad de México*..., p. 40.

[44]M. Sánchez Carmona, *Traza y Plaza de la Ciudad de México en el siglo XVI*, México: Universidad Autónoma Metropolitana Atzcapotzalco, 1989, 140 p.

on two original elements from Tenochtitlan: the Aztec's main streets or avenues and the ceremonial centre's large open space. Curiously enough, the Spanish fear of an indigenous rebellion caused the Hispanic population of New Spain to frequently ask the Spanish monarch for permission to build a wall around the city, a petition that was never granted. According to historian Edmundo O'Gorman, "Mexico enjoys the glory of being the first open city in the history of urbanism."[45]

In effect, few countries had the opportunity to influence the urban design and layout of more cities than imperial Spain. During the colonization of Spanish America, literally hundreds of cities meticulously followed the orthogonal form of the design of the Spanish city (see Figure 3.2). Mexico City was, of course, the largest of them all. Urban form and space were progressively hispanized, interwoven with some indigenous elements, which, by the way, were slowly being segregated to the margins of the city. The dichotomy of the of the Spanish Republic and the Republic of the Indians meant that the city centre was for the Spanish and the peripheral areas for Indians. This profoundly affected the occupation of spaces, the landscape itself, and social and economic life. It is not an exaggeration to say that this separation is one of the most important origins of the inequality that exists in Mexican society today.

The Spanish orthogonal design or grid had straight streets that formed blocks, which in turn formed trapezoidal or rectangular groupings of houses. It is, of course, important to point out that another great Spanish element was the Plaza Mayor, and that Mexico City's plaza was the largest and most monumental in the entire Western Hemisphere. The Plaza Mayor was the vital symbolic centre of the city, and, according to the grid theory, it was the element which generated the rest of the urban design. Beginning with the Plaza Mayor, blocks of equal size were designed, and in these orthogonal house groupings and smaller plazas were arranged.

[45] See M. H. Romero, *Enciclopedia Mexicana del Turismo* ..., p. 242.

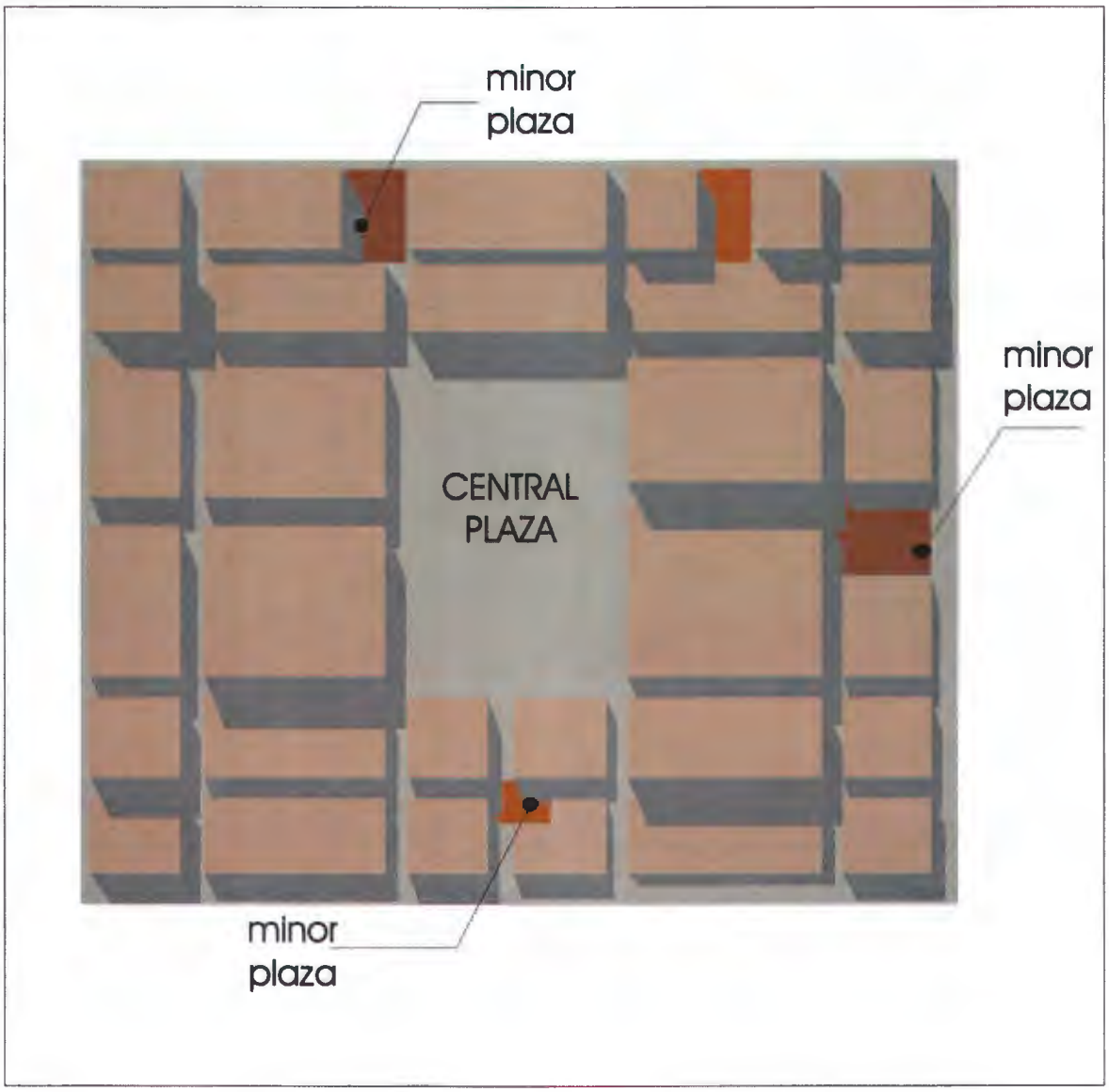


Figure 3.2. The "Mallorquino" Orthogonal Spanish City Model.
Source: Own elaboration based on García Ramos, p. 68-72.

For Mexico City's design, the aforementioned orthogonal plan was used, which was based on blocks of fairly regular length (and house groupings with about the same area) and a rectangular road system. The arrangement was based on the Mallorcan ordinances of the year 1300 of James II of Mallorca, who defined a perfectly quadrangular city, which, it is worth noting, was used in Mexico and not Spain.

The Mallorcan ordinances may in turn have been directly inspired by the Theoretic City of the Franciscan priest Eximensis who in 1383 proved to be a step ahead of Italian Renaissance cities with his central symmetry and work towards designing a city with ideal proportions. In turn, the ordinances of Phillip II (1573) were an exceptional document on urban planning in the tradition of Spanish theorists. But it was not very relevant for juxtaposing the Spanish city and the Aztec city of lakes, whose urban form would be affected from the beginning and would turn out to be highly original.

> One must not forget the circumstance of it being an island, and in good part, a lake City whose channels and irrigation ditches made its definition as the *Venice of the New World* irresistible, nor should one ignore the heritage of the old indigenous City, which left its mark on the design of the new City, or the survival of the aqueduct that brought water from Chapultepec, or much less the legacy of the spirit of indigenous urbanism that is expressed in the audacious and intrepid dimensions of the Plaza Mayor and the open spaces that Hernán Cortés, in emulation of the Mexica princes, reserved as such.[46]

Unfortunately, despite the existence of the *Maguey Paper Code*[47], we do not have enough information to exactly follow the evolution of the design or the exact transition between the Indian and Spanish city, although existing recorded data does allow us to make an acceptable approximation.

Thus, according to the orthogonal theory, in the centre of the island, on top of the ruins of the ceremonial centre, space was assigned to the cathedral, which represented the supreme symbol of the new religion, and the Palace of Cortés, which functioned as the supreme symbol of political power and was built where the Palace of Moctezuma once stood. Even

[46]M. H. Romero, *Ibid.*, pp. 242 y 243.

[47] The name of this code is the Mendocino Code, probably the most important document related to the foundation of Tenochtitlan: a transcription was ordered by the Viceroy of Mendoza.

today Mexico is still governed from this very spot, which is now the National Palace. After this initial layout was established, space was allotted for monasteries, markets, a prison and hospitals. Smaller plazas were designed (fortunately the one in Tlaltelolco was preserved).

More of the Spanish central quadrangle was dividing up into groupings of lots to be sold to the highest bidder, upon which important buildings had to be erected. With this policy, not only was money raised to carry out further construction, but the monumentality of the city was guaranteed. Thomas[48] describes the lively discussions between Cortés and his men about where to locate the public granary, fountains, small squares, and most importantly, bridges and roads, particularly those that connected the island with solid ground. Inspired by the Romans, García Bravo designed systems of running water and drainage for the city. Supplying the city with water would from then on be a municipal responsibility; it would be carried through tubes to the main buildings in the city centre, something which was not done even in Castilla.

Cortés' ambition to build a classic city, although with a Spanish urban design, was the reason behind the establishment of strict codes of style and uniformity for new buildings and the design of roads. Avenues were to be 15 yards wide. Some channels were made wider and deeper along with the streets that ran beside them, although in some cases they were filled in completely. The construction of the Mexico-Tenochtitlan road was a project of epic proportions because of its celerity and dimensions. It began in the city centre and was extended towards the periphery of the city, and included the reconstruction of the four indigenous "partialities" or neighbourhoods, which in themselves turned out to be very similar to those which existed in Tenochtitlan. Thousands of indigenous workers participated in the construction projects; despite the completely different, adverse conditions, they were homesick and therefore willing to return to Tenochtitlan, which had once belonged entirely to them. The twin city of Tlaltelolco was renamed Santiago Tlaltelolco, and its vibrant market was entirely recreated. Undoubtedly, no other project in the western hemisphere, or even in Europe, matched the magnitude of the one in Mexico City.

[48]H. Thomas, *The Conquest of Mexico*...., p. 561

The urban design of the early period of the colonial city is represented in an admirable map which is conserved in the University of Upsala, in Sweden (see Map 3.4). The map of Mexico City in the mid 16th century was commissioned by the Viceroy of Mendoza around 1550 and may have been executed by an indigenous painter. Its grid design reveals how the prehispanic design of the roads –which intersect in the centre of the map-- was preserved. Roads leading to solid ground were rebuilt, and the old Aztec aqueducts kept being used, interrupting the Spanish reticular design of the city. It is evident that life was still centred around the lakes in areas with indigenous inhabitants, especially in the east, where the reconstruction of prehispanic dams, chinampas and the traffic of canoes can be observed. The area of the city was not much larger than that of the Aztecs, except for its extension to the west. There were also signs that the lake was in an advanced stage of desiccation and Spanish houses had been built along Tacuba Road.

In the city centre was the Plaza Mayor, Cortés' houses (which would later serve as the palace of the viceroys), municipal and commercial buildings and the gray, incipient cathedral, which would be replaced a century later by the imposing Baroque structure we now know. The university was also built in this area.[49]

[49]According to María Elodia Terrés, the foundation of the Royal Pontifical University of Mexico was decreed in the Royal Dispatch of September 21, 1551, although its construction was not begun until the end of the century. Up until the 18th century the building had a renaissance style, although its façade was later changed to a Churrigueresque style, and then later to a neoclassical one. It was later destroyed by Justo Sierra. M. E. Terrés, *La ciudad de México. Sus orígenes y su desarrollo,* México: Editorial Porrúa, 1977, p. 50. Ver también, F. De la Maza, *La ciudad de México en el siglo XVII*, México: Fondo de Cultura Económica, [S.I.], vol. 2, p. 37.

Map 3.4. Year 1550. The Original Spanish City.
Source: Own elaboration based on 500 planos de la Ciudad de México, p. 43, Lombardo, il. XXII, and material provided by Ciudad Futura Desarrollo Urbano.

From the beginning, flooding represented the viceroyal capital's most serious problem. A particularly severe flood in 1553 forced the Viceroy of Velasco to order the reconstruction of the *Nezahualpilli* dyke, which was renamed San Lázaro. A number of irrigation ditches, small dams and dykes were filled in, thereby ceasing to function as part of the regulatory system. The viceroyal government stopped using the Aztec aqueducts and built their own. The San Cosme aqueduct was built over an Aztec one, and the Belén aqueduct (Arcos de Bélen) brought the greater part of the city's water from the springs of Chapultepec Hill. There were also several floods in 1580 and especially in 1604, when flooding in the city lasted for several days. The Spanish therefore came to see the necessity of building an artificial drainage system for the basin.

The social and economic segregation between Indians and Spaniards was evident from the beginnings of the colonial period. Indians settled in designated quarters known as "partialities," areas that had once been their neighbourhoods, the Aztec calpullis; here numerous Spanish churches, monasteries, and chapels were now being built. The Catholic church began in earnest to build numerous buildings: the regular clergy erected the impressive Convent of Santiago Tlaltelolco, where the Colegio de la Santa Cruz was established for indigenous people, while the bigger religious orders built the large convents of Santo Domingo, San Agustín and San Francisco. For nuns, the convents of Concepción and Santa Clara were built. For their part, the secular clergy was responsible for the cathedral (still under construction), the Parish of Santa Veracruz and several colleges, monasteries and chapels. The Jesuits, who were to play a decisive role during and after the colonial period, established themselves in Mexico in 1572 and built important colleges.

In order to understand economic and social life during the first decades of the viceroyalty, we should recall the demographic debacle that took place during those years, which Spanish immigration and the importation of black slaves did not come close to compensating. From 1576 to 1579, the indigenous population was further decimated by an

epidemic. The scarcity of labour led to the abolishment of the *encomienda*,[50] since it had been prohibited by the Crown for allowing innumerable abuses against indigenous people. It was replaced with a system of "distribution" of Indians, who were assigned by judges to those who demanded them for a determinate amount of time. The year 1574 marked the establishment of the office of the Magistrate which was to preside over the city council,[51] which from then on was subordinate to the Crown due to its status as the government of the Capital of the Viceroyalty of New Spain.

Despite the high death rate among the indigenous population, the city's Spanish and Creole inhabitants prospered notably because of the discovery of rich silver mines in the elevated plateau of northern Mexico. By the second half of the 16th century, New Spain was the largest producer of silver worldwide. In Mexico City silver was coined and warehoused and then shipped to Spain, an activity which attracted new waves of Spanish immigration to Mexico. By this time, Mexico City had a population 60,000 people of different races, and constituted the only true city in New Spain. The second most important population centre was Zacatecas, in the mining zone, which had a population of 5,000. The silver-trading ports of Veracruz in the gulf and Acapulco in the Pacific had even fewer inhabitants.

After the initial founding impulse of the 16th century, construction in Mexico City declined. It did not pick up again until well into the 17th century, at which time further development made the city more compact, since new house groupings were on average smaller. However, the city's original grid design was still well preserved.

[50]The *encomienda* was an institution born in the Antilles; with it, land was divided up between the conquerors. Its purpose was to fulfill the need for labor in the colony's and Crown's agricultural and mining businesses. In legal terms, it was a system of forced labor without salary. See: S. A. Zavala, *La encomienda Indiana,* Madrid: Junta para la ampliación de Estudios e Investigaciones Científicas, Centro de Estudios Históricos, Sección Hispana, 1935, pp. 1-2.

[51]The first Spanish city council in what was to be the territory of New Spain was established in Hernán Cortés' military camp in Villa Rica, Veracruz, the town being simultaneously founded at that moment. The second city council was founded in Segura de la Frontera, Tepeaca, in what is now the state of Puebla, followed by the one founded in Mexico City in Coyoacán. The city council was composed of town councilors, and was presided over by a First Mayor. The former were responsible for law enforcement and the internal government of the population. Bailiffs were responsible for issuing rulings. See M. H. *Enciclopedia Mexicana de Turismo...*, p. 206-207.

From this point on, the Spanish Crown issued communal property rights to the basin's indigenous inhabitants, outside the area of the city. They were given very humid and fertile lands, located mostly in the southern part of the Mexico Basin in Tláhuac, Xochimilco (whose intense tradition of agriculture and chinampas still continues today) and Chalco, and to a lesser extent in areas that are now part of the Milpa Alta and Tlalpan delegations. These indigenous communities are very old and have strong social cohesion, having had to fight for their lands since colonial times. Much later, these communities would become involved in conflicts with rich hacienda owners, especially in the era of President Porfirio Diaz in the 19th century, when the rich land owners tried to take away their land by invoking the liberal Lerdo Law.

3.4.2. The XVII Century

The 17th century is often referred to as the "century of depression" in New Spain, because of both a declining population and a general drop in mining production. It was also during this century that the environmental destruction begun during the conquest was consummated. This included deforestation, which was the result of a demand for wood used in construction and heaters, and the introduction of livestock and Spanish grains, especially the widespread planting of wheat, which made cutting down large portions of forests necessary. During those years, when colonial agriculture was in an incipient stage, the hacienda --one of the most powerful institutions of agriculture production and land ownership-- was established. This peculiar form of tenure carried out on very large estates would not only dominate the rural landscape of New Spain (until as late as the beginning of the 20th century), but would also constrain and determine the expansion of the cities.

One-hundred years after Hernán Cortés' founding of Mexico City, its urban form and surrounding landscape had changed notably. We are indebted to Juan Gómez de Trasmonte for his splendid painting of the capital around the year 1628, which provides a bird's-eye view of the city from west to east. The painting reveals the large-scale environmental transformation of the capital that took place during 100 years of viceroyalty. Perhaps the most notable change was the now marked desiccation of the lake, especially in the west,

where the city was now for the most part connected to Tacubaya. Much of the lake had turned into muddy ground that flooded during the rainy season. Large extensions of forest were levelled to provide wood for construction –especially to build roofs-- and for fuel. This in turn altered the hydraulic cycle and contributed to the drying up of the lakes.

The Spanish needed a great deal more wood than the Mexicas, and they enormously exacerbated the problem of deforestation in the Valley of Mexico. One immediate consequence was the erosion of exposed soil. When the strong summer rains came, soil was washed into the lakes, causing these to shrink, become even more shallow and evaporate more quickly. By the 17th century, the lakes had shrunk by an estimated one-third. Mexico City (and Texcoco Lake) had noticeably separated from the bodies of water to the north and south.

The evolution of the city's form over the 17th century gradually broke with the island of Tenochtitlan's semi-radial scheme, becoming a kind of peninsula towards the eastern side of the lake (see map 3.5). It remained compact and preserved its Spanish reticular design which included rectangular groupings of densely arranged houses; open spaces were to be found in the plazas and towards the periphery, in the indigenous neighborhoods. The regularity of city's urban form was broken only by the wandering course of the irrigation channels and the Indian huts clustered on their banks. The central nucleus became more compact and monumental. The cathedral[52] –which dominated the Plaza Mayor-- was the city's tallest building. On the eastern side of the plaza, the Palace of the Viceroys was erected, while, on its western side, shops and a fountain were built. To the south, there were houses, an irrigation channel and a corridor of shops.[53] It was the Church that undertook the greatest construction projects of the period, and not the Crown, as is commonly believed, since the functions of the former went beyond religion to include education, health and hospitals, and census taking. Many temples, convents, schools and hospitals were built. The

[52]According to Francisco de la Maza, the construction of the Mexico City Cathedral began in the 16th century, based on the plans of Claudio Arciniega, but in reality it was a project of the 17th century with changes to the primitive plans which made it a different building altogether. Construction began in the year 1573 and ended in 1680. F. De la Maza, *México en el siglo XVII...*, p. 40.

[53]S. Lombardo de Ruiz, Institucionalización de la vida colonial, 1600-1750, *La Ciudad de México en el fin del segundo milenio,* G. Garza coord., México: Gobierno del Distrito Federal, El Colegio de México, 2000, pp. 103-105.

Our Lady of Mercy and Carmelite orders were established during the period. The secular clergy focused on the construction of the cathedral and, towards the north, the temple and college of the Virgin of Guadalupe.

Drainage projects, along with the increased use of Spanish horses and cattle of burden to pull carts, meant the beginning of the end of transport on waterways, as canals and irrigation channels were being frequently replaced by new overland roads (cobblestone streets). This had a big impact on the urban form since new roads were built, including one to the west, one to the south and one to Chapultepec, beside which the aqueduct that brought water to the Falling Water Fountain was built.

In 1607, in the midst of another flood, the colonial government decided to begin the construction of the General Canal of the Valley of Mexico. The project was entrusted to the German engineer Heinrich Martin (who adopted a Mexican-sounding name, Enrico Martínez). He was one of the first to understand the damage the Spanish had caused to the basin's ecology, that deforestation and the consequent erosion of the surrounding mountains had caused enormous amounts of soil to wash down into Lake Texcoco, causing its level to rise until it was at least as high as the water level of the city. Thus, when torrential rains fell, flooding was inevitable. Martínez therefore proposed to create, for the first time in Mexican history, an artificial drainage system for the basin which would run towards the northeast. It was a titanic project for that time and incurred a great cost: this massive project, the largest undertaken by New Spain, was paid for with a special 1% tax on the value of property in the city. The first section was an open canal 6.4 kilometres long, followed by a tunnel through the Nochistongo hills 6.8 kilometres long. With these two segments, water was transported across the basin. Another section of open canal 6.6 kilometres long finally delivered water to the Tula River outside the basin. The canal was ready by 1608, although it was never completely finished and its maintenance was deficient, which led to the eventual blockage of much of the system.

In September of 1629, at the end of a particularly rainy summer, a storm dropped torrential rain for 36 hours in a row. The flood was devastating; the city was almost completely submerged in water, which reached almost two metres in height. The poor indigenous neighbourhoods were hit the hardest, although the Spanish also had to move to the top floors of their houses. Only the Plaza Mayor and the immediately surrounding area were spared. To make matters worse, the water did not recede at the end of the rainy season and the city remained partially flooded for five years (until 1634).

The following is a quote by an eyewitness, Father Alonso Franco, a chronicler who belonged to the Dominican order:

> The canoes were good for everything and were the solution and means for trading and transporting goods, and thus, in a few days, an infinite number of canoes and rowers converged upon Mexico. The streets and plazas were full of those boats and they were good for everything imaginable having to do with the supply of such a great republic; there was also work, which became a source of relief, comfort and recreation. A single canoe carried what was needed by many mules. It was common language for everyone to say: *now we move around in carriages*, because the poor and the rich paraded around the city restfully seated in canoes (...) In canoes the bodies of the deceased were carried to the churches and curious boats brought with much decency the Holy Sacrament to the sick. I saw the one from the Cathedral, very made-up and golden, its rug and chair in which the priest was seated, who was being shaded by another person with a silk parasol (...)[54]

The calamities associated with the flood were severe; epidemics and thousands of deaths led many to emigrate. There were discussions about leaving the city and moving the capital to the western side of the basin, an idea that was ruled out due to the enormous cost it would imply. Martínez was jailed in revenge, although in the end the drainage system was reopened following his instructions. The canals were widened and cleared and dams were reinforced.

The disastrous floods of the 17th century demonstrated from then on that the ecological model chosen by the Spanish was not sustainable. An environmental balance depended on conserving soil and filtrating rain in the perimeter of the basin, since this was the only way

[54]Franco Alonso, cronista de la Orden Dominica, citado en F. De la Maza, *México en el siglo XVII...*, p. 29.

to counteract the rising level of the lakes. Almost 400 years later, this matter continues to be relevant for Mexico City.

It is likely that during the 17th century Mexico City became the one of the most complex, racially mixed cities in all the world at the time. Colonial urban spaces were strictly regulated, with segregation depending on origin and race (Spanish, mestizo and Indian), castes (blacks and mulattos) social position and occupation. Similarly, there were rules for the land distribution of the buildings of the different religious orders. However, it should be noted that, unlike the previous century, the 17th century saw this stratification of social and economic life give way to a mixing of the different ethnic groups and social classes, which created a true urban mosaic and lent the city richness and diversity, especially in its central area.

Well into the 17th century, there were a number of stately houses and estates belonging to urban property-holders which reflected New Spain's growing prosperity at that time. On the other hand, more modest, semi-collective dwellings known as *vecindades* were a product of the 17th century, at times rented out by nuns' convents. [55]

[55] In the San Jerónimo Convent, worked the poet nun Sister Juana Inés de la Cruz, undoubtedly one of the best writers in the world during that century. She lived and died in the convent located in the south of the city centre. Her death in 1695 was caused by the plague that affected the colonial city during those years.

Map 3.5. Year 1650. The Colonial City.
Source: Own elaboration based on 500 planos de la Ciudad de México, and on material provided by Ciudad Futura Desarrollo Urbano.

3.4.3 The XVIII Century

Mestizo (creole) society reached its greatest moment of splendour towards the second half of the 18th century, when, as Octavio Paz would say, New Spain became the "other Spain," rivalling in wealth, power and architectural splendour with Spain which had been in decline for almost a century (see Map 3.6). By that time, it became evident that Spain depended more on Mexico for its rich mines of silver and other metals than Mexico on Spain. The Creole elite of Mexico City became increasingly powerful, and wielded enormous economic influence. The mining economy was at its zenith, and the haciendas achieved high yields in livestock and agriculture. The city became a centre for commerce and government, and, incipiently, a financial centre. All roads and types of transport went through Mexico City.

The Bourbon Reforms of New Spain (1762-1787) had a great impact on the city (and, similarly, on all the rest of Spanish America): the Spanish revitalization reached the Americas. The Bourbon Reforms involved an important component of administrative and territorial reform, which led to the creation of the *intendencias*[56] or departments, which would become the Federal States, although with some modifications made between then.

Some urban elements of the French Enlightenment were introduced in Mexico City. Avenues were broadened and parkways and gardens were built, although the city never lost its orthogonal Spanish form. Throughout New Spain, cities grew as a result of the economic boom and the notable recovery of the indigenous population. It was also a period of agricultural prosperity on the large haciendas (such as the Haciendas of Coapa, Mixcoac-Rancho de los Amores, La Condesa, La Teja and Clavería). A number of rich merchants (and members of the clergy) acquired haciendas on the outskirts of Mexico City and reaped sizable profits by supplying the city with corn and the alcoholic beverage *pulque*, thereby

[56]There were a number of objectives behind the introduction of intendencias during the Bourbon period. On one hand, they were to make the functioning of the state uniform, improve the administration of real income, make taxation more efficient and foment the economy. However, the real concern was to increase the Crown's income. See R. H. De Gortari & R. Hernández Franyuti, *La ciudad de México y el Distrito Federal. Una historia compartida*, [México]: Departamento del Distrito Federal, Instituto de Investigaciones Dr. José María Luis Mora, 1988, pp. 1-2.

becoming part of the caste of great hacienda owners.

With close to 120,000 inhabitants, Mexico City continued to be the largest city on the American Continent and one of the largest in the world. The bureaucracy of the viceroyalty required a number of buildings throughout the city, especially toward the second half of the 18th century, when the Crown grew in power with respect to the Church. Government buildings such as the Real Aduana and the Real Casa de Moneda, whose construction began in 1731, were as grand as religious buildings and the estates of the wealthy.

We directly quote the chronicler Juan de Viera:

> (...) To talk about their offices, their foundries, their yards, their mills, their writings, it would take a book just to scratch the surface of all their content. In this house is the Real Tribunal de Moneda (...) inside live all the ministers of said Tribunal, each with a dwelling so proportionate that each one seems a palace, especially the one belonging to the superintendent, which is so magnificent, that his Excellency the viceroy does not have it; the traffic in this house is such that in its offices and foundries, the most carefree onlooker is bewildered (...).[57]

Similarly, the Royal Gun Power Factory and the Royal Tobacco Factory (today known the Ciudadela) were built. These manufacturing buildings were enormous compared to others of the period. They were the principal factory installations of the time and provided employment for thousands of workers. Later, the Plaza de Toros or bullfight arena and the park known as La Alameda[58] were opened. This period also saw the construction of the Royal College of Mines, which was built to further the development of mining, a highly important activity during at the time, the Botanical Gardens (in Chapultepec) and the San Carlos Royal Academy of Fine Arts for the development of the arts and trades, which was set up in an adapted building that was once a hospital.

[57]J. Viera, *Breve y compendiosa narración de la Ciudad de México*, trascripción de B. Montes y Amado, México: Instituto Mora, 1992 [facsimilar del año de 1777], pp. 43 and 45.

[58]According to Romero, La Alameda was built on what was once a humid, unhealthly parcel of unused land. The construction was ordered in 1592 by Viceroy Luis de Valasco. Its design bordered the San Hipólito market. M. H. Romero, *Enciclopedia del turismo Mexicano...*, pp. 340-341.

Map 3.6. Year 1720. The Mature Colonial City.
Source: Own elaboration based on material provided by Ciudad Futura Desarrollo Urbano.

The intricate and sumptuous Baroque architectural style typical of the end of the 17th century and the beginning of the 18th began to give way to a neoclassical style. An interesting case is the Metropolitan Cathedral, which, without losing its Baroque characteristics, was partially reconstructed and given a new Baroque styling known as Churrigueresque, followed by a neoclassical style. By the end of the 18th century, it was the largest church in the western hemisphere. The university also took up space in important buildings in the city centre. During this period, the city's basic orthogonal-reticular design did not change substantially; it only grew and became denser. It had a centre and its neighbourhoods, but it continued to be a typically Spanish city. By the mid 18th century, the city's compact form was similar to a rhombus since it expanded towards the north and south along its original roads.

The Crown cleared the plazas and streets of the peddlers who set up there (the equivalent of today's street vendors), winning back these areas for public use. New buildings separated living quarters from areas where other activities were carried out, gradually but definitively changing the use of urban space. The city established waste collection services that only reached the Spanish and mestizo neighbourhoods; streets in the city centre were made of cobblestone. The urban physiognomy was improved by the opening of public recreation areas such as the one on La Piedad Road and the parkways of Bucareli, La Alameda and Revillagigedo, which was located at the entrance of the still-functioning La Viga Canal. As was noted previously, in architecture, Baroque was replaced by the neoclassical style, which came to be used in all the city's new buildings.

Slowly, the government took over many of the clergy's administrative functions. In 1768, the city adopted a new type of territorial organization, dividing into eight large sections and 32 smaller ones, which were in turn divided into house groupings (still reflecting the original Spanish orthogonal design) (see Map 3.7). The larger sections were put under the charge of councillors, while the smaller sections were headed by neighbourhood officials. The first census carried out in 1790 counted 111,067 people, and, with its margin of error

of 15%, the official number was set at 129,000.[59] Of these inhabitants, more than half were of Spanish origin, a forth were indigenous and the rest were mestizo or mulatto.

The two modes of transport–by water and over land—continued to reflect the dual conditions that had existed since the founding of the capital of the viceroyalty. Water transport, which was mainly used by indigenous inhabitants, allowed for travel by way of irrigation channels and canals, which continued to decrease in number. They crisscrossed the city as they had three centuries before, connecting the city with areas such as Chalco, Xochimilco, Mixquic and Iztacalco, and other subsisting lakeshore communities. Canoes, ships, barges and rafts were used, especially on southern lakes such as those of Xochimilco and Chalco, which were still quite large.

[59]S. Lombardo de Ruiz, Origen y evolución de la Ciudad de México: siglos XVI, XVII, XVIII y XIX, en *La ciudad de México en el fin del segundo milenio*..., pp. 94-97. These numbers can vary from other authors, like Grijalva, who did his own estimations. See M. M. Grijalva, *El mundo novohispano*, México: El Colegio de México, Fondo de Cultura Económica, 2001, p. 61.

Map 3.7. Year 1780. The Bourbonic City.
Source: Own elaboration based on 500 planos de la Ciudad de México, p. 106-107.

Public transport made an incipient appearance with a small number of carriages for hire. These so-called "cars of providence" parked in pre-assigned spots and provided service on the avenues and the few cobblestone streets within the central perimeter of the city.

The problem of flooding and water supply continued, although to a lesser extent than in the previous century. In 1769 some groups formally spoke out against the progressive draining of the lakes and demanded that this practice be abolished. A few voices among them, such as that of José Antonio Alzate, proposed the implementation of "a canal regulator," although they wanted the lakes be maintained.[60] As would be the case with Miguel Angel de Quevedo a century and a half later, these groups were defeated by those who fought to eliminate the lakes and their natural ecosystem.

The old drainage system to the ancient town of Huehuetoca, to the north of the city, became ever more inefficient in preventing large floods. Once a drainage tunnel dug in the previous century collapsed, it was widened and reopened as an open channel known by the name the Nochistongo *Tajo* (slice). The project was not completed until 1788. Work on the drainage projects continued, since the problem had not been entirely resolved.

Diego García Conde is credited with the plan of the now mature city of the viceroyalty (1793). One notes that its urban form was still compact and orthogonal, with the Plaza Mayor in its dense centre, functioning as the nucleus of social and economic life in the metropolis. It was in this part of the city that the houses of greatest value, commercially and architecturally, were located. In concentric rings, houses declined in value and architectural importance as one moved away from the city centre. By this time, one observes the incipient design of a classic Latin American city, a function of the urban theories of the Chicago School. It is also apparent that the lakes continued to recede, especially after the completion of the Huehuetoca Canal (1788). The urban form was like a rome star, whose expansion "is channelled by the access roads and has spaces in between these (...)"[61] A

[60]E. Ezcurra, El ecosistema Urbano, *La Ciudad de México en el fin del segundo milenio*, G. Garza coord., México: Gobierno del Distrito Federal, El Colegio de México, 2001, p. 450.
[61]Lombardo de Ruiz, Origen y evolución de la Ciudad de México: siglos XVI, XVII, XVIII y XIX, en *La ciudad de México en el fin del segundo milenio...*, p. 112.

system of tollbooths was set up around the city (which were soon overtaken), defining its formal limits. From here, there were roads with limited access due to trees. It was during this period that the Crown began to invade the land of the Indian partialities by erecting buildings and opening roads.

Between 1789 and 1795, the ambitious, authoritarian Viceroy Revillagigedo, a man imbued with the rationalist ideas of the Illustration of the Bourbon era, achieved an ambitious urban transformation of the city, particularly of the Central Plaza. He ordered the elimination of old walls, which were substituted with posts and iron chains, and did away with three depressing fixtures: the gallows, the pillory and a column that was to be used for a statue of King Ferdinand VI. Finally, he had the plaza made level (a fortuitous command that led to the discovery of archaeological artefacts buried underground such as the Aztec Calendar and the Stone of Sacrifices).[62] At the close of the 18th century, the so-called "very noble, loyal and imperial Mexico City" experienced a period of economic prosperity and urbanistic splendour that could only be compared to the final years of the era of Porfirio Díaz, some one hundred years later (see Map 3.8).

The splendour of the Creole bourgeoisie made the colonial world's immense disparity evident. The middle class was small, and, in reality, beside the ostentatious palaces, the numerous indigenous inhabitants and members of the castes lived in miserable shacks made of straw and adobe, without adequately designed roads, and, of course, without garbage collection, running water or drainage. Drinking water was scarce. There were only 28 public fountains in the city which received water from the two aqueducts connected to the springs in Chapultepec and Sierra de las Cruces. In years of drought, corn and other foodstuffs were in short supply in the city and the poor suffered from famine and disease. Public health was nonexistent. The foundations of a very unequal society were laid then. Mexico City was, since the time of its founding, the clearest example of Mexico's formidable inequality.

[62]M. H. Romero, *Enciclopedia Mexicana de Turismo...*, pp. 322-323.

Map 3.8. Late 18th Century. Separation of Mexico City and Texcoco and the Lakes.
Source: Own elaboration based on Messmacher, p. 58.

3.5 The Capital at the Time of Independent Mexico: 1810-1876

At the beginning of the 19th century, it was not easy to foresee the end of the colonial world. The Creole elite that governed New Spain from Mexico City was at its apogee. But in 1810 the War of Independence of Mexico was to begin and would not culminate until 1821. Many of the immediate causes of independence were rooted in Spain's problems more than in Mexico's. In 1808 French troops invaded Spain and made Carlos IV abdicate in favour of his son, Ferdinand VII. However, the latter was soon taken prisoner and forced to hand the Spanish Crown to Napoleon Bonaparte's brother, José or "Pepe Botella," as he was known in Spain and Mexico. Throughout Spanish America, colonial authorities and elites debated about who should govern, considering that Spain herself had been subjugated by France. In Mexico City, Viceroy José de Iturrigaray was asked to govern in the name of Ferdinand VII, although this was done by a group of notables dominated by Creoles. This pitted the Spanish (known as *gachupines*), who wanted no change whatsoever, against the Creoles, who in time favoured independence. The Spanish were able to impose their will temporarily, but in 1810 the priest Miguel Hidalgo rebelled in Guanajuato and sparked the eruption of the War of Independence. Hidalgo was defeated and executed in 1811, but the rebellion continued with the deft warrior and statist José María Morelos, who was also finally executed in 1815.

Mexico City, the centre of the Spanish realists, did not suffer directly from the War of Independence, although it did not escape its manifestations. Its population grew abruptly by 25% due to an influx of war refugees. When agricultural production dropped, food supplies dwindled and people went hungry. Public income also dropped dramatically, as did drainage and cleaning services. In 1813, the combination of famine, flooding and filth caused a severe epidemic –possibly typhus—which cost more than 20,000 lives. It was the most calamitous epidemic of the 19th century and caused the population to drop down to 124,000 inhabitants in 1814.

The War of Independence went into relative recess until, in 1821, Agustín de Iturbide, along with his southern ally Vicente Guerrero, again took up the leadership of the Creoles. Spain decided to accept Mexico's independence when Iturbide took control of Mexico City, converting it immediately into the capital of independent Mexico (see Map 3.9). With the old Criole elite of the Bourbon period in power, this group would now attempt to govern the country without many changes, ensuring a centralist, authoritarian government from the powerful capital. The years following independence, however, were characterized by disillusionment and impoverishment in the incipient republic. Iturbide abdicated after less than a year, giving rise to a period of coups that was to last close to 40 years.

On October 30, 1824, weeks after the country's new constitution was approved, Congress designated Mexico City the seat of federal power, formally making it the capital of the republic. As a consequence the Federal District (Distrito Federal or "D.F.") is designated on November 28th encompassing a radius of 8.8 kilometres from the centre of the Plaza Mayor.

But the city, the undisputed centre of national life, went through a period of instability and corruption without precedent –the decadence was inescapable. The correlating economic and social decline manifested itself in city life and its landscape. The Creole elite tried in vain to stay on the margins of the political turbulence and keep its privileges. The poor – despite the abolishment of castes and slavery—were as destitute as ever. Between 1821 and 1855, Mexico had 42 different governments and impoverishment was generalized. Especially noteworthy were the intermittent governments of the erratic and unscrupulous Antonio Lopéz de Santa Anna, who did not succeed at compensating the abandonment and impoverishment which prevailed in the Mexican capital with a few superficial urban improvement projects, which included the remodelling of the Plaza de la Constitución or Zócalo and some parks and the planting of trees.

Map 3.9. Year 1821. The Capital City of Independent Mexico.
Source: Own elaboration based on 500 planos de la Ciudad de México.

The landscape of the basin aggravated their problems. On one hand, deforestation advanced and the lakes continued to recede. The disappearing water gave way to an arid, melancholy landscape of brownish marshes. The city's population grew, however, since it was a refuge for immigrants, reaching about 200,000 inhabitants.

Drinking water continued to be supplied to the city by way of aqueducts, although by the mid 19th century their capacity was insufficient and costly due to the frequent need for repairs. A program was implemented in which aqueducts were substituted for underground pipes, and in 1850 a number of aqueducts were torn down (fountains as well), including the highly important Chapultepec aqueduct, over the ruins of which Hidalgo and Chapultepec avenues now lie.

The construction of the new Huehuetoca Canal was initiated in 1828, as part of the century-old effort to drain the Valley of Mexico, using the existing channels that frequently became blocked. The project was never completed. Draining began of the San Cristóbal Lagoon – which formed during the rainy season and extended to the Xaltocan Lagoon and Lake Texcoco. In 1858 work was done on the Great Canal, which was to be complemented with a tunnel and an open canal. Similarly, however, the project was never finished.

URBAN FORM

The city's urban form generally remained much the same and the orthogonal arrangement of streets was not substantially altered. The city had extended moderately to lie on an area of 10.7 square kilometres. Its centre continued to be the Plaza Mayor, although its name was changed to the *Plaza de la Constitución.* After the refurbishment of an imposing statue of Carlos IV left only the base (or *zócalo*) in the huge plaza, the Plaza de la Constitución was commonly called the Zócalo from then on. It was from this area that the young, turbulent nation was governed. From here the city's ecclesiastical and military powers ruled. It was the centre for the city's commerce. There was La Alameda Park, where the well to do strolled, although the city was filling up more and more with miserable poor people and beggars ("lepers"). It is important to remember that by 1860, the national

income was even lower than what it had been towards the end of the colonial period. According to some estimates, per capita income declined by over a third.[63]

[63]J. H. Coatsworth, *El impacto económico de los ferrocarriles en el Porfiriato: crecimiento contra desarrollo,* traducción de J. Arteaga Hernández, México: Secretaría de Educación Pública, Dirección de Divulgación, 2 vols, [c.1976].

Map 3.10. Year 1876. The City After Maximiliano and Juárez.
Source: Own elaboration based on 500 planos de la Ciudad de México, p. 200.

We refer here to literature as a historical source, citing Madame Calderón de la Barca, whose account of a trip to the city aptly reflects the poverty of the period:

> As I write a horrible leper is looking at me out of the corner of his eye, through a window, reciting an interminable and strange complaint, at the same time that he extends his hand with only two long fingers (...) I don't dare look up, but I feel that his eyes have fixed upon a gold watch and some stamps that are lying on the table. And now some others have arrived! A paralytic woman riding piggyback on a bearded, very robust man (...) What complaining! What raggedness! What a chorus of lamentations! This gathering is surely due to the fact that yesterday we sent them a few coins (...)[64]

According to B. Navarro and M. Vidrio,[65] there were a great deal more vehicles by 1830, with 145 cars and 24 omnibuses pulled by horse, and numerous stagecoaches, collective carts and horses. Water transport was also modernized, if only fleetingly. The year 1849 marked the appearance of steamboats which navigated the La Viga Canal, providing passengers with a connection from the city to Chalco. However, the shallowness and muddiness of the channels made them prone to frequent blockage. When this happened, attempts were made to free the boats by every variety of propulsion, from long poles, to mules which pulled the boats from the shores of the canals. Blockage continued to be a problem even with the small steamboats that were still in service at the end of the century. However, by the beginning of the 20th century, water transport had for the most part disappeared, holding out only in Xochimilco.

From the beginning of the second half of the 19th century until well into the 20th century, the streetcar, which was pulled by mules, was becoming the main from of transport.

Due to the changes in transportation, urban form changed as avenues were widened and commercial, industrial and residential areas became farther and farther apart. The rich continued to live in the city centre and to the west, while the poor lived in peripheral areas, especially in the east and north. Living conditions deteriorated and the poor increasing

[64]F. E. Calderón de la Barca, *La vida en México durante una residencia de 2 años en ese país*, México: Porrúa, 1959, p. 46.
[65]B. Navarro Benítez & M. Vidrio Carrasco, El transporte en el siglo XIX, en *La ciudad de México en el fin del segundo milenio,* G. Garza coord., México: Gobierno del Distrito Federal, El Colegio de México, 2001, pp. 124-129.

crowded into old *vecindades*. Filth was everywhere and more than 20,000 people lived in the street, dedicating themselves to wandering, thieving or other such activities.

However, segmentation by caste, race and class was no longer a public and private habit. The municipality tried to incorporate the 40,000 Indians living in the city who were trash collectors or beggars. However, indigenous people resisted being incorporated and remained united on the margins of urban social life. The old Creole aristocracy was slowly replaced by a new elite of local members of the military and merchants. The latter group often bought haciendas at reduced prices from the "old" aristocracy. A favourite place was the Chalco area, because of the abundance of water and fertile agricultural land, and its proximity to the city. Even the church was the victim of economic decadence, although the ecclesiastical buildings still dominated the landscape. The city, however, continued to be fairly small. By mid-century it lay on an area of 15.3 square kilometres,[66] measuring a little more than three kilometres wide from north to south, and five kilometres from east to west. At its widest points, it measured 4.5 kilometres from south to north and 4.8 kilometres from east to west.

Things became worse for the country when a new war broke out which had a direct impact on the capital. The conflict was with none other than the emerging hemispheric power, the United States, at the moment when this country recognized Texas as a member of the American Union in 1845. The only option left to Mexico was to declare the annexation of its territory illegal and declare war. The United States humiliated a weakened Mexico with its invasion. Mexico was defeated, and, to top it off, lost half of her territory. During the war, Mexico City was occupied by the troops of General Scott, who stayed on for more than two years. Once the American troops withdrew, the country and the city were submerged in anarchic chaos.

[66]B. Navarro Benítez & M. Vidrio Carrasco, El transporte en el siglo XIX, en *La ciudad de México en el fin del segundo milenio,* G. Garza coord., México: Gobierno del Distrito Federal, El Colegio de México, 2001, pp. 124.

The antagonistic camps of conservatives and liberals were organizing in Mexico at an increasing rate. In 1853, Antonio López de Santa Anna returned from exile and became president for the eleventh time under a conservative flag. He was then defeated by the liberal camp and left the country for good in 1855. The liberals convened a Constituent Congress[67] and Mexico adopted a new liberal Constitution in 1857. A short time later, in 1859, in the midst of a civil war, the new president, Benito Juárez, implemented the so-called "Laws of Reform," which were meant to limit the power and property of the Church and to secularise Mexican society. The laws had a tremendous impact on life in Mexico, especially in Mexico City, where the Church not only owned a number of valuable churches and convents, but also was the principle landlord, especially of the vecindades. A number of convents closed during this period, including that of the sisters of the Hieronymite order (where Sister Juana Inés de la Cruz was laid to rest, as we saw before). In 1861, with the country bankrupt, Juárez decided to suspend the payment of the external debt, provoking a new war and another external invasion. France, with the support of conservative Mexicans, invaded Mexico and occupied Mexico City. This obliged Juárez to leave the capital and set up his government in the northern part of the country (1863). The French army of occupation, under orders of Napoleon III, moved to install Maximilian of Habsburg as Emperor of Mexico.

To the surprise and anger of conservatives, Maximilian upheld the liberal laws, including the expropriation of ecclesiastic property. However, three years later, after being threatened by Prussia and pressured by the United States, France decided to withdraw its troops. This led to Maximilian's fall. He surrendered to Juárez and was shot in 1867. Juaréz reinstated the republic, but died five years later, without having resolved the disorder and bankruptcy which Mexico faced after the wars between the conservatives and liberals. It should be pointed out that during Juárez's presidency construction began of the railroads that would connect Mexico City with the port of Veracruz and the Gulf of Mexico. It was a highly important project since it would give the capital a rapid, safe route to the port and would

[67]The Constitution of 1824 was installed and declared effective on December 6. By May of 1847, the Constitutive Act and Reforms of the Mexican United States were promulgated. In practice, there was a return to the Constitution of 1824, with some additions and adaptations to new circumstances. Said act was in effect until 1853, at which time centralism was reinstalled. See R. H. De Gortari & R. Hernández Franyuti, *La ciudad de México y el Distrito Federal. Una historia compartida...*, p. 9.

expand and lower the costs of commerce. (The railroad was inaugurated in 1873, after Juarez's death). Money was also invested in illuminating the city with gas lamps, especially in the city centre.

Despite their obvious mutual antagonism, the contributions made by Juárez and Maximilian were both aimed at modernizing Mexico City in similar ways, since both carried out the liberal reforms that took away the clergy's property, including convents and a huge amount of real estate (a number of studies indicate that the Church possessed during that period around one-forth of the nation's wealth).

Beginning with the Laws of Reform (1856) the city expanded onto what was once church property and convents. However, the important work of Andrés Lira[68] shows how the city also grew at the cost of the indigenous neighbourhoods, since the "indigenous partialities"[69] were abolished. Although some neighbourhoods remained intact until the beginning of the 20th century (like Tlaltelolco to the north), around this time they began to be broken up and incorporated into Mexico City's single city council.

Around 1859 and 1860, the destruction of the nucleus of convents in the city centre began, with dozens of convents and monasteries torn down. Entire city blocks were broken up and opened to allow for at least 16 new streets.[70] Several other ecclesiastic buildings were transformed into libraries, museums, school and new neighbourhoods. Among such cases was the unfortunate demolition of the enormous 16th century Monastery of San Francisco – supposedly to allow for the opening of two centrally located streets-- the mutilation of the Merced Monastery and the conversion of the San Agustín Monastery into the National Library. It was not the state, however, which appropriated these spaces, but real estate

[68]A. Lira, *Comunidades Indígenas frente a la Ciudad de México*, México: El Colegio de México, 1986.
[69]In 1813, the liberal legislation of the Courts of Cádiz formally abolished the neighbourhoods surrounding the city centre called "partialities," which had been reserved for the indigenous population. Once the full citizenship of indigenous people was recognized, their neighbourhoods were completely integrated into city councils. Despite this, the neighbourhoods remained almost completely intact during the first few decades after independence. It was only until 1849, when the government decided to do away with the General Administration of the Partialities (recently created in 1835), that the neighbourhoods began to be dissolved. A. Lira, *Comunidades Indígenas frente a la Ciudad de México.*
[70]M. D. Morales, Expansión urbanística entre 1858 y 1910, *en La ciudad de México en el fin del segundo milenio*, G. Garza coord., México: Gobierno del Distrito Federal, El Colegio de México, 2001, pp. 116-122.

speculators and businessmen, who used the law and the entailment of the clergy's property to obtain highly valuable parcels of land. It was during this period that a large number of the old open public spaces were divided up and auctioned off, making the central nucleus of the city relatively more compact. After 1850 a number of important avenues were opened, including not only the Paseo de la Reforma which we will discuss below, but also the avenues Belén, La Piedad, Azapotzalco, La Verónica, Niño Perdido, Vallejo and Mexicaltzingo, among others. Despite the opening of new thoroughfares, many roads of prehispanic origin remained intact (some also with navigable canals), such as Tlalpan, Tacuba and Guadalupe.

This development dramatically altered the urban landscape, which to a large extent lost the admirable architectural heritage that its buildings in the celebrated Mexican Baroque-Churrigueresque style represented. It should be recalled that even Spain was influenced by the Mexican neoclassical style which contended with the very Spanish Baroque influence, of which there are so many superb examples in Mexico.[71]

Emperor Maximilian loved architecture and was an ardent urbanist. He explored the city looking for ways to improve the urban landscape. He was interested in the realignment of streets, the planting of trees and the improvement of the water supply. He installed public gas lamps and remodelled Chapultepec Castle and the old viceroy's summer palace. It was also during this period that the first mule-pulled streetcars made their appearance and that the National Museum was opened.

Most importantly, Maximilian ordered the construction of the avenue that would become a fundamental part of the urban form and the future of Mexico City (see Map 3.10). In 1864, a diagonal magnificent avenue was opened that ran from the north to the southwest, connecting the city centre, from the statue of Carlos IV on horseback (known as the *caballito*), close to the National Palace, to the palace of Chapultepec. The avenue, which went from being called the Paseo del Emperador to today's Paseo de la Reforma, was an

[71]G. Tovar de Teresa, *La Ciudad de los Palacios. Crónica de un patrimonio perdido,* México: Fundación Cultural Televisa, Vuelta, 2 tomos.

axis or "backbone" fundamental to explaining urban form and dynamics from then on. Maximilian was inspired by the Champs Elysées for its design. The fact that it was placed diagonally broke dramatically with the Spanish design, and its scrupulously north-south orthogonal layout. From then on, a number of neighbourhoods were built around the Paseo de la Reforma that were aligned at an angle that corresponded to the original rectangular design. Fortunately, the liberal governments that succeded Maximilian continued with the construction of these neighbourhoods, extending them and planting trees.[72]

As we mentioned above, once Maximilian was executed, Juárez triumphantly returned to power. One of his best generals, Porfirio Díaz took Mexico City. He then challenged Juárez in the fight for the presidency. After Juárez's death and a brief period of liberal rule, Porfirio Díaz rose to power. This moment marked the beginning of the large-scale urban transformations that would define the city in the 20th century.

3.6 The Porfirian City: 1876 to 1910

Porfirio Díaz left a lasting mark on the history of Mexico and its capital city. The thirty-four years between 1877 and 1911, during which Diaz served eight consecutive presidential terms, are known as the "Porfirian" era. These years were characterized by relative peace and material progress for a duration longer than any other in Mexican history. Although the capital city benefited greatly from the Porfirian economic boom, the period was also marked by despotic authoritarianism, in which democracy was shelved and social inequalities deepened. The indigenous population in particular joined the ranks of the most wretched of the poor. The health conditions and lack of hygiene of poor citizens were at levels far lower than in European countries and the United States. The mortality rate continued to be high.

During this era the country's railways were dramatically expanded –by a multiple of nearly thirty-- and electrical energy was used on a massive scale. Foreign companies provided electricity, which was heavily subsidized, to Mexico City, giving the city a tremendous

[72]W. B. Coss ed., *Historia del Paseo de la Reforma*, México: Instituto Nacional de Bellas Artes, 1994, 109 p.

advantage with respect to other urban centres that did not receive a subsidy. The mining industry experienced a huge boom, which helped set in motion the beginnings of the industrialization process in such areas as the petroleum industry. This had the effect of attracting foreign investment, as did Mexico's stable, conservatively managed finances and its peaceful society. Agricultural exports surpassed food production for domestic consumption and land became concentrated in the hands of a few.

By the last third of the 19th century, Mexico City's population made up only 2.6% of the national total, although it represented a larger proportion in terms of economic activity: it was home to 12.8% of workers in the business sector, 17.2% in the construction sector and 10.0% in manufacturing. In 1896, domestic tariffs and other taxes were lifted, giving the business sector a huge impulse. By the year 1910, labour market participation was at 17.5% and consumption of electricity was up to 12.9%.[73] Finally, Mexico City consolidated its dominance in three key areas: tobacco, distilled and fermented beverages and textiles (although the neighbouring city of Puebla may still have been the country's leading centre of textile production).

The railway network, whose hub was in Mexico City, and electricity, which had been recently introduced in 1879 and was heavily subsidized in the capital, were two key services established and concentrated in Mexico City and not in other cities, a trend that would last well into the 20th century.

In accordance with these boom conditions, Mexico City grew and transformed like never before. After stagnating for the first few decades after independence, the city's population doubled during the Porfirian era, nearing half a million by the year 1910. However, rapid migration into the city resulted in a lack of adequate housing for at least a sixth of its inhabitants who lived in rented rooms in unhygienic, overcrowded flophouses. It should be noted that all of Mexico had a population of close to 15 million inhabitants; the capital's

[73]G. Garza, El comercio y la Industria hacia finales del siglo XIX, en *La ciudad de México en el fin del segundo milenio...*, pp. 155-160.

index of primacy was still not very high. The neighbouring city of Puebla, for example, had a similar population size.

The capital was well connected by train with the northern part of the country, as well as with the port of Veracruz on the Gulf of Mexico and other urban centres; it had the enormous advantage of being the country's hub or communications centre. It took less than 13 hours to travel to Veracruz by train, a great improvement compared to the middle of the 19th century when the trip took 16 to 30 days, depending on whether or not it was the rainy season. Arriving to the border with Texas now took a couple of days instead of a few weeks. For the first time ever, Mexico had an internal market at a national level. The Porfirian era succeeded at joining Mexico City with its region and the rest of the country, especially with sparsely populated northern Mexico; access to the United States by land was also achieved. Transportation costs dropped dramatically. In Veracruz's case, for example, the price of shipping a ton dropped by one tenth, a development which attracted a great deal of investment to the city. Public investment in infrastructure --80% of which, incredibly, was concentrated in Mexico City—was directed towards the water supply, construction of public buildings, pavement of streets, street lights, schools and the telegraph (and later the telephone); the largest amount of funds, however, went to improving the drainage system. It was not surprising that the city had a per capita income more than three times higher (3.6) than the rest of the country, or that its population grew faster than any other city in the country.

Mexico City, or at least its urban centre, adopted French architectural styles and many great buildings were erected. Without a doubt this was an era of great splendour. French-styled mansions were built along tree-lined boulevards, and a number of multi-storied buildings made of steel and concrete sprung up. This period saw the introduction of electrical streetlights and streetcars, which gradually replaced the old type of streetcar pulled by mules. Water pipes were laid in the centre and drainage systems were built. Theatres, restaurants and recreational areas were opened as never before. In 1900, Mexico's Chapultepec Park, the same spot Aztec emperors and Spanish viceroys once enjoyed, was

opened to the public; it continues today to be a popular place to relax for the middle and working classes.

It was during this time that Mexico saw the beginning of the rise of a middle class, which was mostly employed as part of the new bureaucracy of federal and local government. However, enormous differences between social classes developed during the Porfirian era: despite all this splendour, the city never had so many poor people. Crime rates were high despite the presence of a large police force and Mexico City was much more violent than the great capitals of North America and Europe that it emulated. The police were responsible for expelling from the modern, French-styled city centre all barefoot inhabitants in white blankets, who were almost always indigenous people. The policy of segregation, which had begun during the conquest, had become less strict during the last years of the viceroyalty, only to be reinforced again during the first years of Mexico's independence.[74]

WATER

Despite improvements and some expansion, the old drainage system, whose construction began with the works of Enrico Martínez, was at the end of the 19th century highly inadequate in terms of meeting the needs of a Mexico City with a population seven times greater and a surface area ten times larger than in the17th century. Flooding continued and the streets of the city centre became foul-smelling canals. After numerous false starts, construction of a new drainage system began in 1886; it was the most monumental project carried out by Porfirio Díaz in Mexico City.

The work was contracted out to a British company and the new system, which opened in 1900, consisted of a 49 kilometre-long canal, complemented by a ten kilometre-long tunnel that carried sewage and excess water toward the Gulf of Mexico. Although the tunnel has been enlarged many times, the city still uses the same drainage system to this day. With it, flooding was reduced greatly, although not completely. To improve the situation, a number

[74]Despite the fact that districts were reorganized and regrouped according to natural boundaries, instead of as a function of exclusively Indian and Spanish areas, social differences continued to be evident. A. Lira, *Comunidades Indígenas frente a la Ciudad de México.*

of rivers still had to be dug up and drained in 1908. In fact, flooding still continued fairly often up until the 50s.

Beginning in 1870, the volume of water brought to Mexico City from the springs of Chapultepec no longer met the city's needs. From this year until the end of the 19th century, electric pumps were used to bring water into the city from water springs much further away, such as from the rivers Hondo, Santa Fe and Cuajimalpa and from the Desierto de los Leones. Later, beginning in 1903, water was brought from the springs of Xochimilco.

TRANSPORTATION

Throughout the three hundred years of colonial life, the modes of transportation changed very little and included horses and carriages, and the canoes and small boats used primarily by the indigenous population. Mules were used to haul goods, but walking was the most common form of transportation.

By the middle of the 19th century, however, transportation began to change and diversify with the introduction of streetcars pulled by mules and connections to the railway. Changes in urban transportation began to have an impact on the urban environment; above all else it facilitated the rapid expansion of the city. Along with the railway system, streetcars became more popular and by 1900 were run with electricity instead of mules. The streetcar network expanded from 38 kilometres in 1873 to 310 kilometres in 1910, growing 10 times larger in those years. Both modes of transportation helped move people into the city from outlying towns like Tacubaya, Tlalpan, Xochimilco and Tacuba (this helps explain Mexico City's growth to 720,000 inhabitants).

This growth of the transportation system, branching out from the centre of the city, resulted in a great deal of territorial expansion. In 1896, 19 streetcar lines, tying in with eight train

lines, connected the city to outlying towns.[75] The system was centred around the Zócalo (intra-urban) and the nearby station of Buena Vista, and was connected to the north of the city by rail. Unfortunately, by the middle of the 20th century, the streetcar began to give way to the modern bus and especially the automobile.

Urban form had changed in a very important way: while the population doubled during the Porfirian era, the city's area grew five times larger. It was during this period that a French influence was felt on urban form, and this had a large impact on the city. The incipient, French-styled bourgeois of the Porfirian era settled in the neighbourhoods that surrounded the *boulevard* Paseo de la Reforma, which kept being improved throughout the Porfirian era. (The street ran north to southwest). These neighbourhoods or *colonias* were called Roma, Juárez and Cuauhtémoc. Toward the northwest numerous working class neighbourhoods were founded.

On the far eastern side of the city, close to Lake Texcoco, the poorest of the poor settled, so as to be relatively close to the centre of the city. The conditions were very unhealthy and during the rainy season the area flooded with waste water, which caused a great deal of disease.

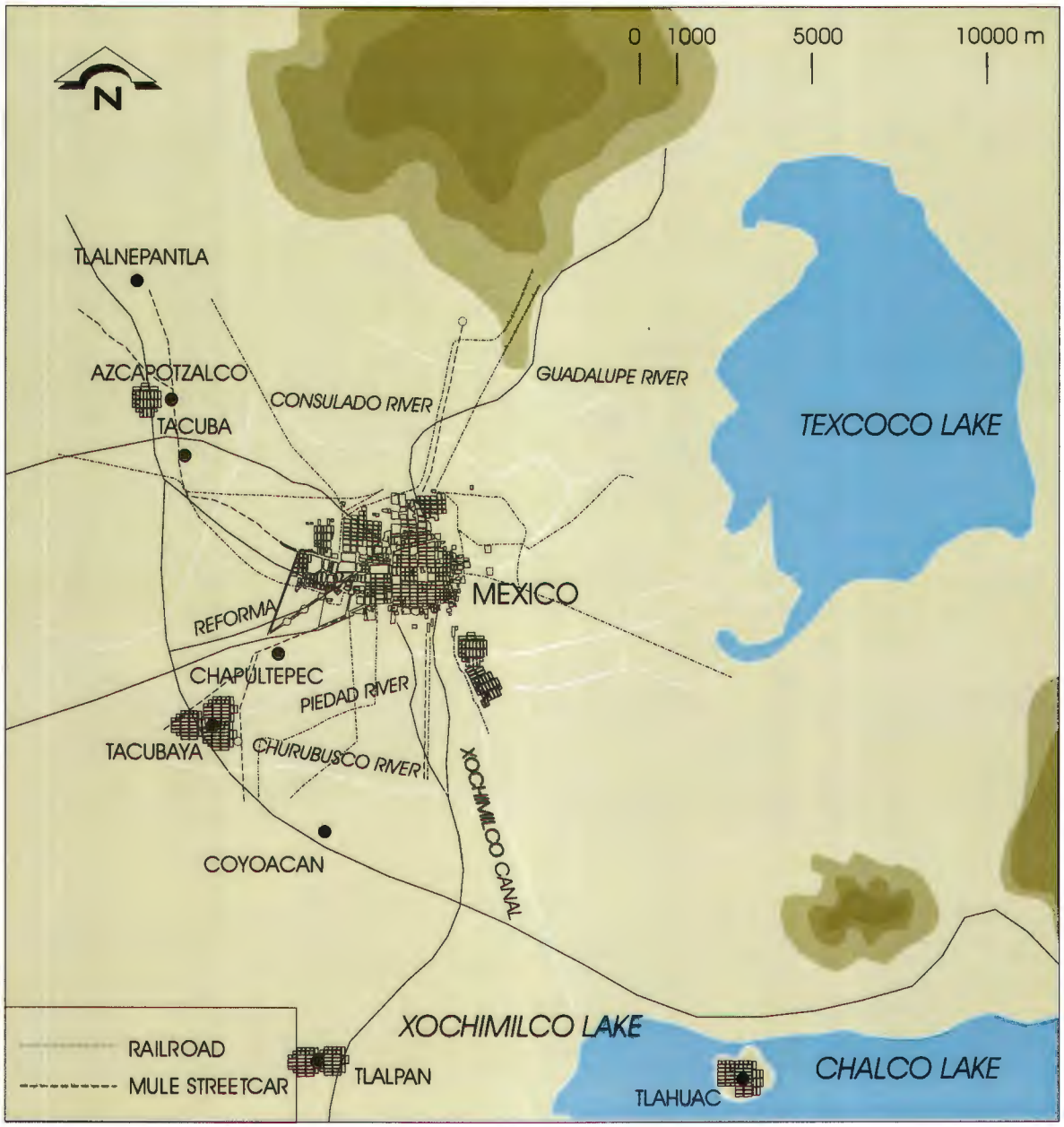
In 1910, at the end of the Porfirian era, the city's northern boundary was marked by the Consulado and Peralvillo rivers, while its southern boundary was the Piedad River (where the Viaducto highway now lies). The city's eastern boundary was Texcoco Lake, which was growing ever smaller. The Balbuena area was the more accurate city limit to the east. To the west was the Calzada de la Verónica, an aqueduct that transported water to the city centre from the Chapultepec Hills (it is now the inner circuit roadway and Melchor Ocampo Avenue). From the Paseo de la Reforma the city expanded mainly toward the west and the north (see Map 3.11).

[75]B. Navarro Benítez & M. Vidrio Carrasco, El transporte en el siglo XIX, en *La ciudad de México en el fin del segundo milenio...*, pp. 128-129.

To the west, the city gradually absorbed the surrounding towns of Tacuba and Tacubaya, which grew by 11.4% between 1882 and 1910,[76] and were home mostly to the upper classes.

In general, the northern part of the city experienced the fastest growth as it absorbed the towns Azcapotzalco and Villa de Guadalupe which had little in the way of public services. However, according to Morales, there was an accumulated growth rate of 56.71% between 1883 and 1910.

[76]M. D. Morales, Expansión urbanística entre 1855 y 1910, in *La ciudad de México en el fin del segundo milenio...*, pp. 116-122.



Map 3.11. Year 1900. The Porfirian City.
Source: Own elaboration based on 500 planos de la Ciudad de México, p. 302-303, and Garza, p. 126.

Toward the south, according to the same author, the rate of growth was at first slower, although it accelerated between 1900 and 1910. Here, colonias such as Juárez, Cuauhtémoc, Roma and Condesa were built with lower population density and good infrastructure by specialized companies. The city expanded onto a large amount of territory toward the south, although this area only absorbed around 12% of overall growth.

To the east was an unhealthy and poor area bordering Texcoco Lake, where the soil was arid and contained saltpetre, and the formation of muddy bogs and flooding were common. Morales mentions that the area's population growth was really a re-densification of population. The rest of the growth is assumed to have come from the centre of the city, although the central nucleus of urban life had moved slightly to the west from the Zocalo to the intersection of the streets known today as Juárez Avenue and Paseo de la Reforma.[77]

In general, the city had extended considerably. It was during this historical period that the city limits overflowed toward the south, beyond what is today Chapultepec Avenue, and overall growth to the west and the north accelerated. But it was a low-lying city to which it was difficult and expensive to provide basic services. Also taking shape was a type of functional city, in the vein of the analytical model of the Chicago School,[78] with a central business district (CBD) of high commercial value and excellent urban infrastructure --at the level of any European or North American city-- placing in the peripheral zones of the city industrial and residential areas. The Paseo de la Reforma was conceived of as the typical *spine* (backbone) from the Chicago School Model, and not long afterward Insurgentes Avenue was built, crossing the city from north to south.

By 1910, the decline of the Porfirian era was evident. The economy had entered a phase of slow growth due to an international mining crisis. Discontent grew as did the number of Diaz's opponents, particularly in northern Mexico. The most notable of these was Francisco I. Madero, who ran against Diaz in the June 1910 presidential elections. The elections were

[77]M. D. Morales, Expansión urbanística entre 1858 y 1910, en *La ciudad de México en el fin del segundo milenio...*, pp. 120.
[78]For more on the Chicago School the recommended work is J. L. Lezama, *La Escuela Ecologista Clásica de Chicago,* México: Centro de Estudios Demográficos y de Desarrollo Urbano, 1990, 48 p.

a sham, Díaz was declared the winner and Madero was jailed. With the pretext of celebrating Mexico's 100th anniversary of independence, Díaz organized an extravagant celebration in hopes of recuperating his sagging popularity. Although he was unsuccessful in this respect, he did improve Mexico City by building the Column of Independence, topped by a golden bronze angel that has since been the city's symbol, as well as theatres, hotels, public buildings and public parks.

After a short time, Madero was released from jail. He declared the elections illegal and called for a revolution in November of the same year (1910). He united his forces with the insurrection of Emiliano Zapata, a leader of farm workers from the state of Morelos, located to the south of Mexico City. At the beginning of 1911 Porfirio Díaz resigned as president, agreed to new elections and departed for Paris, France, to live in exile.

3.7 The Emerging Metropolis: 1910 to 1940

In November of 1911 Madero easily won the presidential elections. For Mexico City the period between the end of the Porfirian era (1910) and the end of the consolidation of the Mexican Revolution, which coincided with the close of the presidency of Lázaro Cárdenas in 1940, was marked by a number of vicissitudes. The decade between 1910 and 1920 was particularly chaotic for Mexico City as it was inundated by poor migrants fleeing the devastation taking place in the countryside. The decades between 1920 and 1940 were years of slow recuperation that accelerated by the end of the period. It is worth mentioning that during this time many important buildings were built to emphasize the solidity of the Mexico City government, as was particularly the case with abolition of the municipality and the creation of the Department of the Federal District to run the D.F.[79] Education and culture were also emphasized during this period.

Madero's government turned out to be weak and did little to stymie the regional insurrections of revolutionary *caudillos* (local chieftains). In February of 1913, after a

[79] Emilio Portes Gil issued a new organic law for the district and federal territories, December 31, 1928. See R. H. De Gortari & R. Hernández Franyuti, *La ciudad de México y el Distrito Federal. Una historia compartida...*, p. 15.

series of episodes of violence and destruction unseen since the conquest of Tenochtitlan, a tragic scene unfolded: Madero was betrayed by one of his generals, Victoriano Huerta, who then ordered him killed. Soon afterwards, the situation became chaotic. Zapata, from the south, and other revolutionary leaders from the north such as Venustiano Carranza, Francisco Villa and Álvaro Obregón took arms against Huerta's dictatorship. The Zapatistas (Zapata's men) mobilized in the south of Mexico City. The United States again invaded Mexico and took the port of Veracruz in April 1914; the revolutionaries of the north advanced and Huerta resigned in July of 1914. The revolutionary leaders then split into factions and fought amongst themselves. Somewhat later, Obregón forged an alliance with Villa and took Mexico City. Carranza became a revolutionary leader and the Americans pulled out of Mexico. Once again Mexico City became the stage for disputes, as conflicts arose between the revolutionary factions. The Zapatistas entered the city from the south and the Villistas (Pancho Villa's men) from the north. The tired and hungry troops soon began to rob and pillage the terrorized inhabitants of the city.

Carranza and Obregón entered Mexico City once again at the end of January 1915. This was a year of chaos and anarchy for the city and a good portion of its infrastructure was destroyed; water and basic services became scarce and the economy collapsed. Finally, in 1917 Carranza legitimately came to power by way of a new constitution for Mexico. Little by little order was re-established in the city.

Not only were episodes of agrarian war played out in Mexico City during the revolution, but many of the principle measures for land redistribution were implemented in the Federal District. Numerous inhabitants in the south of the city, particularly in Xochimilco, Tláhuac, Chalco, Milpa Alta and even Iztapalapa, supported the Zapatistas, and many people in these areas were reinstated with land that was formerly part of the haciendas. The first restitution was carried out by Carranza in 1916 in Iztapalapa. The Federal District was, in fact, one of the first areas in Mexico to allocate new *ejidos* (communal plots of land) as there were many haciendas (on average relatively small in size) throughout Mexico City.[80] It is worth

[80]D. Cymet, *From Ejido to Megalopolis, Another Path. An Evaluation on Ejido Property Rights and Informal Land Development in Mexico City*, P. Lang ed., New York: Another path Long, American University Studies, Series XXI, Regional Studies, vol. 6, 1992, 275 p.

mentioning that there were two important periods in the creation of ejidos in the Federal District. The first went from 1915 to 1934, when the majority of ejidos was allocated. Between 1921 and 1924 President Álvaro Obregón reallocated the largest amount of land (141 square kilometres, or 48.5% of all ejido lands), which benefited the majority of communal land owners (more than 10,000 people, or 44.7% of the total). During this first period, 215.8 square kilometres were distributed, covering 74% of the ejidos, adding up to a total of 66 ejidos. The second period coincided with the presidency of General Lázaro Cárdenas, from 1934 to 1940. In an area of 68.2 square kilometres he created eight new ejidos and expanded (often through the expropriation of the private land of former haciendas) 23 ejidos that had already been reallocated. In total Cárdenas reallocated 23.4% of the total of ejido lands and 9.5% of created ejidos.

Cardenas' successors reallocated only a small amount of land. Between 1940 and 1961, 6.6 square kilometres were distributed, accounting for a minimal 2.3% of all ejidos, the total of which came to 82. Since 1961 not new ejidos have been allocated, but expropriation has continued. This has been a source of innumerable problems involving illegal settlements and poorly defined property rights, which have resulted in considerable damage to the city, as we will see later on.[81]

The situation is even more complicated when one considers that the revolution also reallocated lands to 11 indigenous communities.[82] The members of these communities were almost all indigenous people from the south of the Federal District and they numbered 8,567.[83] They received large amounts of land, almost 500 square kilometres, most of which was forested. Ejidos totalling 290.6 square kilometres were also distributed. Together, these allocations add up to 790.6 square kilometres --almost half the total area of the Federal District. A similar situation was to be found in the neighbouring State of Mexico, in a large

[81]D. Cymet, *From Ejido to Megalopolis, Another Path. An Evaluation on Ejido Property Rights and Informal Land Development in Mexico City...* , p 1-14

[82]The Mexican Constitution has defined communal land as an indivisible good that belongs to the Indigenous community.

[83]D. Cymet, D. *From Ejido to Megalopolis. Another Path. An Evaluation on Ejido Property Rights and Informal Land Development...*, p. 143-144.

portion of territory in the eastern part of the state which is now part of the Mexico City Metropolitan Zone (MCMZ).

THE TWENTIES

Obregón had Carranza assassinated and became president in 1920. The Mexican Revolution had finally come to a close, after an enormous loss of lives. Obregón began a period of slow reconstruction in the city and demonstrated pragmatism while in power. In a sense he laid the foundations of modern Mexico and, up to point, he mollified a country that had suffered through the many turbulent years of the revolution.

During his government Mexico City continued its rapid and disorderly growth, due especially to the influx of poor newcomers from the countryside who left their homes as a result of the disruptions caused by the revolution.[84] By 1925 intense migration pushed the population of Mexico City to over one million inhabitants. The bureaucracy expanded and the elite slowly grew prosperous again. Two thirds of the country's cars were to be found in the Federal District (almost 37,000). Obregón skilfully pacified generals and other members of the army likely to rebel with comfortable public positions. He began to carry out lukewarm agrarian reform and organized workers, especially in Mexico City and other urban areas, into a powerful union loyal to the government (called the Revolutionary Confederation of Workers and Peasants or CROC). While continuing to engage in revolutionary rhetoric, he made pacts with the Church and conservatives. Gradually, the country's situation started to normalize.

With regard to urban form, Mexico City expanded dramatically. Many towns were completely engulfed by urban sprawl. The city's southern and western limits expanded an

[84] Ilán Semo makes the following observation: Francisco Mújica, the second in Cardenas' chain of command, had strong reason to believe that the allocation of land should contain "the waves –the metaphor is neither mistaken or exaggerated—of immigration" to the Federal District, as a result of the 1929 economic crisis. Immigrants hailed from rural areas and the United States, where many workers had lost their jobs. I. Semo, la ciudad tentacular: notas sobre el centralismo en el siglo XX in *Ensayos sobre la Ciudad de México, Macrópolis mexicana,* I. Tovar de Arrechederra comp.., México: Departamento del Distrito Federal, universidad Iberoamericana, Consejo Nacional para la Cultura y las Artes, 1994, pp. 62-63.

estimated 46 square kilometres during the first three decades of the 20th century.[85] A notable development to the west was the upscale neighbourhood of Chapultepec Heights, also known as Las Lomas. There was also remarkable expansion to the north and the south, with considerable environmental impact since trees and bush had to be cleared. Heavily wooded areas were not yet affected, however, except in the case of Las Lomas.

The main environmental problem consisted of the dust storms that occurred in February and March, blowing in from Texcoco, the now partially dry lake to the east. The supplying of water and the drainage system were still a problem. Despite the fact that towards the end of the Porfirian era many wells were dug, water could only be supplied 11 hours a day and only to the city's principle neighbourhoods as a result of rapid urban growth and leaks in the pipe system. Drainage was scarce and many open ditches polluted the rivers. Public markets set up on the streets and garbage continued to be unresolved problems.

But, in spite of it all, the city was by then large and cosmopolitan. It was at this time that the Mexican Revolution inspired the beginnings of a powerful new current in the nation's cultural imagination, with Mexico City functioning as its locus. The works of the muralists, the city's architecture, its vibrant cultural life and its transformation into a refuge for exiles and creative movements gave Mexico City a cosmopolitan air and put it on the map of the great cities of the world.

The muralist movement was, undoubtedly, the most noteworthy part of this cultural flowering. Obregon's minister of education, the important philosopher and politician José Vasconcelos, started an important literacy and education movement. He decided that, in order to educate people about the history of Mexico, the muralists should paint works on the city's most important public buildings. Diego Rivera, as well as David Alfaro Siquerios and José Clemente Orozco, were involved in this project. It was not long before the National Preparatory School (the jewel of the Mexican baroque era, built as a Jesuit School in 1740) and the Ministry of Public Education were decorated with colourful, controversial

[85] A. Cisneros Sosa, *La Ciudad que construimos. Registro de la expansión de la ciudad de México (1920-1976)*, México: Universidad Autónoma de Metropolitana, Unidad Iztapalapa, División de Ciencias Sociales y Humanidades, Casa Abierta al tiempo, 1993, p. 18.

murals that idealized prehispanic Mexico and the recent Mexican Revolution, and they brought Mexico City fame worldwide. Of the muralists, Diego Rivera stands out the most, having continued to paint murals throughout the decade in the National Palace, the Ministry of Health and the Agricultural School of Chapingo. The muralists helped weave a strong cultural movement that for the most part identified with socialist ideas and which included women's participation, enriching city life during that decade and the next.

In 1924 Plutarco Elías Calles was elected president of Mexico, although not without difficulty. His reputation as an anticlerical radical caused him many problems with the Church and other conservative sectors. Nonetheless, Obregón managed to impose his choice. Calles proved to be a strong, intelligent and authoritarian leader. His measures against the Catholic Church inflamed passions throughout the country and from 1926 to 1928 Mexico experienced the bloody rebellion of the Cristeros, which cost 8,000 lives but had few consequences in Mexico City.

Calles was, however, successful on many other fronts. As the economy got back on its feet, the president finished laying the institutional foundations of modern Mexico, which had begun with Obregón. He made slow progress with agrarian reform, advanced notably with irrigation and education and founded the *Banco de México* (the central bank) and other institutions.

Perhaps his most famous accomplishment was the founding of the National Revolutionary Party[86] or PNR (renamed the Revolutionary Institutional Party or PRI) which joined numerous disparate groups into a single party. The PRI, with its rigid hierarchal structure, governed Mexico until December of 2000.

[86] According to Alexandra Lajous, the National Revolutionary Party was the solution for Calles who put his personal prestige as a fundamental attraction during its creation. "Calles knew that "his party" would count on the support of the most prominent politicians of the country due to the lack of democratic practices in Mexico which resulted in being the only element necessary for his success just as in the pre-revolutionary regime, when people continued supporting policy decisions. See A. Lajous, "*Las origenes del partido único en México*" UNAM, Instituto de Investigaciones Históricas, 1979, p.171

Once the pacification of the Cristeros was achieved, or at least partially, Calles negotiated a new election with Obregón. However, Obregón was soon murdered. With the formation of the formidable PNR complete, Calles proved his political skill by going on to name the next three consecutive presidents of Mexico, all of whom ruled under his shadow, thereby earning himself the name of *Jefe Máximo* (maximun chief). The first one of these presidents was Emilio Portes Gil.

As we mentioned before, in August 1928, toward the end of Calles' term, Congress approved the creation of the Department of the Federal District, placing Mexico City under the direct control of the president, who was responsible for naming a mayor to govern the city in his name. Legislation for the city was made the responsibility of the Congress of the Union. In essence, the different municipalities that made up the city were eliminated and unified under a central authority, with some local responsibilities given to the political districts called delegations. On January 1, 1929, during the presidency of Portes Gil, the Department of the Federal District appointed José Manuel Puig Casauranc the first regent (or mayor) of Mexico City.

During his brief administration, Puig opened new wells to help increase the city's water supply, especially in the dryer northern part of the city. To alleviate sewage problems, the San Lázaro Channel was extended to the east, transporting waste water to what was once Lake Texcoco. It is important to mention that in these years trees were planted along many important avenues, especially Insurgentes, and other improvements were made to other main thoroughfares. Car traffic was already intense in the city centre. To alleviate congestion, the first major ring road was built toward the north, connecting the downtown area with Calzada Nonoalco, Santa María la Ribera and Tacuba. From north to south the avenues of Santa María la Redonda, San Juan de Letrán and Niño Perdido were joined.

THE THIRTIES

Between 1930 and 1934 two weak presidents governed Mexico: Pascual Ortiz Rubio (1930-1934) and Abelardo L. Rodríguez (1932-1934). Both were, in reality, appointed by Calles, who was still making important decisions from behind the scenes.

It was during this period that the first urban plans for the city (and the entire country) were begun. The first Master Plan for Mexico City of 1930 included some sound ideas about how to reorder the metropolis. Concerning the environment, there were proposals to plant more trees and plants in the centre of the city, make the downtown's population denser, extend the water supply network, carry out water treatment and incinerate garbage. There were plans to concentrate railroad connections in a single station and the Buena Vista station, to the north of the city, was chosen for this purpose. The plan also called for the expansion of some roads, with particular emphasis on improving downtown road connections to the west and the south. This period also saw the completion of the magnificent Palace of Fine Arts, the transplanting of the Plaza del Volador and the considerable improvement of the Zócalo or Plaza de la Constitución. Both San Juan de Letrán Avenue, connecting the south and the north of the city, and Insurgentes Avenue were expanded. However, these projects, along with the expansion of the water supply network and the pavement of streets, were the only parts of the plan that were carried out.[87] As new neighbourhoods were built, segregation became even more pronounced in the city. The middle to upper classes lived in the west and the south while workers and poorer inhabitants lived in the north.

In 1933 Plutarco Elías Calles's health was failing and he was faced with an economic slow down due to the depression. It was also during this time that he began to look for a competent presidential candidate. He chose Lázaro Cárdenas, a young general with leftist ideas, who had a reputation for being honest and firm. He had fought alongside Calles and later was a competent governor in his native state of Michoacán. Elected in 1934, Cárdenas

[87]A. Cisneros Sosa, *La ciudad que construimos. Registro de la expansión de la ciudad de México, (1920-1976)...*, pp. 53-56.

soon demonstrated he was a strong, independent president. Agrarian reform advanced like never before. He organized new, more aggressive unions, like the Confederation of Mexican Workers or CTM, and promoted public education. His most notable achievement was the expropriation of the oil industry from foreign owners, which encouraged nationalist fervour in social groups. The economy, however, did not fare so well. At the end of his term, inflation grew and the national currency had to be devalued. And as of a result of growing foreign debt, social programs had to be scaled back.

Cárdenas did, however, make progress with urban planning in the city. He improved land registration, and promulgated the still effective Expropriation Law and the Planning and Zoning Law. These laws were more modern and explicit and contained provisions that used more modern financial mechanisms. Also dating back to this time were the visionary proposals of Architect Carlos Contreras, who called for the preservation of 16 ecological reserves, the majority in the south and the west. The projects were never completed but served many years later as important guides for new projects.

Cárdenas, in accord with the ideas of Miguel Ángel de Quevedo, the first great Mexican environmentalist known as the "Tree Apostle," reforested and declared the Tepeyac Hill of the Sierra of Guadalupe, in the north, a National Park (1937). He expropriated land from the former hacienda of Eslava in order to turn it into ejidos and to create the Ajusco National Park. In 1938 he declared another national park called Historic Coyoacán, a small but strategically located parcel of land in an area where the city was expanding; today it is a park known as the Viveros de Coyoacán. He improved Chapultepec Forest, and moved his residency to Los Pinos, an extensive green area within the forest. As we have seen, the allocation of ejidos was a decisive factor in the expansion of Mexico City and Cardenas would be the last president to allocate land in this way. Motivated by poverty, however, the ejido owners often divided and sold their land illegally. Additionally, the ejidos were often logged and subject to ecological damage, instead of serving as areas for agricultural production and forest conservation.

During the second half of the 30s, Mexico City saw two important additions to urban life. The first of these was the automobile, which, as it became more popular and accessible, required more space. Measures were thus taken to expand Revolución Avenue and efforts were still underway to expand Insurgentes Avenue. The form of the city by the 40s was not, however, much different than at the beginning of the decade except in terms of expansion and consolidation of the downtown area.

Cárdenas' government did not see the importance of saving Texcoco Lake, not even partially, and allowed the Federal District government to use the land made available through its desiccation for purposes such as the production of salt and partial reforestation at its fringes. Part of this area was given to families for farming. The land –which was arid and high in salt-- was never planted, however, and was instead sold for the construction of working class housing. During the Cárdenas administration, the digging of artesian wells to extract water for constantly expanding neighbourhoods became a common practice; at least twenty wells, a drinking water pipe network and pumping stations were put into operation.

In terms of urban planning, not much progress was made, although many working class neighbourhoods sprang up. It was at this time that the practice of founding neighbourhoods through invasion or squatting came into existence.[88] Dozens of thousands of people benefited from these practices, squatting on either public or private land that the city later expropriated and signed over to the illegal settlers. Squatting tapered off until the presidency of Luis Echeverría, when the practice spiked. It continues today, although to a lesser extent.

Cárdenas' term gave new meaning to the Mexican Revolution, as a transition to constructing the Mexican nation was made. In the area of culture, Mexico City continued to be the vibrant, cosmopolitan centre for an innovative cultural scene. Although the muralists lost momentum, there was a golden era in radio, the novel and especially cinema, all of which tended to celebrate the Mexican Revolution. Exiles living in Mexico, such as

[88]A. Cisneros Sosa, *La ciudad que construimos. Registro de la expansión de la ciudad de México (1920-1976)...*, pp. 57.

Trotsky (who was later assassinated in Coyoacán, in the south of Mexico City), and especially the Spanish Republicans who had been defeated in the Spanish Civil War, left a lasting mark on the humanities, schools and the business world. The National Polytechnic Institute, based in the Santo Tomás area in the north of the city, was founded in 1937 and the world renowned Colegio de México, based in the Colonia Roma, was founded in 1940.[89] All this represented an important seal for the Cardenas era for both the city and the nation as a whole.

Mexico City in the first 40 years of the 20th century had progressed more than the rest of Mexico, its product growing at more than double the rate of the rest of the nation (5.3% annually). This was especially the result of the city's strong industrial growth, which accounted for 30% of the Gross National Product (GNP). The growth of this participation with respect to the national total was the greatest to have occurred in the 20th century. [90]

3.8 From Metropolis to Megalopolis:1940 to 2000

During this time frame, two important, consecutive sub-periods need to be considered. The first, from 1940 to 1970, was an era of incredible demographic expansion and economic vigour. Although there were problems and it was at this time that the seeds of a posterior urban crisis were sowed, it was a period of growth and relative improvement of the quality of life of the city's inhabitants. Economic growth was of more than 6% and per capita income grew by 3% annually. Mexico City's growth rate was of 6.7%, again higher than that of the rest of the country, thereby making the city's participation in the GNP grow even more –to 37.52%. Per capita income was still double that of the rest of the nation.[91] It is important to note that by the end of the 70s, Mexico was primarily urban, with almost 55% of its population living in cities.

[89]The Colegio de México began the systematic urban study of Mexico City. It was this institution which produced the pioneering work of Luis Unikel on Mexico's urban development. Other works followed by such distinguished researchers as Gustavo Garza, Marta Schteingart, and many others.

[90] J. Sobrino, Participación Económica en el Siglo XX, *La Ciudad de México en el fin del segundo milenio*, G. Garza coord., México: Gobierno del Distrito Federal, El Colegio de México, 2001, pp. 162-163.

[91]J. Sobrino, Participación Económica en el Siglo XX, *La Ciudad de México en el fin del segundo milenio...*, p. 164-165.

We can call this era the Boom of the Metropolis. It was a period of prosperity that was the result of the era's high degree of political stability and policies of state intervention and public investment which steered clear of tampering with the balances of finance.

This generated a virtuous circle that brought on a good deal of private investment, national as well as foreign. It was precisely during these decades that the industrialization through the import substitution model, (known as ISI) was successfully implemented. The industrial sector was the most dynamic, expanding 8% annually. The phenomenon was called the "Mexican Miracle," since it seemed to have redistributed income to the middle classes. [92]

However, in the second sub-period, from around 1970 to 2000 (the year at which the historic analysis of this thesis ends), the city seemed to sink gradually and without remedy into an inevitable crisis. These years can be divided into two smaller periods. The first was the serious crisis (for both the city and the nation), lasting from 1970 to 1990. The second, from 1990 to at least 2000, was a time of readjustment and of a gradual hesitant improvement.

3.8.1 The Boom of the Metropolis: 1940 to 1970

The thirty or more years of economic boom for the city (and the country) which lasted approximately from 1940 to the beginning of the 70s represented a dramatic transformation, similar to the three decades of Porfirian rule (see Map 3.12). At the beginning of the 70s, Mexico City was one of the largest, most modern cities in the world. Many of its problems and its social inequalities had not been resolved, but they seemed to lessen with economic growth. Furthermore, the expectation of continued expansion created a positive climate of prosperity and hope. During these years the population of the city grew six times larger, shooting up from 1.5 to 8.5 million people, as a result of rural migration to the city. Its surface area grew from 117.5 square kilometres to 746.4 square kilometres. It was above all an era of great industrial expansion, as we will see later on.

[92] R. Hansen, *The Politics of Mexican Development,* (2nd ed), J. Hopkins, Baltimore: University Press, 1974, cited en P. M. Ward, *México City*, (Revised 2nd ed.), Austin, TX: Department of Sociology and Lyndon B. Johnson School of Public Affairs, The University of Texas at Austin, 1997, p. 9.

This period is also characterized by a surge in cultural production, and its writers, such as novelist Juan Rulfo and poet and essayist Octavio Paz (*El Laberinto de la Soledad*), may stand out the most. Of the period's novels, Carlos Fuentes' *La región más transparente*, set in Mexico City, is among the best. Cinema flourished and also dealt with urban themes, the best example of which is perhaps *Los olvidados* by Luis Buñuel. The nationalism of the twenties to the forties gave way to a modernization that was at times confused with the Americanization of the culture and people's lifestyles.

The first president in this golden age was General Manuel Ávila Camacho (1940-1946), a practical man who was less interested in ideology than Cárdenas. He was president during World War II, and inevitably sought closer relations to the United States. In part because of the war, he initiated the industrialization through the import substitution model (ISI). Inflation and high prices were also prevalent as a result of the war. Despite being part of the military, establishment, Ávila Camacho strengthened the civilian government, and Mexico experienced an era of relative peace and prosperity.

Beginning in the early 40s, the city began an era of rapid growth that continued into the 50s and did not begin to taper off until the 70s. In the face of the inflation and high prices caused by World War II, President Ávila Camacho decided, as in so many other parts of the world, to freeze rents in the Federal District until the end of the war. Due to the pressure of neighbourhood organizations, Camacho's successor, Miguel Alemán, continued with the policy of rent control --although only for buildings included under the first decree—and in 1948 he announced that the freeze was to be indefinite. It was only until 1992, during the government of Carlos Salinas de Gortari, that rent control was finally ended. Frozen rents were the cause behind the deterioration of the historic centre and other parts of downtown Mexico City. At first, families poorer than former tenants settled in the deteriorated dwellings, while those who were better off migrated to the south or the west; the poorest citizens lived in the north and the west. The profitability of these buildings slowly declined, as did investment in their maintenance and improvement. Immediately after rents were

frozen, population density increased noticeably, although investment lagged.[93]

With the progressive deterioration of the centre and the city's demographic boom (its population had reached 1.7 million), expansion along the periphery began to accelerate notably. During this time, popular movements were as active as the Mexican Revolutionary Party or PRM (formerly the National Revolutionary Party and later PRI) was in power; the latter organized and absorbed these movements within its corporate structure. However, the political and economic cost of meeting the demands of such groups was very high. To be specific, a huge number of associations petitioned for housing, and, as a result, squatting was encouraged and the government was forced to expropriate or buy lands. It was during these years that squatters appropriated environmentally valuable land –precious for either its forests or its proximity to wetlands or lakes-- in such places as Xochimilco or Iztapalapa.

Conflicts over the possession of recently urbanized land in the city began to be serious during this period and would come to a head during the Echeverria administration at the beginning of the 70s; such conflicts continue to some extent even to this day. Backed by public utility laws, President Ávila Camacho began the inevitable and traumatic expropriation of ejidos (and communities) to make more space for urban dwellings. The process of expropriating ejidos was often achieved by initiating a squatter settlement. At times, agreements were reached with ejido owners, who would benefit economically by giving up their lands, but at other times the process could lead to disputes and even violence. At the same time that the expropriation of ejido lands could be complex, contentious and even corrupt, it also benefited certain political leaders belonging to the PRM-PRI, who gained seats in Congress or other government or party positions in exchange for favours. In 1942 occupation permits for communal land were approved to help relocate those who had been displaced and to allow for the creation of urban residential and industrial zones. Ejido expropriations permitted the founding of the National Autonomous University of Mexico (UNAM) and residential areas like Ciudad Satélite and Jardines del Pedregal and San Ángel.

[93] In the 1940s, colonias such as Centro, La Merced, Obrera, Doctores and Buenos Aires reached a population density of 30,000 inhabitants per square kilometre. Such levels were also to be found in surrounding neighbourhoods.

The amount of hydraulic works needed by a city in such rapid expansion was enormous. The construction of artesian wells as the main source of water was not enough. In 1942, work was begun to bring water to the city from the neighbouring Lerma River Basin in the State of Mexico. Water was also piped in from the San Joaquín and Consulado rivers. The drainage canal was expanded and construction continued of public markets aimed at replacing unhygienic markets on public streets, a project that was not finished until the 60s.

The expansion of the northern part of Insurgentes Avenue made it one of the most important north-south thoroughfares in the city and another important *spine* (backbone) in the urban development of the Mexico City Metropolitan Zone. San Juan de Letrán Avenue was also extended. New avenues were opened which extended towards the cardinal points and had little to do with the original form of the city centre. These were perhaps the best years for Juárez Avenue, the street that connected the historic centre with the backbone of the Paseo de la Reforma, since this period saw the construction of the National Lottery building at the intersection of Juárez and Reforma and the Prado Hotel, which housed the latest murals by Diego Rivera (it was destroyed in the 1985 earthquake, although the murals were preserved). The statue of Diana the Huntress was placed along the Paseo de la Reforma. This stretch of the avenue, between its intersections with the avenues Juárez and Insurgentes, was the symbol of splendour in the Mexican metropolis of the 40s and 50s.

Coinciding with the beginnings of the great industrial boom, the government designated specific areas for industrial development, particularly in the north of the city. Thus, important industrial areas such as the Vallejo Industrial zone were born.

Ávila Camacho ended his period as president amid relative calm. The more dominant figure of this dynamic decade was his successor, Miguel Alemán, who governed from 1946 to 1952. He was a civilian and the first president to have not fought in the revolution; he appointed civilians, and especially lawyers, to government posts. The economy skyrocketed during his presidency, especially in the industrial sector. The city's population grew 5.7%

annually, the highest level in its history. From 1940 to 1950 the number of the city's inhabitants surged from 1.7 to 3 million.

Mexico City became the dynamic centre of the country and experienced an era of splendour that lasted more or less until 1970. The finances of the capital improved, the economy grew, and the government undertook major public works and large-scale architectural projects. The city's growth was at levels never before seen and its physiognomy transformed; it was at this time that the metropolis' urban form began to take on its present day appearance. Levels of industrial growth were also at an all time high, and the number of industrial establishments doubled, contributing 40% of national industrial production. Industrial expansion was made possible in part by infrastructure. The north consolidated itself as the industrial heart of the city, as well as the nation. This zone expanded further north, along the highways to Pachuca and to Monterrey and Laredo.

Of the great public works of the era, the most outstanding was undoubtedly the new campus of the National Autonomous University of Mexico (UNAM), known as University City. It was built between 1949 and 1952 on an enormous tract of land of about 700 hectares in San Angel, in the south of the city. Its splendid architecture lent the capital an air of grandeur, although it also contributed to the decline of the city centre, the former site of the university, since it lost the vitality and activity (as well as the conflicts) that came with the presence of 15,000 students and thousands of professors and workers. Both the UNAM and the upscale Jardines del Pedregal neighbourhood, which is contiguous to the university, were built on a unique surface of lava and porous soil. Construction in this area, known as the Pedregal, was done at a high cost to the environment since it affected a great number of endemic species of brush and xerophytes which had for centuries remained untouched. Of the original *Pedregal*, only three square kilometres remain.

A number of other important public buildings were erected (at an unprecedented pace). Among the most important were the international airport, built in the dry lake bed of Texcoco, the National Auditorium and –making their first appearance—large apartment complexes, such as the ones bearing the names of presidents Alemán and Juárez. A number

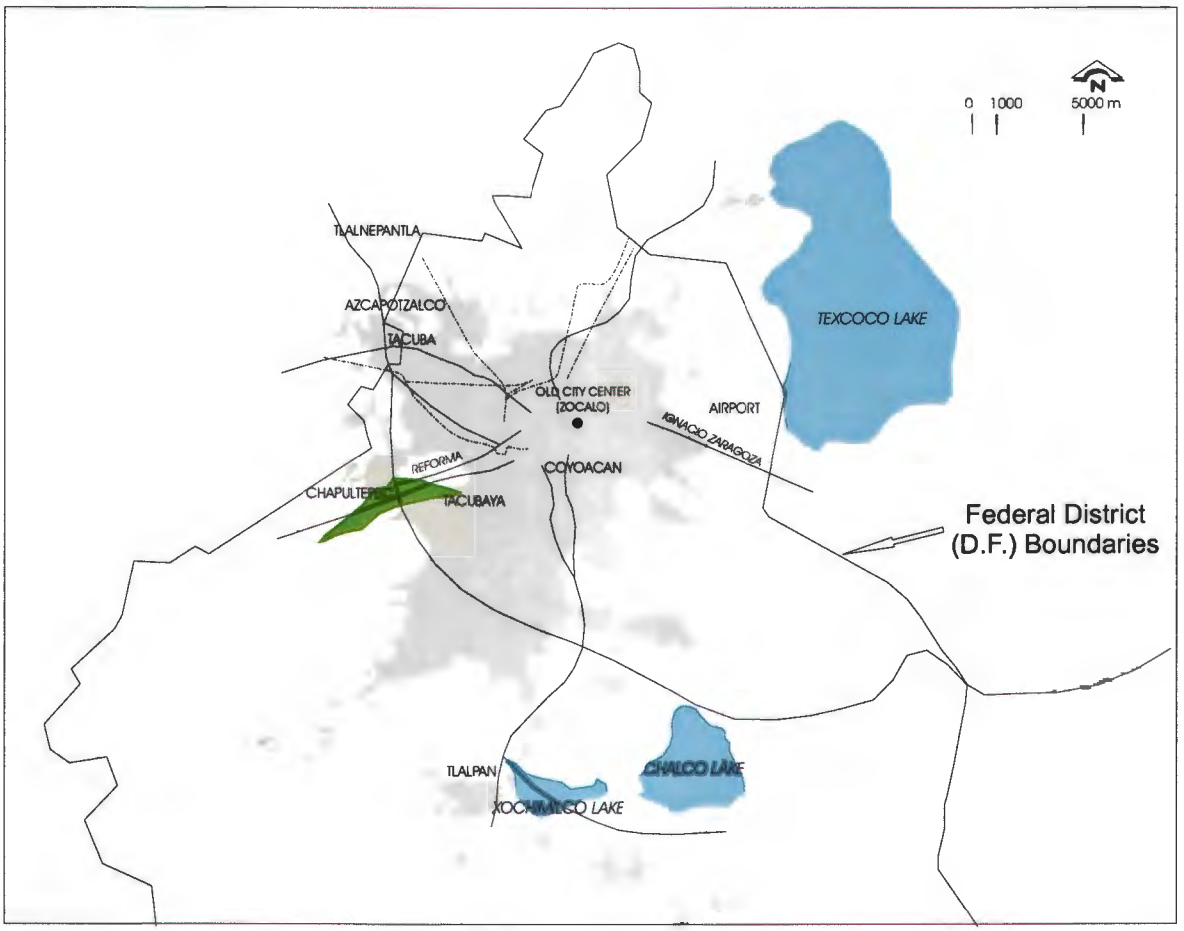
of internal highways were built, the most important being the Viaducto Piedad, which was laid over the river by the same name, now channelled through pipes. A number of emblematic monuments were installed such as the Fountain to the Nationalisation of the Oil Industry at the entrance of the Las Lomas area and the "Child Heroes" monument in Chapultepec Park. The most notable private constructions were the Latin America Tower, which was the first skyscraper in the capital, and the Cuatro Caminos Bullfighting Ring. The city overflowed towards the south and the west. Foreign investment poured in and the government stimulated the city's growth with numerous (and excessive) subsidies which made it attractive to locate industries in the capital. The real estate business was thriving. Fortunes had always been made in Mexico City by land speculation, but in Alemán's time the phenomenon came into full force. The period saw a general expansion which included the construction of the residential area of Pedregal de San Ángel, a garden city built amongst cactus and lava, whose bold, innovative design was the work of the great architect Luis Barragán.

Many ejidos were transformed into densely populated colonias inhabited by the urban poor; an estimated 50% of the city's expansion was onto these communal lands. The government attempted to put a stop to illegal settlements and the formation of irregular neighbourhoods to little avail, and it was at this time that the squatter shanty towns known as "lost cities" were born. During Alemán's term, a great deal of urban development was carried out in the south in the peripheral and independent towns of Coyoacán, San Ángel and Tlalpan. This had a negative impact on the environment since many of the green areas that had previously separated these towns from the city were destroyed. The dramatic increase in jobs created by industrialization and economic expansion caused the peripheral delegations of the city to grow in a truly spectacular manner. From 1940 to 1950, Iztapalapa and Azcapotzalco grew 200% and, to the northeast, Gustavo A. Madero grew 392%, its population swelling to 204,000 habitants.[94]

[94]A. Cisneros Sosa, *La ciudad que construimos. Registro de la expansión de la ciudad de México (1920-1976),* México: Universidad Autónoma Metropolitana, Unidad Iztapalapa, División de Ciencias Sociales y Humanidades, Casa abierta al tiempo, 1993, pp. 128-129.

The government authorized the exploitation of the forests of the Ajusco foothills to supply the paper factories of San Rafael, Loreto and Peña Pobre, setting off the serious deforestation of the Summits of Ajusco Park.

With regard to hydraulic works, many large and important projects were carried out during this period. In 1951 the Lerma River water supply system was completed and 54 kilometres of channels and a six kilometre-long tunnel were built to bring water from the Valley of Toluca to the city. An additional 4,000 litres of water were gained; almost the same volume of water extracted from Xochimilco and a little more than what was supplied by wells and small springs. There was now a total of 388 litres per inhabitant, which was double the amount available in 1940. With the water supply system from the Lerma River, Mexico City for the first time abandoned the hydraulic model of self-sufficiency in which it basically only used its own ground water. Although the reduced need to extract water from wells lessened the sinking of the centre of the city for a while, the importation of water turned out to provide only temporary relief.



Map 3.12. Year 1950. The Metropolis.
Source: Own elaboration.

Miguel Alemán was followed by Adolfo Ruiz Cortines (1952-1958), who continued to preside over the economic boom that began with his predecessor's administration, although growth did taper off slightly. He was a much more austere president and he corrected to some extent his predecessor's excesses. The books were balanced, urban planning was reinstated and the city's growth continued at an accelerated pace. The regent (mayor) named by Ruiz Cortines for the city, Ernesto P. Uruchurtu, was perhaps the toughest and most efficient head of the city government during this expansionist era. He served as regent for an unusually long period, a total of 13 years, from late 1952 to early 1966, during three presidential terms. Toward the end of the 50s, the city continued its uncontrollable growth toward the south and the west.

Among the great works of the period, the suburban city to the northwest called *Ciudad Satélite* stands out. Begun in 1957 as a private enterprise, it was the first great modern suburb in the American style, built in Mexico for the sons and daughters of the expanding middle class whose formation had begun at the close of the Mexican Revolution. The construction of Satélite attracted many other developments to this part of the State of Mexico, outside of the jurisdiction of Mexico City, partly due to the fact that Uruchurtu prohibited further residential development within the Federal District in 1954. In time, this area, along with its nearby industrial development, generated a great urban sub-centre to the west of the city, especially in the municipalities of Naucalpan and Tlanepantla, the industrial heart of the emerging metropolis.

In order to make space for affordable housing, Ruiz Cortines developed the phony concept of the "Urban-Ejido Zone" (ZUE) in 1954, which made it possible to sell ejido parcels to third parties and made way for settlement of land. Although they were rather illegal, these "Urban Ejidos" were home to hundreds of thousands of irregularly established inhabitants.[95] They also perpetuated urban poverty by creating a clan of marginalized urban land owners.

[95]D. Cymet, *From Ejido to Metropolis, Another Path, An Evaluation on Ejido Property Rights and Informal Land Development in Mexico City...*, pp. 145.

Toward the end of the 50s, the difference between incomes in the capital and those in the rest of the country was huge. The average family income in the capital surpassed the national average by 185%.[96] There still was, however, a great deal of inequality within the city. In Mexico City, according to Hansen, 10% of the population received 40% of all available income and 3% of the population received 21%. At the same time, purchasing power was declining.[97] Housing conditions were still very deficient. The majority of migrants who came to the city in the 40s and 50s landed first in the old, semi-deserted neighbourhoods that the middle class had left in order to live further to the south. Almost a third of the population lived in the dilapidated dwellings known as vecindades which dated back to the Porfirian era. It was during these years (1955) that Oscar Lewis wrote the now classic study *Los hijos de Sánchez*, which narrates the troubles of a poor family living in the old and legendary central neighbourhood of Tepito.

The population explosion and the urgent need for services led to the emergence of a number of veritable mafias. The problem of garbage disposal was partially solved through the consolidation of six large dumps, but these ended up in the hands of a group known as the trash collectors mafia. The poor sanitary conditions of the dumps did not improve and, together with the dust storms coming from Texcoco in the east every spring, a great deal of air pollution was created. Bus drivers also formed a strong mafia-like organization called the Bus Drivers Alliance or "octopus," which enjoyed an almost complete monopoly for at least 20 more years, while providing deficient service.

Despite the Lerma works, the issue of the water supply continued to be a priority. It was at this time that the Chiconautla springs were added to the sources of water for the north of the city. Work continued on draining water out of the Mexico Basin, since flooding had again occurred in the city centre. To this end, nearly 100 large pumps were installed in strategic locations in response to the continued sinking of the city, which had dropped to a level lower than the drainage area to the north.

[96]O. Oldman *et. al., Financing Urban Development in Mexico City*, Harvard: University Press, 1967 p.21.
[97]R. Hansen, *The Politics of Mexican Development...*, pp. 72-73.

The next President of the "Booming Era" was the charismatic Adolfo López Mateos (1958-1964). As well, his mandate developed in the middle of great economic growth in Mexico. The city continued growing and prospering. Inflation was low and macroeconomic statistics in Mexico were the best in Latin America.

To the west, (of our city) offered our eyes the bubbling spectacular of Juarez avenue...our grand white avenue adorned with skyscrapers, since the first was erected in La Nacional (that today Seguros de México looks over its shoulder). With them they seem to avenge the eight chapels linked together for the exercise of the stations of the cross, a century that awakened to rectify only ending up Porfirista, had already begun to bring down 1825, to substitute them much later for French style mansions that today, restored and practical, we use for quick and graceful demonstrations of the new architecture..[98]

Although López Mateos had to confront a mayor protest from the electric and railroad unions and in general a more powerful left, closer to the triumphant Cuban Revolution. In a very able way, he knew how to balance a symbolic closeness with Cuba and a leftist rhetoric, with an economic model that-like his three predecessors - privileged over all the super- concentration of industry in the Capital, like the territorial expression of the model of industrialization by Import substitution (ISI). To do this, life in the city was amply subsidized -transport, popular foods, light, water- meanwhile salaries were kept low: the magnet for investment and this continued without limitations.

During the López Mateos administration many important public works were implemented including the expressway "The Periférico Ringway"; which marked the automobile as the official use of transportation in the Mexico City, that even in this era started to become a serious problem.

The "ringway", at first encourage new investment, neighborhoods and buildings in the south, the west and later the east toward the areas of Tlalpan and Xochimilco. However fifteen years later the expressway became saturated with traffic and began to generate serious economic problems and to the west growth was converted into a disincentive.

[98]S. Novo, *Nueva grandeza mexicana, Ensayo sobre la Ciudad de México y sus alrededores en 1946,* México: Consejo Nacional para la Cultura y las Artes, Cien de México, 1996, p. 68.

Overpasses and tunnels were built in the south and the centre of the city, but relieve was only temporary.

The government made a great effort to extend services in many neighbourhoods and areas of the city like water supply and drainage, lighting and pavement. But many poor areas remained without modern services. A large urban housing complex was built called "Nonoalco Tlalteloco" that contained almost 12,000 apartments in 102 enormous buildings in the north of the city and expanded the north-east Paseo de la Reforma, its first change in one hundred years. As well the housing complex "San Juan de Aragón" was built which housed close to 10,000 small houses, a large urban forest and a zoo of 36 hectares. Aragón was a healthy green enclave in the north of the city, traditionally more arid without large green spaces. During these years the population with scarce resources grew toward the north and east and now included areas: Naucalpan, Tlanepantla, Ecatepec and Netzhualcoyotl.

Not any less important was the construction of the National Museum of Anthropology, that has given Mexico City great prestige and converted the city into a national and international tourist destination. The museum was aptly built in front of the Chapultepec Park.

Water needs were supplied with the expansion of the system in Xochimilco, incorporating Chalco. In this era the construction of deep drainage systems continued and drilling dozens of metres until the they arrived at the site of the Tajo of Nochistongo. This project would continue for another 20 years before it concluded.

López Mateos's successor was the last president of the "Boom Era of the Metropolis", Gustavo Díaz Ordaz (1964-1970). He was a hard and austere man who presided over Mexico in part spurned on by his own success, began to overwhelm the state with his rigidity and authority. The growing urban middle classes, above all in Mexico City, played an important role in urban civic life and were giving signs of rebellion. During this decade demographic growth continued in Mexico and the Metropolis, whose progress continued in the industrial sector. Even though the era is one of stability and growth, political conditions

began to change and in fact, by 1968 the popular perceptions of the government and its mighty ruling party, the PRI, turned upside down.

During the long period of the Regent (mayor) of Mexico City, Uruchurtu ended in 1966 when he was forced to resign by the president after a conflict with communal landowners whose land he had recently expropriated to build the mighty Azteca football stadium, the second largest in the world with a capacity of over100,000 spectators. The same happened to General, Alfonso Corona del Rosal, that faced many difficult political periods. The ejido conflicts for urban land continued increasing in intensity to the proportion to the growth of the city. It was not for nothing that the ejidos surrounded Mexico City and made rational urban expansion difficult. The ejidos[99] were conceived as agricultural land not urban land and a complicated legal matter and strictly speaking cannot be sold. However some communal land owners sold their land in a fraudulent manner. As well as selling the land, expropriation and regularization of the land had to done legally by proper authorities. Corruption by city and agrarian authorities has been studied and had a negative impact on the environment, as many ejidos and communities were located in rich agricultural zones or in dense forested land in the south of the city. During this era as well the invasion-sale and regulation of the ejido of San Bernabé in the Cerro del Judío, that was a forest on the south-west of the city. The excellent work of David Cymet[100] describes with clarity and precision these aspects.

From a strictly urban viewpoint, the government of Díaz Ordaz, like previous governments, made advances and initiated many public works projects. In urban terms, the city in these years distinguished itself through the construction of the XIX Olympic Games facilities and above all the opening of the subway system, called the Metro (1969). However the historic centre was completely abandoned and its decline, which began in the 50s, was now more evident. Many people left the downtown neighbourhoods like in the case of Tepito, Morelos, Guerrero, Peralvillo, Merced and Centro.

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[99]The ejido is a modern version of an old form of semi comunal land possession where the state gives a portion of land to a group of peasant farmers divided into individual plots. But ownership is limited in the sense that the land in question cannot be sold, rented or used as collateral.

[100]D. Cymet, *From Ejido to Metropolis, Another Path, An Evaluation on Ejido Property Rights and Informal Land Development in Mexico City...*, 275 p.

The first subway line of the metro was 12.4 kilometres and connected the west to the east, Chapultepec with the Puebla city exit, the highway of the Zaragoza. By 1970 subway lines 2 and 3 with 17.3 kilometres, this time connected the north and the south by the Tlalpan highway and 4.7 kilometres between Tlaltelolco and the General Hospital. The metro was an instant success and gave efficient and cheap service to 900,000 people. Although buses continued being the most popular mode of transportation with over 5.7 million users. The metro was subsidized almost from the very beginning and soon became a several financial burden for the city and still is.

Public housing for the middle classes continued being constructed. The largest was the Villa Coapa Unit, in Xochimilco, with almost 10,000 departments. This building produced important expansion in the south east of the city, an area that was rich with forests and lakes. The expansion of the delegations of the Federal District continued at a brisk pace, and the city began to overflow into the State of Mexico, particularly in the eastern zone close to the neighbouring Texcoco Lake, where the City of Nezahualcóyotl had no access to services as they were outside the city limits, a city that now had a population of 651,000 habitants (1970) up from 65,000 habitants in 1960.

The proud City of the Mexican Revolution became the host of the XIX Olympic Games, the first time a developing country ventured to celebrate the Olympic Games, but the infrastructure of Mexico City and its capacity to build the necessary facilities was not questioned by anyone. For the Olympic games, the great Villa Olímpica was built along side the Tlalpan forest, swimming pools, sporting domes; the Tlalpan viaduct and the Periferico was expanded. The city was filled with flowers and splendour and was ready to be considered one of the great cities of the world, but scarcely three months before the games one of the most powerful students protest occurred. In 1968, with more than 300,000 students, many from the influential and enormous UNAM, the centre of academic and university life in Mexico inspired by Marxism and sympathetic to the Cuban revolution protested for democracy and liberty in Mexico. The large protests in the streets of Mexico City and coupled with the upcoming games which would put Mexico on the world stage, the government of Díaz Ordaz ordered the army to occupy the UNAM campus and in less

than ten days of the opening of the games, the protests became violent as many students were killed in a protest at the symbolic square *Plaza de las Tres Culturas*, in Tlalteloco. It is still not known exactly how many students were killed in Tlaltelolco (official statistics vary between 34 and over 300), nor the circumstances of why the students were killed. This was clearly the most difficult moment in the life of Mexico City and the country in many decades. Perhaps not since the death of Madero in 1913 had there been such a tragic episode or social conflict: the killing of students on October 2 1968 is a watershed period in the history of the city in the 20th century.

Díaz Ordaz assumed responsibility -historically and personal of what happened and the Olympic Games which were carried out peacefully and much success. In 1970 Mexico City hosted the World Cup of Soccer taking advantage of the facilities built for the Olympics and the majestic Azteca Stadium. The government of Díaz Ordaz ended two years later on November 30, 1970 and although the economy continued growing, the trauma of Tlateloco and the accumulation of social tensions, a product of inequality and impoverishment of the majority, created in part by a social and economic model that was so successful for over thirty years, it would now prolong an irreversible crisis.

3.8.2 Megalopolis in Crisis: 1970 to 2000

THE FALLEN YEARS 1970 TO 1988

Beginning with the 70s the crisis of the city becomes apparent and a cycle of declining growth, quality of life and the environment that arrived at its lowest point around 1990. In September 1985 the city was struck by a catastrophic earthquake that cost over 10, 000 lives. It was without a doubt the worst tragedy of the time, perhaps only compared to the great flood of 1629 and the plagues of 16th and 17th centuries and only surpassed by the terrible birth of Mexico-Tenochtitlan in 1521. The 90s was a period of slow recuperation and the arrival of a kind of governmental democracy. But the recuperation process was problematic as it was fraught with errors and contradictions, too many to overcome the crisis of the city.

But in the 70s the economy was still expanding particularly in the period of López Portillo although the growth was inflationary and after a few years it crashed. The GNP per capita was not growing as it was in the previous period. In this decade the hegemony of Mexico City and its Metropolitan zones (MCMZ) begins to decline. Measures were implemented to stimulate the industrial disconcentration and some critics anticipated diseconomies of agglomeration. Therefore but this measures backfired since it depressed the overall economy of the Metropolis.

It is important to note that toward the end of the 80's the dominance of the services sector or *"terciarización"* of the Mexico City economy happened very much in the same direction as the "Services Revolution" in the advanced urban areas of the world regarding financial services, trade, technology development, education and training.[101] By 1998 the Mexican City's Metropolitan Zone absorbed 41.1% of the national services sector: 64.8 of production services and 45.9 % from commerce.This trend would be very positive for Mexico City

It is now convenient to analyze the pattern of segregation in Mexico City around the 1980's and the 1990's since it seems that it began to change. Throughout this thesis we have discussed a constant pattern of segregated growth in Mexico City. In the era of Tenochtitlan, the tlatoani and his military court, his priests and traders (*pochteca*), occupied the center of the island. At the beginning of the Viceroyalty, the government and the Spaniards also occupied the centre and moved the indigenous to the margin of the city. Later, a division in New Spain in "castes" segregated the city even more, now in terms of class and ethnic group. The passage of time trivialized segregation instead of abolishing it. The Porfirio Díaz era heightened and advanced this phenomenon in terms of class and income throughout the 20th century. In the enormous Mexico City, to the west and south live the middle classes and toward the north and the east the poorer classes. The important

[101]G. Garza, Servicialización de la Economía Metropolitana 1960-1998, *La Ciudad de México en el fin del segundo milenio,* pp. 182-183 y 190-192.

analysis of Peter Ward[102] concerning expansion and the spatial segregation of the population during the crisis years is important and deserves consideration.

In the first place, Ward points out that the now classic mechanism identified by John Turner[103] for migration and urban living in Latin America (and Mexico) in the 1940s to the 1960s, stops being relevant by the 70s and onward.[104] Turner spoke about settlement patterns of poor habitants in two phases: the first generation that settled in the central areas of the city and the second generation immigrated to the periphery. Ward indicates that the urban dynamic of Mexico City consisted in a movement similar to Turner's model: "From the Plaza to the Suburbs and to the Mega city". This signified the strengthening of the pattern of spatial segregation. The creation of suburbs simply extended on a geographic scale much bigger than the old pattern of segregation.[105] As well, the prohibition of Uruchurtu in 1954 to create more settlements in the federal district did not alter the process. An exception was the high-class neighbourhood of Tecamachalco, developed in the 60's and part of the State of Mexico adjacent to the Lomas area where prohibition did not apply.

As well, as we have seen, the work of Cymet[106] demonstrates how the phenomena of the ejidal land around the city of Mexico did not avoid the process: while the rich exercised legal permits and the poor invaded or brought ejidal land and some emigrated to the south and west and others to the east and the north (and the middle classes remained in the central and southern area.) The expansion in the last two decades of these poor zones was in concentric cycles of large and small commercial and urban value, beginning with the "initial border" basically in the 50s. It is important to point out that these expansion zones to the east, particularly the most recent a little to the south, are areas of high environmental value, a lot of green, more humidity, less contamination and a better climate.

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[102]P. M. Ward, *Mexico City...*, 332 p.
[103]P. M. Ward, *Mexico City...*, pp. 66-68.
[104]J. Turner, 'Housing priorities, settlement patterns and urban development in modernizing countries', *Journal of the American Institute of Planners,* 34, pp. 354-363, in P. M. Ward, *Mexico City...*, pp. 66-68.
[105]P. M. Ward, *Mexico City...*, p. 74.
[106]D. Cymet, *From Ejido to Metropolis, Another Path, An Evaluation on Ejido Property Rights and Informal Land Development in Mexico City...*, 275 p.

Ward indicates that the 70s and onward, the process of segregation begins to reverse in a limited way. To draw this conclusion he analyzes his own research and the works of Ruvalcaba and M. Schteingart.[107] Above all, they indicate an improvement of the middle groups in detriment of the two extremes: the ones with higher income and the poorest ones. This is due to a large extent to the economical crises of these last decades that allowed a growing "gentrification" of the old neighbourhoods that had declined, as Roma or Condesa neighbourhoods, or even some neighbourhoods close to Ciudad Satélite. Furthermore, the "gentrification" happened as well in the area of the old towns that were incorporated to the City such as Tlalpan and Coyoacán or San Jerónimo, on the south of the City.

In December 1970 Luis Echeverría assumes the presidency (1970-1976). By that time the Mexican metropolis had turned into a voracious megalopolis, terribly polluted and out of control growth. With a surface area three times bigger than New York, it perhaps turned into the biggest single urban concentration in history.[108] Echeverría attempted a change, taken into effect more on words than in facts. The unstoppable expansion of the urban area towards the municipalities of the State of Mexico made impossible to postpone the creation of a coordination mechanism between the two federal entities: the Federal District and the State of Mexico. A Conurbation Commission was created though it was a very weak organization.

During his government the city started a descending spiral; he had to change his first mayor, Alfonso Martínez Domínguez under the suspicion that he ordered the repression against a group of students with a confrontational group known as the "Halcones". The successor, Octavio Sentíes, left a sequence of unfinished works: an inner round highway in the zone of heaviest traffic, which was born congested and could not be finished, the Circuito Interior. The dynamic zones of growth to the south and southeast of the City were left out from the works to improve traffic conditions (with the exception of Periférico Sur, from the previous administration.) The construction of the subway was almost completely

[107] R. M. Rubalcaba & M. Schteingart, Segregación Socioespacial, *La Ciudad de México en el fin del segundo milenio...*, pp. 278-296.

[108] It is not the case for the large agglomerations that come together between various urban or rural populations as is the case in New York, Tokyo, or Los Angles, called "conurbations".

stopped and the acute pollution problems were barely paid any attention at all. Precious opportunities to face the big problems that were piling up were lost in those years.

The effort in the construction of housing was remarkable. It brought very uneven results and generated other problems. Echeverría set out to finish with the marginal neighbourhoods or "lost cities" (squatter camps), there were some advances in some places, but the strategy of building popular housing of very low quality in far away places generated in a few years other "lost cities" but this time in the periphery, were urban services were more expensive and of lower quality. As the economic crisis advanced, with low growth and growing inflation, rented housing got into a crisis as well.

In the Echeverría era new institutions for the promotion and financing of housing and for the normalization of the urban land proliferated. Foremost, of course, is the creation of the Institute for the National Fund for Workers Housing (INFONAVIT) in 1972, which had a large budget to build large housing complexes for workers. Other funds were the FOVI and the FOVISSTE for government workers. A lot was built in many places but in areas too far away from the city centre and of low quality: the end result was more crowding and chaotic expansion of the city.

In those years the government was very tolerant of illegal land invasions. Invasions to ecologically very valuable lands were tolerated, such as the mountainous forested zone in the south, in the Ajusco, the Santa Catarina Range and the ex-lake of Texcoco, these latter two to the east. The equivocal and permissive attitude of the government generated land ilegal occupations and very serious conflicts, such as the one in Santo Domingno de los Reyes in the central Coyoacán.[109] Invasions in Nezahualcóyotl, on the boundary of the ex-lake of Texcoco[110] kept on being tolerated, and in a zone of canyons known as Cerro del Judío, to the south west.[111] After failing with a trusteeship fund for the normalization of the land, (FIDEURBE), the government created the Commission for the Normalization of the

[109]P. M. Ward, *Mexico City...*, pp. 70-71.
[110]M. De la Rosa, *Nezahualcóyotl: Un fenómeno,* México: Fondo de Cultura Económica, 1974.
[111]J. Durand, *La Ciudad Invade al Ejido*, Ed. La casa Chata, México, 1983.

Ownership of the Land (CORETT), that would, in effect, create duplicity of functions with other already existing institutions.

But the biggest and most complex illegal occupation of land happened in the Iztacalco zone, to the east of the city. It is there that the radical organization "*Campamento 2 de Octubre*" was created. This organization was the origin of very radical urban groups. The Echeverría government was incapable of controlling the problem and it let it grow out of control and out of proportion. It was until the next government, in 1981, when the police makes the final eviction, relocated the inhabitants and normalized popular housing is created there.

But on the other hand, paradoxically, the Echeverría government attempted for the first time, to face the acute air pollution problem and other environmental problems of the City. The government created the Urban Development Law of the Federal District, a law that already recognized the need to face the ecological deterioration, and also the first Federal Law Against Pollution. Later, it would promulgate the General Law of Human Settlements. But little was done in fact to slow down the environmental problems that in those years began to become very serious. There was also an expansion of (the third section) the Chapultepec Forest, but in the overall air quality continued to decline, out of control.

In terms of water policy and infrastructure, a hydraulic model was upgraded and continued to bring water into the city from a water basin outside Mexico City but without treatment or recycling. An example of this was the implementation of the large drainage project that consisted in creating the "deep drainage system", large deep tunnels (the largest of its kind in the world) 90 kilometres long that dumped sewage from the city. The large project was expanded and completed only by the next government. Although the drainage system functions, what needs to be pointed out is that improvements on a hydraulic model that at the core looses massive amounts of such a scarce resource such as water.

The successor of Echeverría, José López Portillo (1976-1982) took over a country that was in crisis and a MCMZ that continued growing in a rapid and chaotic way. The national

currency had been devalued and inflation was high. Growth was low and intensified social problems. However, López Portillo was able to give a new dynamism to the economy -to boost a high level of growth- Between 1978 and 1981 the economy grew an average of 8% annually, this time because Mexico discovered important oil fields of petroleum. Unfortunately, the price of oil collapsed five years later, the oil boom came to abrupt halt and the country plunged into a crisis.

In terms of public investment in the sector, Mexico City and later the whole MCMZ, was a privileged territory throughout the 20th century, and even more so during the Lopez Portillo administration. Statistics from the last 40 years indicate that the city was sustaining a level close to 25% of overall investment. The investment was productive if we consider Mexico City's contribution to the GNP of the Mexico City's Metropolitan Area.[112] During the governments of López Mateos to that of López Portillo 1958 to 1982, the City was the privileged place for industrialization and development policies of the entire country, investment in Mexico City would continue to climb. However during the government of La Madrid and Salinas de Gortari (1982 to 1994) investment would fall but not in abrupt way; in fact with De la Madrid, in part because of reconstruction work after the earthquakes of 1985, public investment was almost 30%, the highest in this era. But during the Zedillo government public investment fell in a pronounced way (only statistics up until 1998) to the lowest level in 40 years.[113]

The Mexico City (and the MCMZ) received, under López Portillo, the highest ever level of investment. The level was larger than the accumulation of twenty previous years and was not been surpassed until the year 2000. Federal investment in the Mexico City's Metropolitan Area reached close to 25 billion pesos. During these years expansion of construction projects was on all fronts. Construction of the metro, the important street overpasses and underpasses, the enormous central market, drainage systems and networks of portable water.

[112]J. Sobrino, Participación Económica en el Siglo XX, *La Ciudad de México en el fin del segundo milenio...*, pp. 220-226.
[113]J. Sobrino, *Ibid.*, 223.

The Regent of Mexico City appointed by López Portillo, Carlos Hank González, a politician of great strength that implemented vigorous growth policies and urban projects. The metro was expanded with vigor, key axis were developed in the heart of trafficked areas and helped to relieve some traffic congestion. A gigantic city whole sale market was built in the eastern-central part of the city, (Central de Abastos). And above all in the forgotten and impoverished northern part of the city, important roads and streets connecting avenues were constructed. This urban form was very much affected by the widening of mayor roads in a grid-like pattern , known as "*ejes viales*" or "road axis" which greatly improved traffic.

It is in the government of López Portillo that faced off problems of land acquisition, invasions and squatting. This practice began at the beginning of the great urban expansion of the 40s and took great momentum during Echeverría. Beginning in 1977, the government of Hank decided to end with these negative practices of tolerating illegal land invasions to accommodate urban growth in *ad-hoc* designated and suitable areas. But this increased the incentive to use the instrument of "Urban-Ejido Zone" to expand urban zones in a more or less legal way, (but at the base of it the ejido continued being inalienable). Another effect of this was the increase of the density of popular city centre neighbourhoods or "barrios". In reality, each process of land regularization initiated by CORETT or FIDEURBE was converted into a great political conflict that was costly and difficult to resolve.[114]

Enormous subsidies persisted in Mexico City, which helped to stimulate a vast migration toward the capital city but in terms of pollution abatement he did very little. The availability of water, electricity, and the subway, were much cheaper than in other cities. As well food and health services were subsidized, more worrying was the large subsidy of gasoline that tremendously stimulated automobile use. Large solutions were carried out in

[114]D. Cymet, *From Ejido to Metrópolis, Another Path, An Evaluation on Ejido Property Rights and Informal Land Development in México City…*, pp. 87-90

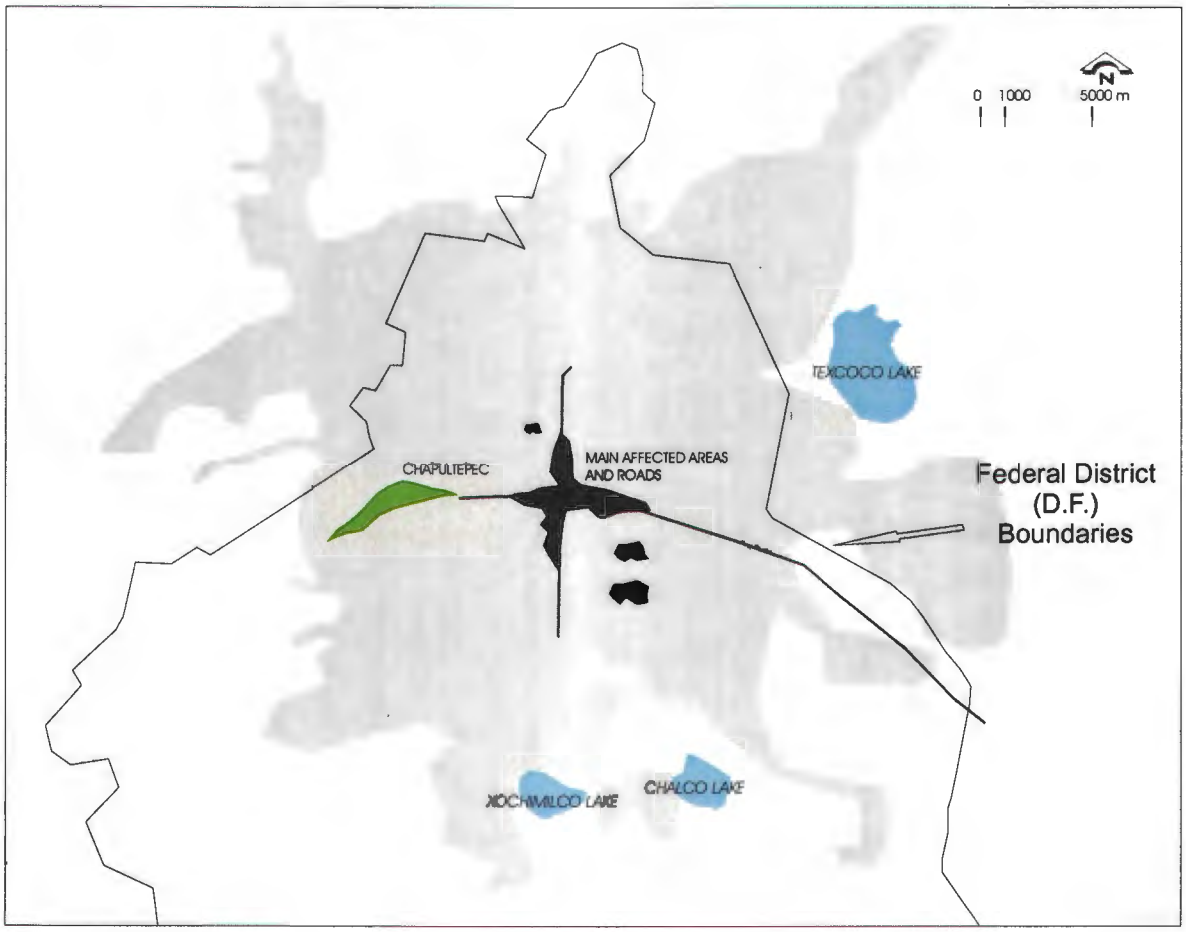
the public works sector but not in the economic productive sector which could not correct the so called "urban bias".[115]

During this era the last productive *chinampas* were eradicated in Iztapalapa, near Xochimilco, where there were a good many flower markets, chiefly for tourist reasons.

Lopez Portillo's successor, Miguel de la Madrid (1982-1988), presided over the country in the middle of an economic crisis, just as the public was losing confidence in the government that would never be won back. De la Madrid abandoned the outmoded model of industrialization through import substitution (ISI); he then opened up the economy, implemented deregulation and promoted exports. But economic growth during De la Madrid's administration hardly reached 1%. Salaries eroded as inflation reached 150% and by 1987 Mexico City was in the midst of a deep crisis. The city's economy shrunk during this period at an annual rate of -1.1%, and its share of the GNP with respect to the rest of the county slipped, dipping down to 32% by 1990. Per capita income dropped and the informal economy grew in the capital at a rate 1.7 times higher than the national average. But nothing represented these dark times more than the tragic earthquake of September 19, 1985, which took place not long after the city suffered the death of 500 people as result of a terrible explosion of PEMEX, the national oil Company, gas tanks in the neighbourhood of San Janice, in the Tlalnepantla industrial area in the north of the MCMZ.

The earthquake of 1985, registering 8.1 on the Richter Scale, caused unparalleled destruction, and struck the central part of the city at the beginning of the morning rush hour, at 7:19 a.m. (see Map 3.13) . Close to 10,000 people were killed and tens of thousands were wounded. Some 100,000 people were left homeless, 855 buildings were affected and damages were estimated at two billion dollars. The most affected areas were the central, south central (the colonias Roma, Hipódromo and Condesa) and eastern parts of the city. The large apartment colony of Tlaltelolco was particularly damaged (ironically this was the same place where students were killed in 1968).

[115] M. Lipton, *Why poor people stay poor: Urban Basin World Development,* Cambridge Mass: Harvard University Press, 1980, 476 p.



Map 3.13. Year 1985. The Earthquake Main Devastation Area.
Source: Own elaboration.

When the authorities' response to the earthquake proved to be hesitant and lukewarm, the inhabitants of Mexico City took it upon themselves to participate in the rescue and clean-up effort. Some say this is what sparked in Mexico's civil society an impulse to more actively participate in civic affairs and led people to call for greater democracy and accountability. The earthquake consolidated powerful popular organizations involved in urban political action such as the radical National Coordination of Urban Popular Movements (CONAMUP) and the Neighbourhood Assembly, which promoted the illegal settlement and invasion of land.

The 1985 earthquake –caused by the collision of the enormous Cocos and North America tectonic plates below the Pacific Ocean—once again made the vulnerability of the Mexico City Metropolitan Zone evident. Although the city slowly recovered, the year 1985, like the year 1629, will be remembered as one of most the terrible in Mexico City's history. Already hampered by an economic crisis, the federal government's ability to effectively respond to the natural disaster was limited to say the least.

Despite economic hard times, federal subsidies for Mexico City were still enormous and were approaching the total amount of subsidization for all other municipalities in the rest of the country. With fewer resources, the government tried, especially after the 1985 earthquake, to diminish subsidies and to carry out a policy of decentralization that had actually begun during the previous administration. This policy was, however, fundamentally ill conceived since it tried to promote investment outside the metropolitan zone by doing away with incentives for investment (and job creation) in the megalopolis. What it should have done is restructure the economy of the Mexico City Metropolitan Zone through economic diversification and a shift to an emphasis on services, high technology and, above all, less polluting industries. None of this was done.

Population growth also began to decrease, although this was more a reflection of the demographic transition occurring throughout the country than of the government's urban policies. At the national level, the rate of population growth went down from its high point of 3.5% per year in 1970 to just 2.25% in 1985. The decrease was most pronounced in

Mexico City, where growth dipped down to less than 2%, although growth in the metropolitan zone as a whole continued to be high at 4%. There was a great deal of growth in the poorest peripheral parts of the city, in areas that were valuable in environmental or aesthetic terms. A good example is the area to the east the city, built right up to the shores of the partially dry Lake Texcoco, called Nezahualcóyotl City (nicknamed Neza by its inhabitants). In 1957, there were only 10,000 people living in Neza, but by 1975 there were a million, and by the 80s, two million.

De la Madrid began the opening of the Mexican economy and carried out reforms aimed at deregulating and reducing the public sector. It was during the midst of the economic crisis, in the mid-80s, when it began to be evident in Mexico City that the industrialization through import substitution model (ISI) –which favoured the excessive industrialization of the metropolitan zone—was no longer viable. The lower prices of urban services in other parts of the country had the effect of diminishing the "Urban Bias" in economic policies which had existed since the 30s. The country's largest market was the city, and this caused foreign companies to choose it as a base for penetration. Local industry therefore suffered, since companies located in the megalopolis tended to be inefficient, having formerly depended on a huge captive market. This caused the MCMZ position of industrial dominance to weaken even more, a trend which had begun in the 70s.

It was during De la Madrid's administration that Nezahualcóyotl grew to maturity and other immense squatter cities such as Chalco and Chimalhuacán sprung up in peripheral areas, mostly to the east. It would have been better if this disorderly growth through squatting or illegal purchase of "informal" land could have been directed elsewhere, perhaps through the re-densification of neighbourhoods in the north. Neza's maturity and Chimalhuacán's growth forever cancelled the possibility of a continuous lacustrine, green area between Texcoco and Chalco. It is now almost impossible to bring about complete environmental restoration of the eastern lakes and the Sierra de las Cruces.

During the 80s, in Mexico and the rest of the world, environmental issues were drawing attention and finally being placed on political agendas. Mexico City's enormous size,

pollution problems and lack of green areas made it truly notorious. In January of 1989, Mexico City made the cover of *Time Magazine*, and was described as living within as an "urban gas chamber" and the "anteroom to an ecological Hiroshima," which was of course an exaggeration. This caused a great deal of damage to Mexico City's image, however.

But this does not mean that by the end of the 80s the city was not experiencing its worst moment in terms of the environment. Air pollution rose to very dangerous levels, despite the fact that city authorities implemented air quality control measures for the first time ever. In a location such as Mexico City's, in a closed basin 2,240 metres above sea level, the amount of oxygen in the atmosphere is 23% less than normal, and consequently automobiles emit double the carbon monoxide and other gases. The population continued to grow and measures taken to improve environmental conditions were too weak to reverse the situation.

It was during these years that an effort was made to resolve not only the problem of air pollution, but also that of the protection of the few remaining green areas in Mexico City. After more than eight decades of rapid expansion, the extensive megalopolis began to spread into the "environmental frontiers" located especially in the south, and to a lesser extent in the west and the southeast. In these areas were forests, aquifer recharge zones, springs, canyons, streams, wetlands and traditional agricultural lands.

The most dramatic case was that of the Sierra del Ajusco (and Chichinautzin) in the southernmost part of the city, a range of majestic green mountains, dominated by the towering Ajusco volcano, which is at times covered with snow. The volcanic clay soil of the Sierra del Ajusco- Chichinautzin is crucial for recharging the city's aquifer,[116] and the area is the most biologically diverse in the Mexico Basin.[117] There had been a number of small villages in the Ajusco foothills dating back to prehispanic times, and they continued to exist in the 20th century without causing major damage to the ecosystem. As previously

[116]Quadri De la Torre, quoted in K. Pezzoli, *Human Settlements and Planning for Ecological Sustainability, The Case of Mexico City.* London, England, Cambridge Mass: The MIT Press, 1998.
[117]Soberón, in K. Pezzoli, *Human Settlements and Planning for Ecological Sustainability, The Case of Mexico City.* London, England, Cambridge Mass: The MIT Press, 1998.

mentioned, President Cárdenas created an ejido in San Nicolás Totolapan. The only significant deforestation of the Ajusco up till this period had been perpetrated, beginning in the 40s, by logging companies, especially during Miguel Alemán's administration.

At the end of the 70s, but especially during the 80s, squatter settlements sprang up, especially in the central part of the foothills. The invasion of lands happened for a number of reasons, but the primary cause was the government's irresponsible decision in 1974 to open the Scenic Highway to the Ajusco. Soon afterwards construction began, at the intersection of the Scenic Highway and Periferico, of the Colegio de México's new campus, the Fund of Economic Culture's headquarters, the Pedagogic University, and even the largest amusement park in the city. Middle and upper class neighbourhoods soon followed, along with massive illegal invasions of the upper portions of the foothills, right in the middle of the Ajusco's forested area. In the 80s the population of the area went from a little over 20,000 inhabitants to 250,000 (and in the 90s growth accelerated even more; unconfirmed numbers indicate that there were 500,000 inhabitants by that decade, mostly living in irregular settlements). From the 60s to the 90s, almost 6,000 hectares were lost to urbanization in the Ajusco area (which is part of the Tlalpan Delegation). At first, most of this was agricultural land, but towards the end of the process, valuable forests of oyamel pines, cedars and oak trees were destroyed. The De la Madrid administration attempted in vain to stop the destruction of the city's last green frontier with a "Green Belt" containment strategy, similar to programs that had already failed in other parts of the world. De la Madrid proposed the Urban Reorganization and Ecological Protection plan (PRUPE), which called for the expropriation of 77,000 hectares –where almost all the irregular settlements were located—to turn this area into a special ecological protected area. However, he was met with a great deal of resistance and thus the expropriation was shelved.

In the middle section of the Ajusco, a number of working class neighbourhoods were illegally founded, forming part of the colonias known as Los Belvederes, Bosques del Pedregal, Lomas del Seminario and Dos de Octubre. Due to the environmental destruction that the settlers had caused, the government unsuccessfully tried to relocate them. The

squatters, in turn, formed political organizations allied with leftist political groups, students, academics and non-governmental organizations. They decided to form Ecologically Productive Neighbourhoods (known for their Spanish acronym as CEPs), the idea being that, in this forested area of great environmental and aesthetic value, sustainable urbanization would be carried out through the implementation of such practices as composting, recycling and organic agriculture. They also demanded that they be given a sort of collective ownership of the land. This strategy was devised to obstruct the attempt to evict the settlers with the presentation of a credible, "alternative" project, as Keith Pezzoli asserted in his comprehensive book on the subject.[118] Of course the CEPs did not work, since the inhabitants of the Ajusco had to concern themselves with trying to earn a living in the city, and did not have the time or the inclination to sustain an environmental utopia, as noble and well intentioned as it may have been. The CEPs did not take into account that massive deforestation was taking place or that the recharging of aquifers was being blocked. A project that benefited a few thousand people to the detriment of 18 million others did not make much sense. But it was not until the following government administration that a settlement was reached through political compromise, with results that would prove to be detrimental to the environment.

THE UNCERTAIN RECOVERY: 1988-2000

The last decade of the 20th century saw the introduction of a new model of development for the country known as neoliberalism; it was based on open markets, deregulation and free trade agreements, particularly the North American Free Trade Agreement (NAFTA) between the United States, Mexico and Canada. Despite the enormous economic setback of 1994 and 1995, the economy eventually picked up, with growth reaching 3.5%, although this was only a little over half the rate achieved from 1940 to 1980. Per capita income was only somewhat higher than 6% of what it was in 1980. During these years, the MCMZ rebounded and grew at a pace similar to that of the rest of the country. As the century drew to a close, Mexico City was responsible for 32.4% of the national product, about the same

[118] K. Pezolli, *Human Settlements and Planning for Ecological Sustainability. The Case of México City*, England, London, Massachusetts, Cambridge: MIT Press, 1998, 473 p.

level as in the 70s. But there was an interesting change in terms of the breakdown by sectors: the city lagged compared to the rest of the country in industrial growth, but it was by far the number one leader in service sector expansion. At the end of the century we can only barely observe that the city is starting to move towards an economy based on financial, social (commercial) and personal (education, health, etc.) services. This does not mean that it is de-industrializing (its manufacturing product is five times greater than that of Monterrey, the second industrial city in Mexico), but it does imply that its economic foundation is increasingly being built on services, which could augur good things for the future. But we should first take a closer look at these years.

Carlos Salinas de Gortari (1988-1994), a young, brilliant technocrat and Harvard graduate, became president at the end of 1988. Perhaps just a couple years later the situation began to change. Salinas' government initiated ambitious programs aimed at the right direction: reforesting the Mexico Basin and protecting aquifer recharge areas, and increased the area of the city's ecological reserves by 3,000 hectares. An exact evaluation of these initiatives does not exist, although general data on the city allows us to conclude that they were not wholly successful. More than anything else, they set projects in motion that continue to this day, but which have not yet yielded significant results.

At the beginning of the Salinas administration, 44% of the enormous metropolitan zone was still owned by communal land owners, whose property was mostly located in the semi-rural south --no less than 662.1 square kilometres. This proportion probably had not changed significantly by the year 2000. According to data cited by David Cymet, 42.4% of this land is classified as agricultural, 38.7% is forested and 11.8% is used for grazing. Of the 38 ejidos still in existence, 19 are home to the highly valuable forests that still remain in the metropolitan zone.[119] Communal land owners are extremely poor, and are therefore motivated to sell their property (even though it may be illegal to do so). Conventional agricultural activities cannot compete with the price of urban land.

[119] D. Cymet, *From Ejido to Metrópolis, Another Path, An Evaluation on Ejido Property Rights and Informal Land Development in México City...*, p. 146.

A highly important step was taken during the Salinas administration with respect to agricultural land. In 1992 article 27 of the Constitution was changed to allow for the sale, under certain conditions, of parcels of *ejido* lands (although this did not include communal ejido lands or parcels belonging to indigenous communities). This, in principle, would have generated a more efficient market for land in the peripheral areas, since political groups would no longer have a virtual monopoly on making land available on the outskirts of the city by expropriating ejidos. However, ten years later, things have not worked out this way and very little land has changed hands. Squatting continues, although on a smaller scale, mostly because the authorities from the still-functioning CORETT, who are in charge of regularizing land, are left out of informal accords. With the new legislation there is also a risk that forests or other areas of high ecological value could be subdivided for development.

The problem of the Los Belevederes neighbourhood and the other illegal settlements in the Ajusco was once again addressed, this time by the Salinas administration. The government decided to expropriate only 727 hectares of the middle section of the Ajusco and, by way of the National Program of Solidarity (or PRONASOL), steps were taken to legalize property invaded by squatters and to bring in water, electricity and other urban services. A fence was built around the Reserve Zone to prevent illegal settlement, although squatting still continues.

Further on we will discuss a proposal made in this thesis to generate, precisely in these areas, a large, continuous Low Environmental Impact Perimeter around the metropolitan zone, where farm workers and poor citizens could earn money by providing environmental services and engaging in other activities that protect forests and the sustainability of Mexico City.

It was also during these years that one of the poorest communities in the southeastern part of the city, Chalco, underwent a great deal of expansion. Chalco's growth had begun during the De la Madrid government, but accelerated at the beginning of the 90s, as squatters settled on the Chalco and Ayotla ejidos. Chalco is an old prehispanic town built on the

shore of a lake that has since disappeared. The surrounding area is of notable environmental value. Salinas made Chalco an example of his social development strategy implemented through the PRONASOL. In effect, the land that had been invaded or illegally purchased was legalized, and water, electricity and public services were brought in. Living conditions improved and the area attracted more newcomers, some coming from the city centre (their departure worsening downtown's abandoned state), some from nearby municipalities and even some from other states in Mexico. Although Chalco did not reach maturity (as did Neza, for example), its expansion could affect areas of high environmental value and aquifer recharge zones which lie near its borders with Tláhuac, an area rich in wetlands and farmland, and Xochimilco, where a lake and some chinampas still exist.

Two additional subway lines were built and transportation was deregulated with the introduction of microbuses and taxis called *ecológicos*, an ironic misnomer considering that the highly polluting Volkswagen Bug was still being used. A program to improve gasoline by making it cleaner was begun and catalytic converters were used in new cars. Precise measurement of pollution levels began through the use of an index relevant to and adequate for Mexico City's needs, the Mexican Index of Atmospheric Pollution (IMECA). And, most importantly, the *"Hoy no circula"* program (prohibiting the use of one fifth of the cars, each of the working days of the week) was put into effect in 1989. The program vas successful at the beginning but with the advent of catalytic converters lost most of its relevance.

Carlos Salinas' successor, Ernesto Zedillo (1994-2000), was the last Mexican president of the 20th century and the last of an uninterrupted series of PRI presidents, beginning with Plutarco Elías Calles. During Zedillo's term, Mexico City elected for the first time ever the head of the city government. The elections were won by the opposition candidate, Cuauhtémoc Cárdenas, from the leftwing Party of the Democratic Revolution or PRD. He thereby became the first elected governor (or mayor) of Mexico City. Cárdenas resigned in 1999 to become a presidential candidate in the July 2000 elections, which were to be won by Vicente Fox. Cárdenas was succeeded as governor of Mexico City by two other members of his party, Rosario Robles (1999-2000) and Andrés Manuel López Obrador,

who has been in power since December of 2000. Soon after Zedillo was sworn in, in December of 1994, Mexico was subjected to a traumatic devaluation of its currency and the country again entered an intense recession that lasted throughout 1995. A number of public programs were put on hold and Mexico City felt the full effects of the slowdown. But things started to look up in 1996 and the economy gradually recuperated. By the time Zedillo's term came to an end in December of 2000, growth had reached an acceptable rate.

In terms of economics, Zedillo did not change the neoliberal policy of opening markets and promoting exports; the huge impact of NAFTA on Mexico's economy was by now apparent. There was a boom in imports during these years, especially with manufactured goods. Companies based in Mexico City performed well and continued to be the country's most important exporters. In 1992 the city's total exports were of 8.676 billion dollars, while by 1997 they had reached 20.935 billion, more than doubling in those five years. The textiles and machinery sectors took the lead, although exports diversified in a healthy manner. Mexico City's position as a centre for manufactured exports slipped somewhat with respect to the northern cities, which are home to numerous in-bond assembly plants known as *maquiladoras*.[120] Financial services also diversified and Mexico City continued to be the nation's most important financial centre. The largest Mexican banks opened their doors to foreign investment and have served many international investors. In the 90s the megalopolis began to reorganize its economic structure and it is safe to say that by the end of the 20th century, the metropolitan zone was responding well to some of the challenges presented by globalisation.

Nonetheless, the road ahead is long. A recent study carried out by the Monterrey Institute of Technology (ITESM)[121] indicates that Mexico City not only remains the highest contributor to the GNP and has the highest per capita income, it also has the highest educational level and less than 3% of its population is illiterate. However, according to the ITESM competitiveness index, the city dropped from first place in 1994 to sixth place in

[120] H. Millán, Exportaciones y Servicios Financieros en la Globalización, *La Ciudad de México en el fin del segundo milenio...*, pp. 195-199.
[121] *La competitividad de los estados de la federación*, Instituto Tecnológico de Monterrey, Monterrey, México, 1999

1999. Mexico City came in third for the "power" of its economy measured in terms of infrastructure, finances and telecommunications and eighth in technology production, relative to other Mexican cities. Its effort to become more international has been limited. Despite the fact that the Mexico City metropolitan zone is the country's leading importer and exporter, it came in 25th in foreign promotion, putting it under the national average. The city's poor image abroad earned it 17th place among Mexican cities.

But public federal investment allocated to Mexico City fell dramatically during the Zedillo administration, and was less in absolute terms (and constant prices) than what the city received during Echeverría's government, more than twenty years earlier. This was due in part to the inexperience of the new administrations of Cárdenas and Robles, and in part to the low priority that the federal government gave to the city that was in the hands of the opposition.

Although the Zedillo government was the first to introduce the concept of sustainable development in urban planning, its only real success was to improve air quality, which was achieved through cleaner gasoline (lead was removed), the mandatory introduction of catalytic converters in cars and the continuation of the "*Hoy no circula*" program. Few other environmental gains were made. Despite some success in the fight against photochemical air pollution, audio and visual pollution[122] worsened, as did soil pollution, and an unsustainable model for water management was continued.[123]

The Zedillo administration also promised to protect ecological zones from illegal settlement, not only in the Ajusco area, but also in the Sierra de Santa Catalina to the southeast and the Sierra de las Cruces to the west. The City Legislative Assembly promulgated a new environmental law that would penalize environmental crimes for the first time. However, illegal settlements continued.

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[122] J. L. Lezama, Contaminación auditiva y visual, *La Ciudad de México en el fin del segundo milenio...*, pp. 483-489.

[123] E. Ezcurra, 1999, pp. 77-90; H. Cotler & Christina Siebe, Suelo y Medio Ambiente, *La Ciudad de México en el fin del segundo milenio...*, pp. 469-474.

The government was unable to carry out plans to build an important peripheral highway just 22 kilometres long, that would have gone from La Venta to the Military College, connecting the western (Cuajimalpa) and southern parts of the city. Its construction was indefinitely postponed following the protests of local people who would have been affected. Once again environmental reasons were wrongly cited.

At the end of the Zedillo administration, the economic weight of Mexico City had fallen even more with respect to the beginning of the urban crisis of 1970, although it continued to be Mexico's principle economic, financial and cultural centre, as well as its political capital. But theMCMZ was not able to fully recover from the crisis.

3.8.3 The Megalopolis in the Central Region

The centralisation of investment and decision making in Mexico City between 1940 and 1980 resulted in the conurbation in 1980's of its metropolitan zone with that of Toluca, (to the west) which put the city in the category of megalopolis. Mexico City thereby consolidated itself, at the dawn of the new millennium, as the central node of economic, political, social and cultural activity at the national level. It should be noted that by 1995 Mexico's urban system consisted of 348 cities, defined as population centres with 15,000 or more inhabitants, of which Mexico City was the largest with 16.9 million inhabitants.[124]

The megalopolis' hegemonic position has implications for the sustainable development of not only Mexico City, but also of other surrounding cities that are an integral part of central Mexico's urban landscape. Although these cities occupy a less important position within the region's urban subsystem or "crown of cities," they have a close functional relationship with the megalopolis; Mexico City's economic, social and environmental prospects therefore affect their future. Among the other characteristic processes of this mega-urbanization, we should mention the rapid growth of smaller urban centres, the consolidation of a polycentric urban form, the dispersion of manufacturing production to

[124] G. Garza, coord., *La Ciudad de México en el fin del segundo milenio,* México: Gobierno del Distrito Federal, El Colegio de México, 2002, 768 p.

selected cities and the increase in the flows of people, merchandise and information within the system of settlements in this region.[125]

Despite the fact that Mexico City's demographic growth has slowed down markedly and its physical growth is limited by geographic factors, and notwithstanding the emergence of other large economically active cities in the north of Mexico as a result of NAFTA, the "critical mass" of the megalopolis –which is considered to be the second most populated in the world-- has been a determining factor in causing other cities to gravitate towards it, especially those that are part of the crown of cities, such as Toluca, Cuernavaca, Pachuca, Puebla and Querétaro, among others minor towns. .

According to Garza, in 1970 these cities had a total of 10.6 million inhabitants, who represented 22% of the country's total population and 47.5% of its urban population. The number of people living in the cities in the urban subsystem of Mexico City more than doubled in the last 30 years, reaching in 2000 a total of 23.2 million and a 23.8% share of the nation's population.[126]

It is important to stress that, in contrast to the relatively slow growth of Mexico City, the cities of Puebla, Cuernavaca, Querétaro and Pachuca expanded rapidly, at an annual rate of 6% between 1980 and 1990, and by 3.4% between 1990 and 1995. It should also be pointed out that Mexico reached its highest level of population concentration in 1980, when 19.4% of all Mexicans lived in the capital. The point of inflection in the concentration trend occurred with the reduction of this proportion in 1990 to 18.8%, and in 2000 to 18.4%.[127]

In terms of migratory movements, Mexico City has attracted fewer and fewer national emigrants over the last few decades, with the proportion who chose the city dropping from 47.8% between 1965 and 1970 to 29.1% between 1985 and 1990.

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[125] A. G. Aguilar, Localización geográfica de la Cuenca de México, *La Ciudad de México en el fin del segundo milenio...*, pp. 31-38.
[126] G. Garza, Ámbitos de Expansión Territorial, *La Ciudad de México en el fin del segundo milenio...*, pp. 244-245.
[127] G. Garza, coord., *La Ciudad de México en el fin del segundo milenio...*, 768 p.

Beyond socio-political concerns, there are a number of determining factors that could be attributed to the point of inflection in population concentration mentioned above. Most, however, are directly related to the consequences of the big environmental problems that were created in past decades and which are discussed throughout this thesis, such as high levels of air pollution, the inefficiency of the public transportation system and roadway infrastructure, the degradation of green areas and the landscape in general, the lack of formal housing markets, the deficiencies of urban solid waste management or the general low quality of water supplied to the city's population, to mention only those points related to the environment.

Besides the phenomenon of urban decline, sustainability problems of a social nature should be taken into consideration, such as high crime rates and violence, urban marginalisation, the reduction of opportunities caused by recurrent crises and the general deterioration of the quality of life in the city in comparison to other periods.

On the other hand, in contrast to the presence of diseconomies of agglomeration (pollution, crime, etc.), forces exist which, as generators of economies of agglomeration, favour urban expansion and demographic growth. The most important of these are the processes of tertiarization and digitalization of the megalopolis' economy, which are possible thanks to the city's large population. That is, despite intra-urban inequality, the existence of a large consumer market, with its "critical mass," allows for the recovery of investment in sectors of a much larger aggregated value, such as in financial, educational and research and development services –or professional services in general.

Proof of these processes was made especially evident during the Salinas administration, when investment and the real estate business in the Federal District were booming, and a number of office buildings, corporate centres and shopping centres were built at an amazingly rapid pace.[128] The city thus set itself up as an economic pole where political power, the media, innovative technologies and high-level corporate administration and decision making became concentrated.

[128] M. E. Negrete Salas, Dinámica Demográfica, *La Ciudad de México en el fin del segundo milenio...*, p. 252.

With the more widespread use of information technologies, the city's condition as the nation's most important consumer market is also a determining factor for recouping the investments needed to bring about greater penetration of digital technologies.

The concentration on services (or "tertiarization") and digitalisation of the megalopolis' economy will lead to a higher proportion of less environmentally intensive activities, and presumably both factors will bring the city closer to a scenario of environmental sustainability, a possibility we will examine in more detail later on.

Hopefully, the combined effect of these two forces will be to reverse the megalopolis' urban decline, without necessarily affecting the stabilisation of population growth rates, which are the product of a demographic transition taking place throughout Latin America. In the absence of the processes that led to urban concentration in the past, on the one hand, and with growth of the "crown of cities" expected to continue at a higher rate than the megalopolis, on the other, the reconfiguration of Mexico City's mix of economic activities should strengthen and diversify its functional relations with the cities in its urban subsystem, especially Cuernavaca, Puebla, Pachuca and Querétaro.

Although in the future a great many industries and offices are expected to leave the megalopolis for less congested areas to reduce the inherent costs of their economic activities, any large network requires a great centre of distribution, where specialized services are offered, a fact that could help Mexico City regain its economic importance.

For some specialists,[129] urban primacy, in its being associated with regional income distribution imbalances and with generally unequal opportunities for economic development, could be a serious symptom of underdevelopment. However, in a more recent context, it has been pointed out that this association is not entirely substantiated, since the

[129]Unikel, L, Ruiz C. C. and V. G. Garza., *El Desarrollo Urbano de México, Diagnóstico e Implicaciones futuras* .El Colegio de México, 1976, 466 p.

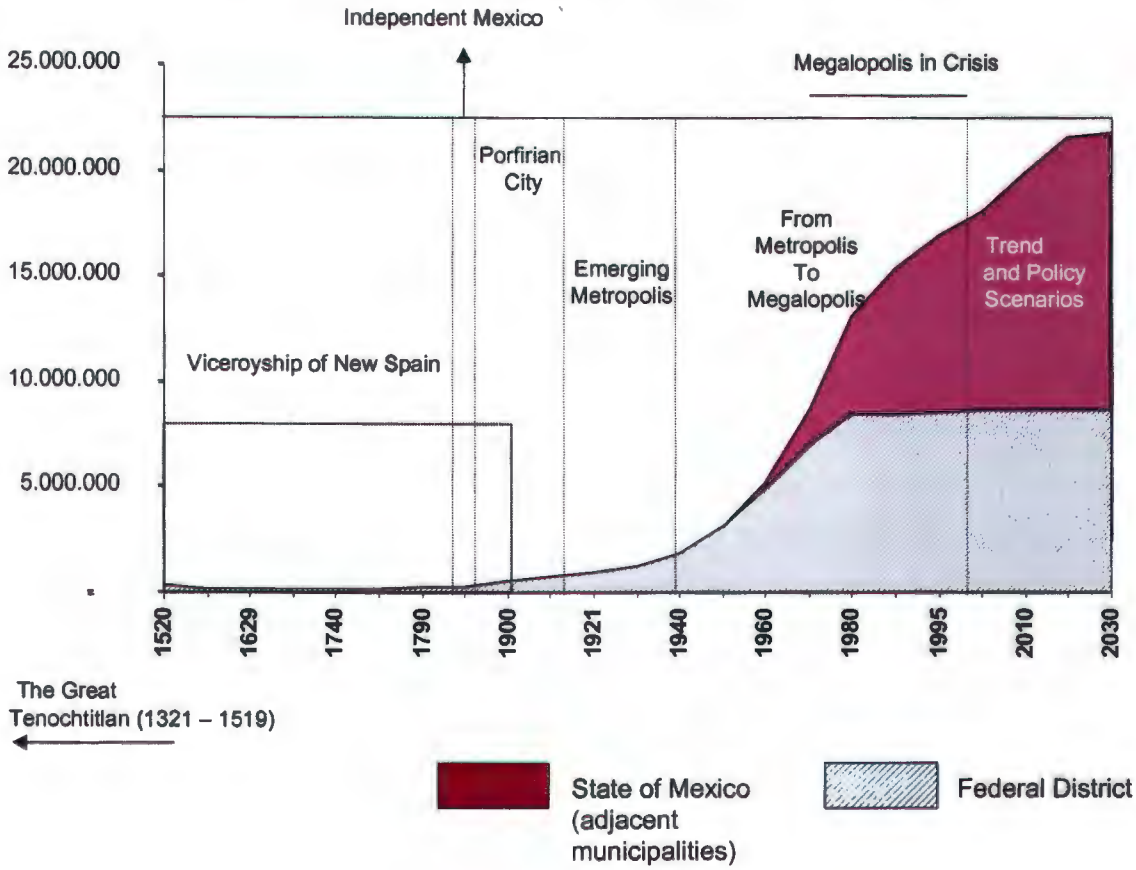
majority of developed economies depend, to a large extent, on the economies of agglomeration that exist in their principle urban centres.[130]

Perhaps a succession of stages with a necessary point of inflection would cause functional relations with other urban centres to yield benefits that were regionally disseminated, such as in the case of Mexico City. In other words, "megaurbanization should be described as a process with a regional foundation, instead of as an urbanization with an urban foundation, due to the territorial scope that the process' dynamic has (...)."[131]

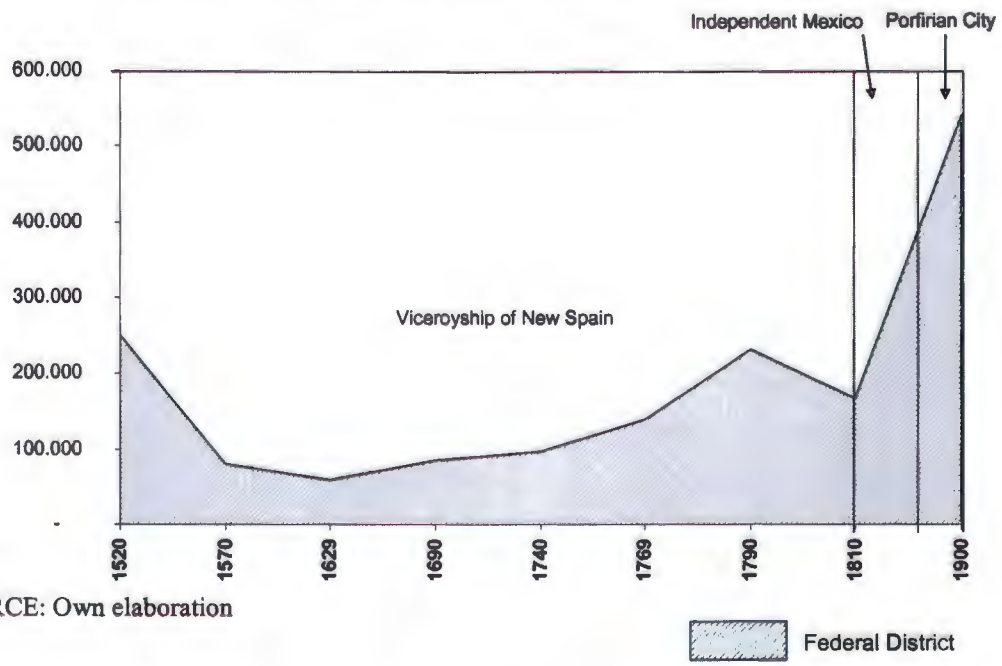
There is no avoiding the fact, however, that this process will be accompanied by new environmental challenges, especially in terms of the zoning policies in the border areas that divide urban and rural zones, since they are characterized by their concentration of businesses along the length of the main highways that connect the megalopolis with the "crown of cities," the rapid growth of small urban centres and the arrival of manufacturing activities to backward rural zones.

[130] G. Garza, 1985.
[131] A. G. Aguilar, Localización Geográfica de la Cuenca de México, *La Ciudad de México en el fin del segundo milenio...*, p. 79.

GRAPH 3.1
Mexico City Population: Historical Evolution, 1520 to 2030



GRAPH 3.2
Mexico City Population: Historical Evolution, 1520 to 1900



SOURCE: Own elaboration

CHAPTER 4

TREND SCENARIOS FOR THE MEXICAN MEGALOPOLIS

Let us now discuss about the actual trends that will shape Mexico City's future. Some are well established trends such as the demographic and even some structural economic changes that were noticeable even 15 or 20 years ago. But others relate to entirely new phenomena such as the technological revolution the goes hand in hand with globalization. In a second part of the chapter we analyze the basic trends of key sustainability variables.

4.1 General Perspectives of the Demographic Composition

As we discussed earlier, Mexico is currently undergoing the well established phenomenon of demographic transition. In the first phase, this process is identifiable because mortality rates fall faster than fertility rates do, generating high rates of population growth. Later, with the drop in fertility rates, the global rate tends to stabilise itself. During this phase, the structure of the population is predominately formed by inhabitants of a working age. This, in turn, represents an opportunity for the growth of an economy, as long as adequate policies are implemented to balance labour demand and supply.

Mexico City[1] is expected to finalize such demographic transition before the rest of the country does because its indexes of education, relatively higher than the national average, favours a faster drop in fertility rates to take place. Proof of this is that over the last few years, the rates of mortality and fertility have already displayed behaviours that are much more moderate than they are in the rest of the country.

The population of children under the age of five will decrease annually as an effect of this phenomenon. This proves to be extremely important, since the demand for urban facilities and public services will change their composition as a result of the needs of a population

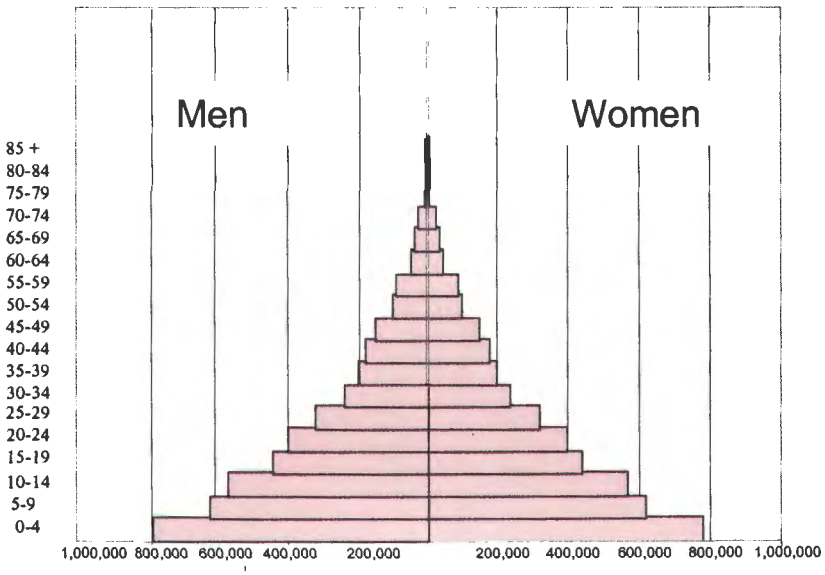
[1]For all the quantitative analyses that are presented hereinafter, "Mexico City" will be considered equivalent to "Mexico City Metropolitan Zone".

with fewer children. With it, this will bring about a lesser need for space for elementary and middle schools, but more for secondary and higher levels of education.

The 1970s was characterised by fertility rates that, even when they showed a downward trend, were considerably high compared to those of other countries in the world. That decade is the last phase of a period that began in 1950 and that was characterised by the highest population growth in Mexico City.

As mentioned in the last chapter, the presence of a closed economy and Industrialisation through Import Substitution model (ISI) in that decade propitiated concentration in Mexico City, generating in turn high rates of migration to the nation's capital. Immigrants to the capital rose from 825 thousand in 1965 - 1970 to almost a million in 1975 - 1980. It can be said that this demographic dynamics directly or indirectly gave birth to most of the environmental sustainability problems the City currently faces.

GRAPH 4.1
Population Pyramid for Mexico City, 1970



SOURCE: Graph is by author and is based on demographic and urban scenarios of MCMZ 1990 - 2010.

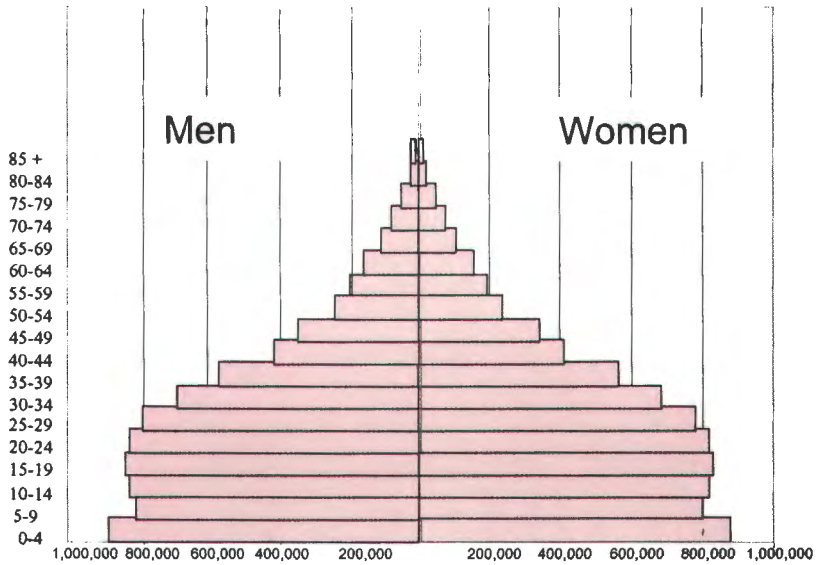
The last two decades were characterised by a deceleration of the population growth in Mexico City. The number of immigrants to the City registered between 1985 and 1990 dropped considerably to 559,000 compared to almost one million in the previous decade. Even though most of the emigrants from the Federal District moved to the adjacent metropolitan municipalities in the State of Mexico, a negative migration rate for the city took place in this period for the first time ever.[2]

Migration to the capital of the country had its culminating moment in 1970, when the influx of immigrants represented 38.2% of all interstate moves in the country. Since then, its importance has diminished to the point that, by the end of the 20th century, growth in the capital became practically zero.[3]

Furthermore, the fertility rate in the Federal District dropped from 5.24 children per woman in 1970 - 1975 to 3.36 in 1980 - 1985 to 2.27 during the period from 1990 - 1995. In the State of Mexico, this process was faster and the fertility rate reached 6.38, 4.10 and 2.71 respectively. Thus, 1990 Census data demonstrated that the population of the City would never reach beyond 24 or 27 million inhabitants, which proves vital in re-establishing and re-assessing the sustainability problems in said city.[4] As mentioned in Section 3.8.3, between 1990 and 1995, Mexico City had a lower growth rate than other cities such as Puebla, Cuernavaca, Querétaro and Pachuca, while the maximum level of population concentration in Mexico City was reached about 1980.

[2]However, inter-metropolitan flows are the main cause of the physical expansion of urban sprawl. See M. E. Negrete Salas, Migración, *La Ciudad de México en el fin del segundo milenio*, G. Garaza coord..., p. 268.
[3]M. E. Negrete Salas, Migración, *La Ciudad de México en el fin del segundo milenio,* G. Garza coord..., pp. 265-278.
[4]A. Rowland & P. Gordon, *Mexico City: No Longer a Leviathan?, The Megacity in Latin America,* United Nations University Press, Tokyo, Japan, 1986: pp. 172-203.

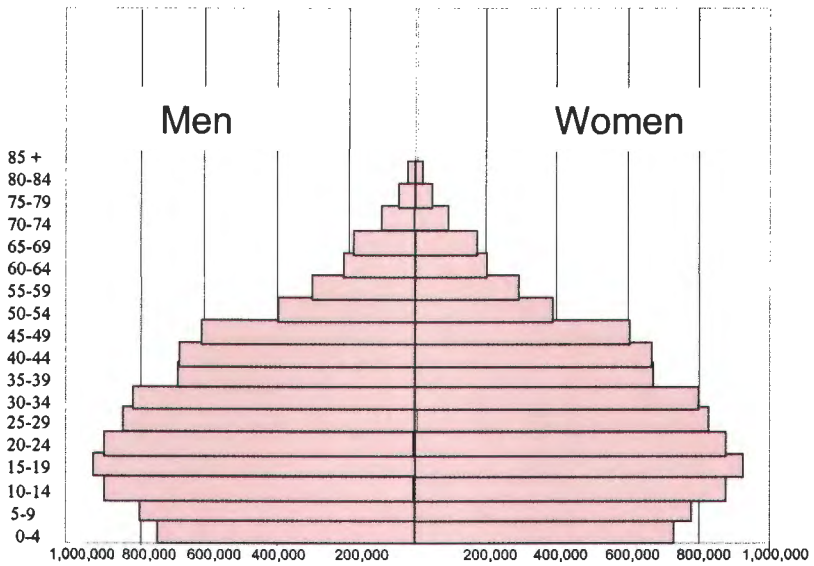
GRAPH 4.2
Population Pyramid for Mexico City, 1995



SOURCE: Graph is by author, and is based on CONAPO Projections: Demographic and Urban Scenarios of the MCMZ., *1990 - 2010*. Mexico,1999.

As a result of this period of demographic transition in Mexico City economically active age groups are expected to increase their participation in the work force, thus creating an opportunity for the economic growth of the city.

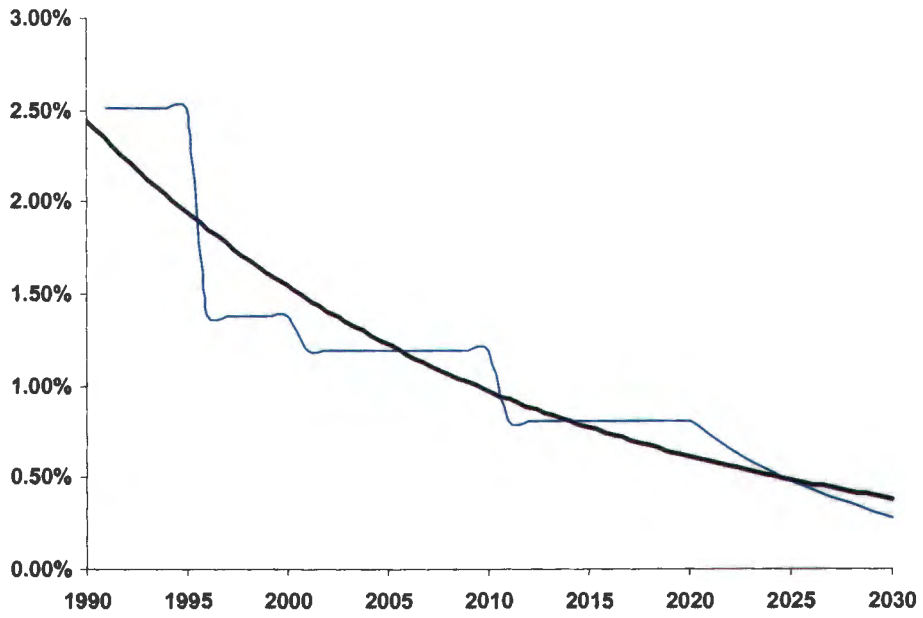
GRAPH 4.3
Population Pyramid for Mexico City, 2010



SOURCE: Graph is by author, and is based on CONAPO Projections: Demographic and Urban Scenarios of the MCMZ, 1990 - 2010. Mexico.

This process will also imply stability in the global rate of growth in the population, which will bring about a "window of opportunity" to improve the living conditions of City inhabitants. Meanwhile, the economic growth will allow for the implementation of processes and mechanisms to reach higher levels of sustainability.

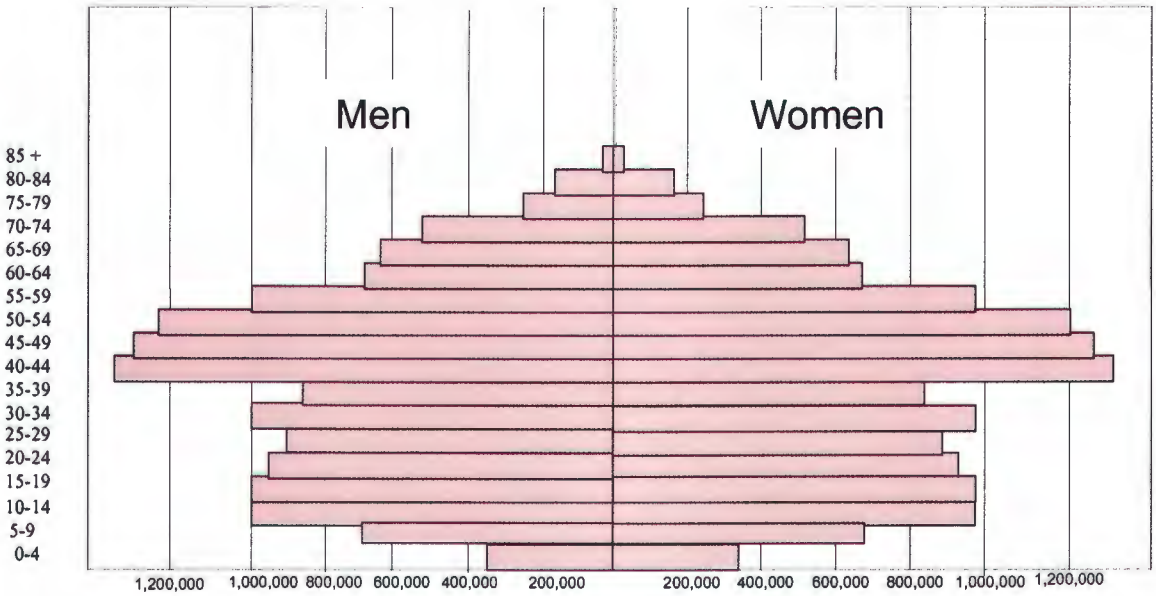
GRAPH 4.4
Expected Rate of Population Growth, 2000 to 2030



SOURCE: Graph is by author, and is based on the analysis of the following sources: CONAPO Projections. *Escenarios demográficos y urbanos de la Zona Metropolitana de la Ciudad de México, 1990-2010.* Mexico, 1999; Unikel Spector, Luis; Borah, Calnek, et. al. *La Dinámica de Crecimiento de la Ciudad de México*; F. Covarrubias, Prospectivas de la Urbanización en la Ciudad de México in *Mercado de Valores*, Abril 2000.

The average age of the general population in Mexico City is expected to rise by the end of the demographic transition. There will still be a significant proportion of the working age population. Therefore, it is possible to say that even in this decade, the current situation in demographic terms could be taken advantage of to amend many of the deficiencies in the areas of economics and the environment. However, it must be taken into consideration that one of the challenges will be the increase of the dependency ratio. This challenge implies the need to foresee the necessities of the most vulnerable sectors of the population (children and the elderly).

GRAPH 4.5
Population Pyramid of Mexico City, 2030



SOURCE: Graph is by author, and is based on *Escenarios demográficos y urbanos de la Zona Metropolitana de la Ciudad de México, 1990 - 2010.* Mexico, 1999. Data for 2030 is estimated according to the growth rate trends for the different five-year age groups from 1970 to 2010.

The participation of population over 65 years old will continue to grow from 3.6% in 1990 to 6.4% in 2010. This will therefore become another reason for which the composition of public services in the City should change.

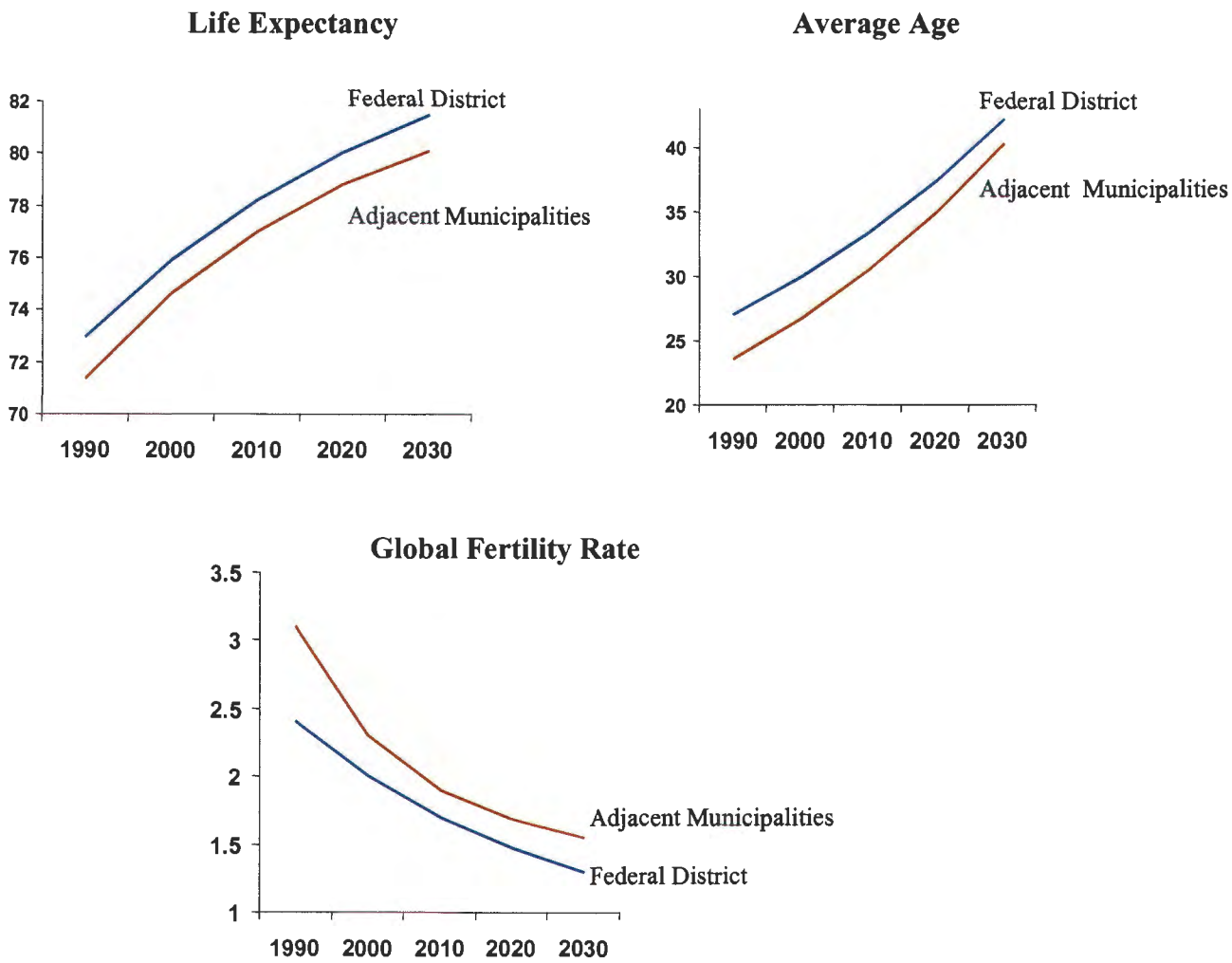
In terms of the population at a working age, in 1990 the median age stood at 22.2 years old, but it is expected to continue to rise to 29.4 in 2010. Together, the importance of the population between 15 and 64 will increase overall in such a way that the group that is formed of the economically active population will grow from 62.8% in 1990 to 70.3% in 2010. This will be a determining factor in reaching the high levels of economic growth the City will need in the future.

On the other hand, we should consider that the diversity that characterises an urban area in terms of economic activities and the process of population displacement towards peripheral areas also related to said activities are closely linked to a series of demographic variables among the different regions of Mexico City.

There are marked contrasts between the Federal District and the adjacent municipalities of the state of Mexico. In the upcoming years, the ageing population in the Federal District will grow in comparison to that of the adjacent municipalities. However, the rate of dependency (the sum of those under 15 and older than 65 divided by the total population) will stand at 0.46 in the adjacent municipalities and at 0.40 in the Federal District.

Since the process of integrating some municipalities of the State of Mexico into Mexico City the MZMC is a relatively recent phenomenon (in the 70s), there is still a process of convergence in demographic terms. In other words, as to the relevant variables in the phenomenon of demographic transition, the adjacent municipalities are behind the Federal District. In a span of thirty years, life expectancy will rise faster, the global fertility rate will fall faster, infant mortality will decrease faster in the Federal District. This trend is observed in other variables in comparisons made between the Federal District and adjacent municipalities, as seen in Graph 4.6.

GRAPH 4.6
Selected Demographic Indicators



SOURCE: CONAPO. *Escenarios demográficos y urbanos de la Zona Metropolitana de la Ciudad de México, 1990-2010*, México, 1999.

In summary, it can be said that Mexico City has gone through a demographic transition process that is characteristic of mature developing countries. However, this process has been much faster compared to that of the rest of the country due to, among other factors, higher levels of education in its population. This allowed for a much faster decrease in fertility rates than in other cases nation-wide. The City currently faces a situation of stabilisation in global rates of population growth. Therefore, it is valid to say that in demographic terms, "the worse is over" and in consequence, the same also happens in many ways in the issue of environmental sustainability.

Furthermore, the demographic transition that the City faces implies more participation from the working age population, which translates into what we call the "window of opportunity" that could be used to generate higher rates of economic growth and thus a more favourable situation for sustainability processes.

4.2 Socio-economic Characteristics of the Population

The socio-economic dimensions of Mexico City are vital in understanding all other economic and environmental processes in the city that will naturally be decisive for the challenges in looking towards the year 2030. These aspects principally include the level of education, the differences in socio-economic levels which are measured mainly by levels of income or consumption and others such as private property, crime or religious idiosyncrasies.

As to indicators of education, the City has always had the highest levels of schooling and over time has concentrated an important part of the educational infrastructure. This concentration was significantly salient with the creation of several universities, such as the UNAM[5] CCH[6] and ENEP[7], and the UAM[8], located in then peripheral areas of the city, in the sixties.

[5] UNAM stands for "Universidad Nacional Autónoma de México".
[6] CCH stands for "Colegio de Ciencias y Humanidades" and it is a kind of high school within the UNAM education system.

Even though high indexes have been reached in all levels of education in the City, it should be stressed that there are still significant disparities within. For example, while in 1990, 91% of the population in the Benito Juárez delegation had completed primary education, only 63.5% did in the Chalco municipality. Thus, great contrasts are found between adjacent municipalities and Federal District delegations. The same occurs in middle school education.

However, it is important to note that due to the importance of the informal economy in municipalities with lower levels of education, this translates into an unbalance in the indicator of income by years of schooling.[9]

TABLE 4.1
Percentage of Population over 15 Finishing Primary School, 1970 - 1990

	1970	1980	1990
Mexico City	**27.8**	**72.2**	**80.2**
Federal District	**29.6**	**75.5**	**82.6**
Adjacent Municipalities	**21.2**	**65.4**	**79.9**

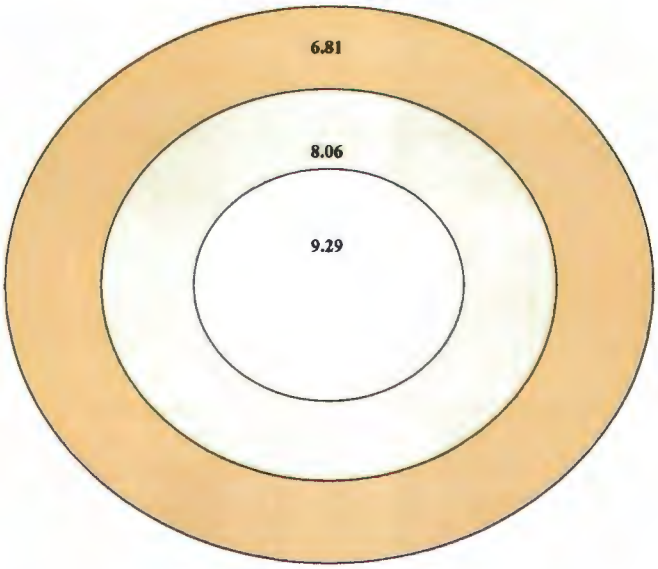
TABLE 4.2
Percentage of Population over 15 Finishing Middle School, 1970- 1990

	1970	1980	1990
Mexico City	**5.10**	**37.30**	**51.50**
Federal District	**5.70**	**41.20**	**55.50**
Adjacent Municipalities	**3.10**	**29.40***	**46.20**

SOURCE: CONAPO. *Escenarios Demográficos y Urbanos de la Zona Metropolitana de la Ciudad de México, 1990 - 2010*, México, 1995.
*The change is due to the great number of municipalities that were integrated into Mexico City or merged into the urban sprawl, between 1970 and 1980.

[7] ENEP stands for "Escuela Nacional de Educación Preparatoria" and is a kind of high school within the UNAM education system.
[8] UAM stands for "Universidad Autónoma Metropolitana".
[9] A. Calderón, El DF y otros problemas, *Nexos*, October, 1997, pp. 53-64.

FIGURE 4.1
Years of Schooling in Mexico City, According to Urban Rings, 1995



SOURCE: Graph is by author, and is based on information from the *Conteo de Población*, INEGI, México, 1995.

On the other hand, regional distribution of income in Mexico City is directly related to other social and economic processes. Some examples are the displacement of population towards peripheral areas and the fact that many of these municipalities have recently merged into the urban sprawl or are still in the process of such consolidation.[10] Other examples are the distribution of economic activities with more importance placed on the industry in the adjacent municipalities and more participation of the service sector in Mexico City delegations. All of these are demographic dynamics that show there is a more economically active population in central delegations at present. As mentioned in Section 3.8.3, the existence of a large consumer market in Mexico City allows service activities and digitalisation to advance more every day.

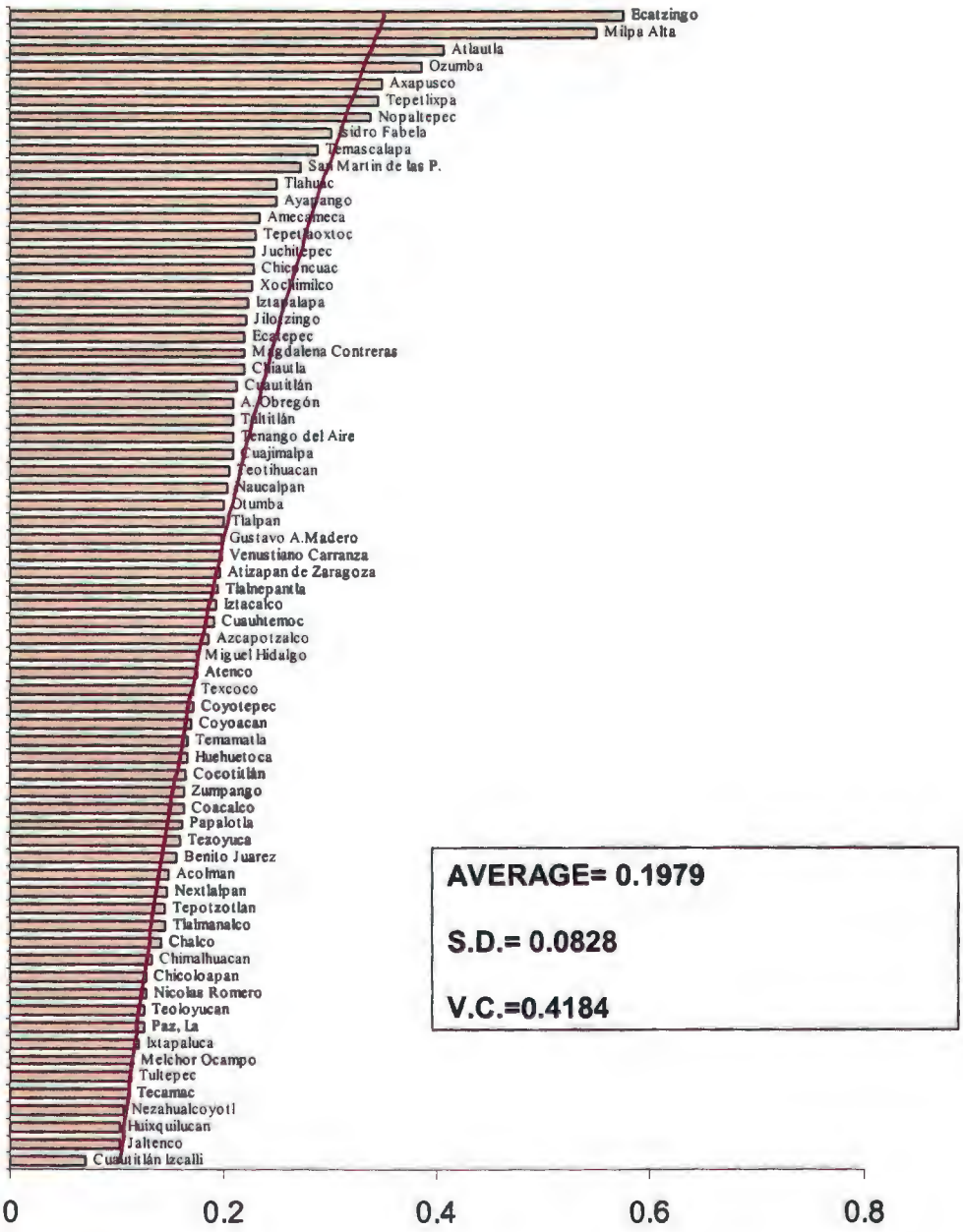
[10]Even then, recent studies show the possibility that lesser state participation, resulting from structural reforms carried out in the 80s, could be holding back said process of consolidation since supplies of housing and services depend more on the income of the population. See R. M. Rubalcaba & M. Schteingart, *Segregación Socioespacial, La Ciudad de México en el fin del segundo milenio..., pp. 287-296.* However, it must be noted that in the years of structural reforms, public spending was not reduced in real terms. See A. Damián, Pobreza Urbana, *La Ciudad de México en el fin del segundo milenio...,* pp. 297-302.

Hence, the areas with higher levels of income are the central delegations and the municipalities that are adjacent to north-eastern Mexico City. Meanwhile, the further away a municipality is from this area, the more its levels of income tend to fall almost proportionally, as if the circles that determine the behaviour of this variable around the central area truly existed.

As can be seen in Graph 4.7, there are marked differences between the delegations and adjacent municipalities of Mexico City, in terms of social and economic marginalisation. If the percentage of people earning less than minimum wage in 1990 were measured, the result would be a large concentration of marginalized population in suburban areas in the northeast and southeast of the city. The areas with the highest levels of poverty are Ecatzingo (57%), Atlautla (41%), and Tepetlixpa (34%).

GRAPH 4.7

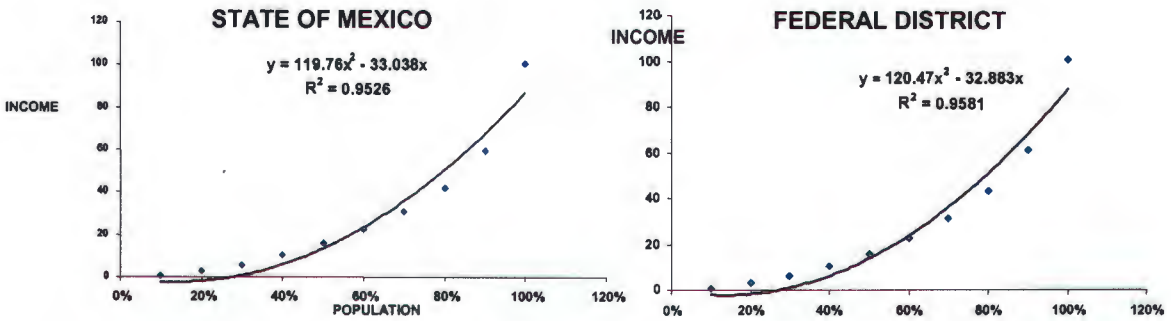
MCMZ: Percentage of the Population Earning less than Minimum Wage, 1990



SOURCE: INEGI. *XI Censo General de Población y Vivienda*, México, 1990.

Even though the Gini Coefficient (calculated with exactly the same methodology in both cases) gives very similar results for the State of Mexico and the Federal District, the highest value for the former is surely due to the regional pattern that income distribution follows in the adjacent municipalities of the MZMC.

GRAPH 4.8
MCMZ: Gini Coefficient and the Lorenz Curve



GINI COEFFICIENT: 0.53198

GINI COEFFICIENT: 0.52569

SOURCE: Graph is by author, and is based on information *from Encuesta Nacional de Ingresos y Gastos de los Hogares*, México, INEGI, 1996., using Excel 5.0

In summary, it can be said of the socio-economic characteristics in the City that even though it has always had the highest levels of education in the country, there are marked inter-regional disparities, especially when comparing delegations in the Federal District with municipalities in the State of Mexico. The differences between the two are striking, as in the cases of the Benito Juárez delegation with 91% of the population having completed primary education and the municipality of Chalco with 63.5% of the population having completed primary school.

In terms of distribution of income, there are also significant inter-regional disparities. Comparing the percentage of the population that in 1990 earned less than minimum wage in all the areas that form Mexico City (municipalities and delegations), it is possible to obtain a very high Variation Coefficient of 0.4184 (Standard deviation / average). Considering the Gini coefficient and calculating it using the same procedure for each state (the Federal District and the State of Mexico), this indicator is very high in both cases, thus confirming that there is significant unbalance in the distribution of income throughout the City.

4.3 Urban Form and Expansion

Although there is no large organised body of knowledge as to the development of Latin American mega-cities, including Mexico City, different studies and theoretic approaches show that there are at least variables and inter-relationships that should definitely not be ignored in a study of this kind. These variables and inter-relationships reveal a pattern of spatial affinity with a distribution that is similar to that of a set of concentric rings defined according to the common denominators in question.[11]

Generally, the concepts that should be taken into account are the following:

I. Characteristics of the population (growth, gender, size, etc.)
II. Dimensions and Housing Shortages (energy, water, drainage and sewers, etc.)
III. Economic Factors (work force, unemployment, etc.)
IV. Social Class (education, level of incomes, etc.)

Based on the analysis of these topics by means of corresponding variables, it is possible to theoretically define the existence of a general model in Latin American cities, like Mexico City, in which there are three clearly observable concentric rings.

[11]See A. Rowland & P. Gordon, *Mexico City: No longer a leviathan? The Megacity in Latin America,* Tokyo Japan: United Nations University Press, 1986, pp. 173-203.

The first ring finds itself in a phase of population decline and consolidation of the trade and service sectors. The second is distinguished in that it conforms to the areas in which they are already or about to consolidate themselves in terms of urbanisation. Furthermore, there is a higher concentration of industrial activity. The third ring is characterised by having human settlements of recent conurbation, with high rates of population growth, some industrial activity and low levels of activity in the service sector.

So far, there is a coincidence between Latin American and non-Latin American cities. However, the former have the added trait of comprising areas that coincide with the different rings, as in the case of residential areas near industrial areas or areas where industrial activity co-exist with commercial activity in the first ring in which human settlements are in decline.

In the specific case of Mexico City, based on the historic evolution of population growth rates, a study was carried out to define the delegation / municipal composition of the urban rings in question. In the rest of this thesis and starting with the proposed groupings, reference will be made to the analysis of said urban rings so as to present the dimensions of each issue within the context of the inter-regional unbalance in Mexico City.

First Ring: Population Displacement

This ring consists of seven delegations in the Federal District and one adjacent municipality of the State of Mexico. These areas have been historically characterised by very high rates of growth in the decade of 1950 - 1960, but they began to fall in the following decades, until they become negative between 1970 and 1990. This phenomenon took place as a result of the process of displacing the population to other urban rings in the City and the consolidation of the trade and service sectors in this ring, confirming with this data the above mentioned Turner Model (see page 140-141.)

TABLE 4.3

Population in the First "Urban Ring", 1950 to 1990

DELEGATION / MUNICIPALITY	POPULATION					AGR*			
	1950	1960	1970	1980	1990	1950-60	1960-70	1970-80	1980-90
Azcapotzalco	187,864	370,724	534,554	601,524	474,688	7.03%	3.73%	1.19%	-2.34%
Benito Juárez	356,923	537,015	605,962	544,882	407,811	4.17%	1.22%	-1.06%	-2.86%
Cuauhtémoc	1,053,722	1,072,530	927,242	814,983	595,960	0.18%	-1.45%	-1.28%	-3.08%
Gustavo A. Madero	204,833	579,180	1,186,107	1,513,360	1,268,068	10.95%	7.43%	2.47%	-1.75%
Iztacalco	33,945	198,904	477,331	570,377	448,322	19.34%	9.15%	1.80%	-2.38%
Miguel Hidalgo	454,868	650,497	648,236	543,062	406,868	3.64%	-0.03%	-1.75%	-2.85%
Venustiano Carranza	369,282	572,091	721,529	692,896	519,628	4.47%	2.35%	-0.40%	-2.84%
Tlalnepantla	29,005	105,447	366,935	778,173	702,807	13.78%	13.28%	7.81%	-1.01%
TOTAL C1	**2,690,442**	**4,086,388**	**5,467,896**	**6,059,257**	**4,824,152**	**4.27%**	**2.96%**	**1.03%**	**-2.25%**

SOURCE: CONAPO. *Escenarios Demográficos y Urbanos de la Zona Metropolitana de la Ciudad de México, 1990 - 2010*, México, 1999.
*AGR stands for "Average Growth Rate".

Second Ring: Industrial Concentration

This ring is formed of 18 administrative entities, seven of which are delegations in the Federal District and eleven are adjacent municipalities in the State of Mexico. The common trait, in terms of population growth, is the presence of growth rates that were very high from 1950 to 1980, but the trend has stabilised in recent years. Only in a few cases have these growth rates become negative because they are areas that are still in the process of urban consolidation and a significant proportion of industrial activity of Mexico City's Metropolitan Zone has concentrated in them.

TABLE 4.4

Population in the Second "Urban Ring", 1950 to 1990

DELEGATION / MUNICIPALITY	POPULATION					AGR			
	1950	1960	1970	1980	1990	1950-60	1960-70	1970-80	1980-90
Álvaro Obregón	93,176	220,011	456,709	639,213	642,753	8.97%	7.58%	3.42%	0.06%
Atizapán de Zaragoza	4,827	8,069	44,322	202,248	315,192	5.27%	18.57%	16.39%	4.54%
Chicoloapan	3,229	4,719	8,750	27,354	57,306	3.87%	6.37%	12.07%	7.68%
Coacalco	2,315	3,984	13,197	97,353	152,082	5.58%	12.72%	22.12%	4.56%
Coyoacán	70,005	169,811	339,446	597,129	640,066	9.27%	7.17%	5.81%	0.70%
Cuajimalpa	9,676	19,199	36,200	91,200	119,669	7.09%	6.55%	9.68%	2.75%
Ecatepec	15,226	40,815	216,408	784,507	1,218,135	10.36%	18.15%	13.75%	4.50%
Huixquilucan	13,491	16,229	33,527	78,149	131,926	1.86%	7.53%	8.83%	5.38%
Iztapalapa	76,621	254,355	522,095	1,262,354	1,490,499	12.75%	7.46%	9.23%	1.68%
Magdalena Contreras	21,955	40,724	75,429	173,105	195,041	6.37%	6.36%	8.66%	1.20%
Naucalpan	29,876	85,828	382,184	730,170	786,551	11.13%	16.11%	6.69%	0.75%
Nezahualcoyotl			580,436	1,341,230	1,256,115			8.74%	-0.65%
Cuautitlán Izcalli				173,754	326,750				6.52%
Tláhuac	19,511	29,880	62,419	146,923	206,700	4.35%	7.64%	8.94%	3.47%
Tultitlán	9,237	15,479	52,317	136,829	246,464	5.30%	12.95%	10.09%	6.06%
Xochimilco	47,082	70,381	116,493	217,481	271,151	4.10%	5.17%	6.44%	2.23%
Chimalhuacán	13,004	76,740	19,946	61,816	242,317	19.42%	-12.61%	11.98%	14.64%
La Paz	4,194	7,880	32,258	99,436	134,782	6.51%	15.14%	11.92%	3.09%
TOTAL, C2	**433,425**	**1,064,104**	**2,992,136**	**6,860,251**	**8,433,499**	**9.40%**	**10.89%**	**8.65%**	**2.09%**

SOURCE: CONAPO. *Escenarios Demográficos y Urbanos de la Zona Metropolitana de la Ciudad de México, 1990 - 2010*, México, 1998.

Third Ring: Process of Conurbation

This ring is formed of 16 administrative entities, only two of which are delegations in the Federal District and the rest are adjacent municipalities of the State of Mexico. In the last decades, all of these areas have been characterised by maintaining positive growth rates with a decreasing trend, though in some cases, they continue very high (Tultepec, Jaltenco, Chalco, etc.).

TABLE 4.5

Population in the Third "Urban Ring", 1950 to 1990

DELEGATION / MUNICIPALITY	POPULATION					AGR			
	1950	1960	1970	1980	1990	1950-60	1960-70	1970-80	1980-90
Acolman	9,422	12,230	20,964	32,316	43,276	2.64%	5.54%	4.42%	2.96%
Atenco	5,424	7,341	10,616	16,418	21,219	3.07%	3.76%	4.46%	2.60%
Chalco	22,056	29,725	41,450	78,393	282,940	3.03%	3.38%	6.58%	13.70%
Ixtapaluca	10,787	20,472	36,722	77,862	137,357	6.62%	6.02%	7.81%	5.84%
Jaltenco	2,767	3,322	4,738	7,847	22,803	1.84%	3.61%	5.17%	11.26%
Melchor Ocampo	4,928	6,537	10,834	17,990	26,154	2.87%	5.18%	5.20%	3.81%
Milpa Alta	18,212	24,379	33,694	53,616	63,654	2.96%	3.29%	4.75%	1.73%
Nextlalpan	2,611	3,602	4,360	7,380	10,840	3.27%	1.93%	5.40%	3.92%
Nicolás Romero	23,346	29,617	47,504	112,645	184,134	2.41%	4.84%	9.02%	5.04%
Tecámac	9,104	11,971	20,882	84,129	123,218	2.78%	5.72%	14.95%	3.89%
Teoloyucan	7,446	9,939	15,477	28,836	41,964	2.93%	4.53%	6.42%	3.82%
Texcoco	32,265	42,525	65,628	105,851	140,368	2.80%	4.43%	4.90%	2.86%
Tultepec	5,517	7,744	11,480	22,910	47,323	3.45%	4.02%	7.15%	7.52%
Zumpango	17,498	22,677	36,105	51,393	71,413	2.63%	4.76%	3.59%	3.34%
Tlalpan	32,767	61,195	130,719	368,974	484,866	6.45%	7.89%	10.93%	2.77%
TOTAL, C3	**204,150**	**293,276**	**491,173**	**1,066,560**	**1,701,529**	**3.69%**	**5.29%**	**8.06%**	**4.78%**

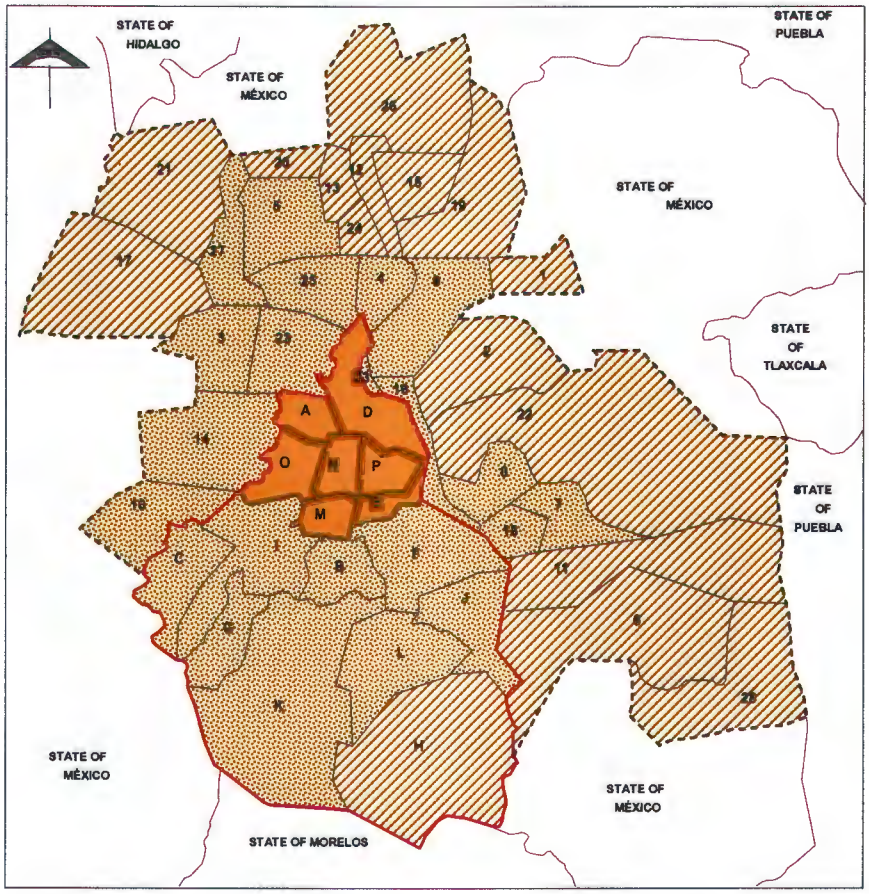
SOURCE: CONAPO. *Escenarios Demográficos y Urbanos de la Zona Metropolitana de la Ciudad de México, 1990 - 2010*, México, 1998.

The following illustrates the way in which the proposed distribution of the different Federal District delegations and adjacent municipalities of the State of Mexico would look in urban rings (see Map 4.1).

MAP 4.1
Geographic Grouping of Municipalities / Delegations in the City by Urban Rings

DELEGATIONS

A AZCAPOTZALCO
B COYOACÁN
C CUAJIMALPA DE MORELOS
D GUSTAVO A. MADERO
E IZTACALCO
F IZTAPALAPA
G MAGDALENA CONTRERAS
H MILPA ALTA
I ALVARO OBREGÓN
J TLÁHUAC
K TLALPAN
L XOCHIMILCO
M BENITO JUÁREZ
N CUAUHTÉMOC
O MIGUEL HIDALGO
P VENUSTIANO CARRANZA



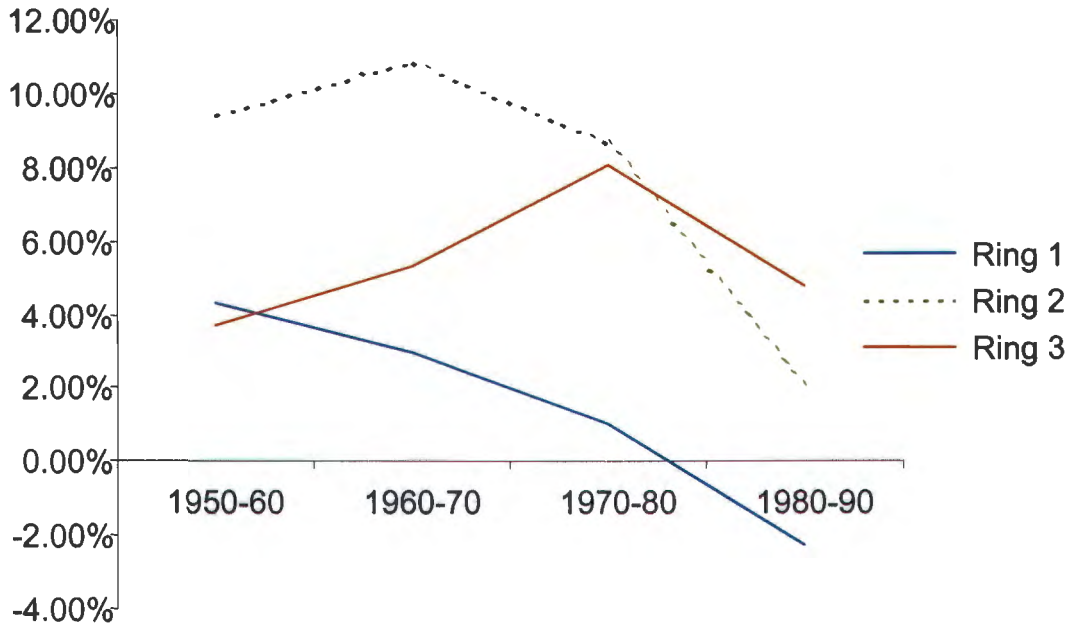
MUNICIPALITIES

1 ACOLMAN
2 ATENCO
3 ATIZAPÁN DE ZARAGOZA
4 COACALCO
5 CUAUTITLÁN
6 CHALCO
7 CHICOLOAPAN
8 CHIMALHUACÁN
9 ECATEPEC
10 HUIXQUILUCAN
11 IXTAPALUCA
12 JALTENCO
13 MELCHOR OCAMPO
14 NAUCALPAN DE JUÁREZ
15 NEXTLALPAN
16 NEZAHUALCOYOTL
17 NICOLÁS ROMERO
16 LA PAZ
19 TECAMAC
20 TEOLOYUCAN
21 TEPOTZOTLÁN
22 TEXCOCO
23 TLALNEPANTLA
24 TULTEPEC
25 TULTITLÁN
26 ZUMPANGO
27 CUAUTITLÁN IZCALLI
28 TLALMANALCO

SOURCE: Graph is by author, and is based on data from CONAPO. *Escenarios demográficos y urbanos de la Zona Metropolitana de la Ciudad de México.* México,1999.

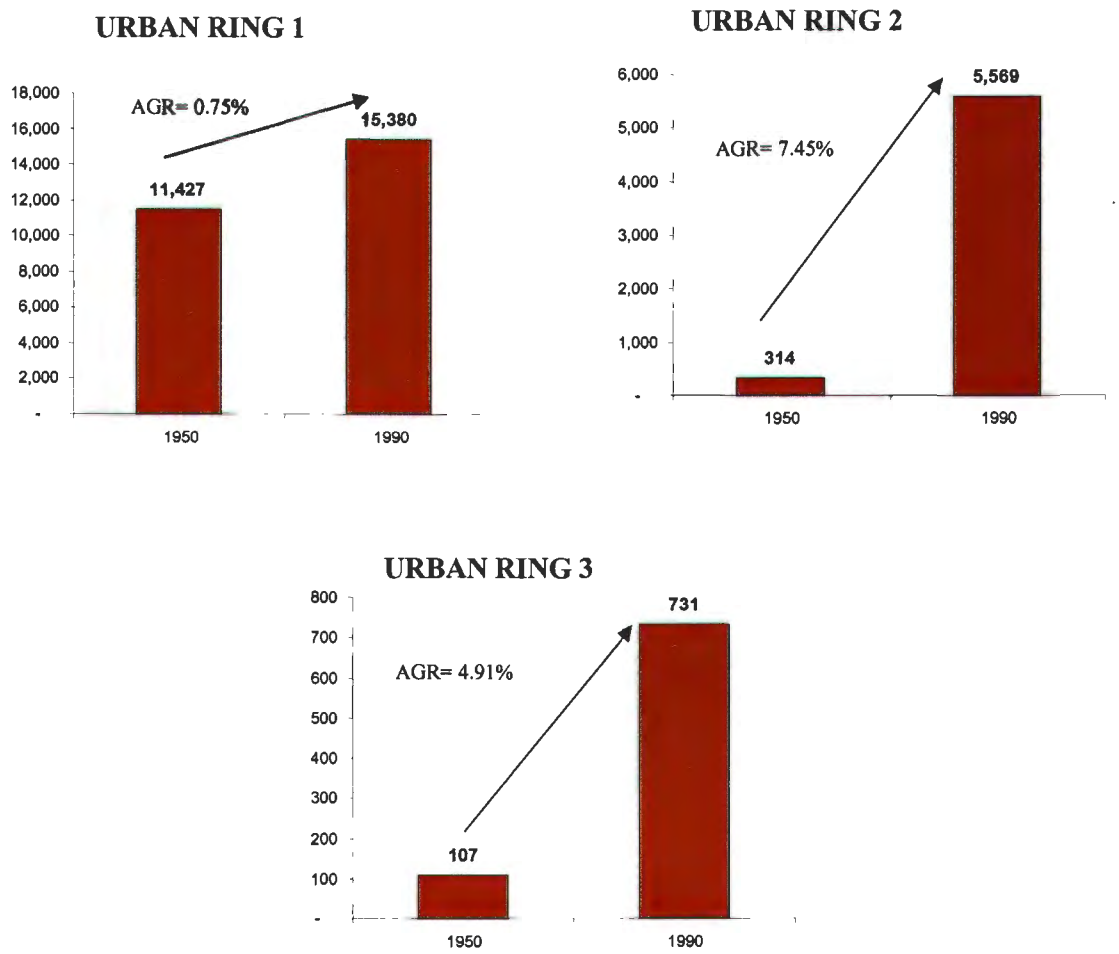
The following graphically illustrates the combined evolution of the average rate of growth by decades for each urban ring of the Mexico City Metropolitan Zone. As shown, the first ring is found in a perceptible process of population displacement, the second follows the same trend, while the third tends to stabilise itself with positive rates of growth.

GRAPH 4.9
MCMZ: Evolution of the Average Rate of Population Growth by Decades based on "Urban Rings"



SOURCE: The graph is by the author and is based on data from CONAPO. *Escenarios demográficos y urbanos de la Zona Metropolitana en la Ciudad de México*. México, 1999.

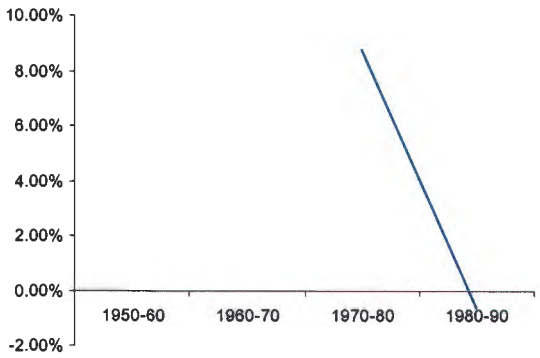
GRAPH 4.10
MCMZ: Evolution of Population Density (pop/km^2) in "Urban Rings"



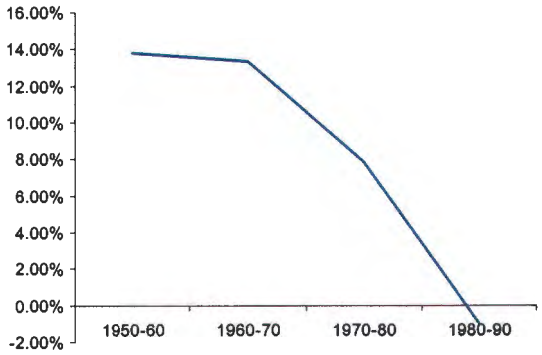
SOURCE: Graph is by author, and is based on data from CONAPO. *Escenarios demográficos y urbanos de la Zona Metropolitana en la Ciudad de México.* México, 1999.

GRAPH 4.11
Evolution of the Average Rate of Population Growth by Decades in Delegations / Municipalities with Atypical* Behaviour

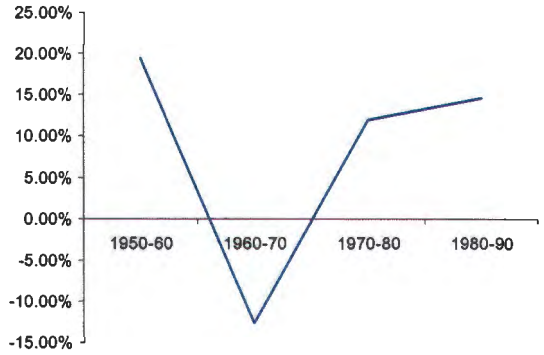
NEZAHUALCOYOTL



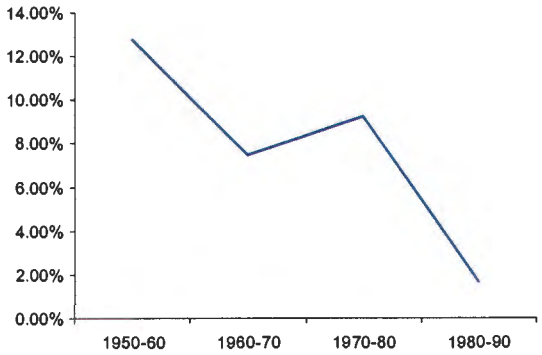
TLALNEPANTLA



CHIMALHUACÁN

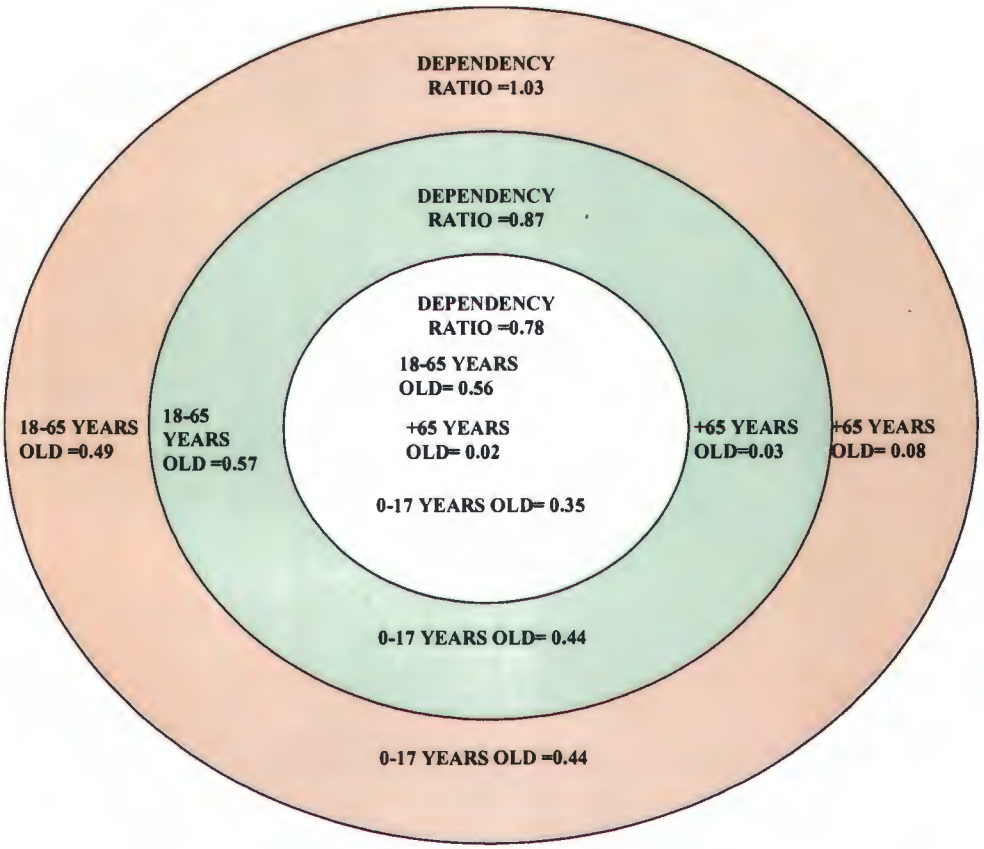


IZTAPALAPA



SOURCE: The graphs are by the author and are based on data from CONAPO. *Escenarios demográficos y urbanos de la Zona Metropolitana en la Ciudad de México.* México,1999.
*Their growth pattern does not coincide with any of the other delegations or municipalities that make up the urban rings.

FIGURE 4.2
Age Indicators in Mexico City, According to "Urban Rings", 1995



SOURCE: Figure is by author, and is based on data from *Conteo de Población*, INEGI, México, 1995.

Analysing the structure by ages within the population according to the different urban rings, a perfectly defined pattern can be observed. The highest dependency ratio is found in municipalities in the State of Mexico and delegations in the Federal District that belong to the third urban ring. This means that these areas will present the biggest challenges regarding the services needed by the age groups that depend on the working age population.

THE ENLARGEMENT OF THE URBAN SPRAWL IN MEXICO CITY

The urban form of Mexico City as a rough pattern of concentric rings has been in turn translated into a model of "encircling" urban expansion (see Map 4.2, Map 4.3, Map 4.4). Among other factors, said phenomenon has been conditioned by geographic elements, regulatory standards in the field of land use, the peculiarities of the land squatter settlements and real estate market, as well as by the magnitude and criteria for allotting public investment in works and services, in which roads and the mass transport system (subway) play an essential role.[12]

For example, the highest growth in the urban sprawl between 1980 and 1990 took place in Cuautitlán Izcalli, Ecatepec, Nicolás Romero and Coacalco. At the same time, municipalities such as Nezahualcoyotl and Tlalnepantla showed low rates of growth. This is due to the fact that urbanisation has practically reached its limit in these entities. One decisive factor in this dynamic has been the development of industries that frequently form economic enclaves. Examples of this are the large automobile and plastics plants in the Tultitlán and Cuautitlán municipalities, warehouses and gas distributors in Tlalnepantla, assorted industries in Ecatepec and the chemical pharmaceutical industry along avenues such as División del Norte, Calzada de Tlalpan and Calzada México – Xochimilco.[13]

[12]G. Garza, Ámbitos de Expansión Territorial, *La Ciudad de México en el fin del segundo milenio...* p. 237.
[13]For more information on the historical process of urban expansion see J. Gamboa, *Ciudad de México. Una Visión*, México: Fondo de Cultura Económica, 1994; G. Garza, Concentración Industrial en la Ciudad de México y la Región Centro del País, 1930-1985, *El Economista Mexicano*, Vol. XX, 1988, pp. 95-106; F. Rodríguez, Crecimiento urbano y condiciones de vida en 1970-1990. *Comercio Exterior*, 45(10), 1995, PP. 735-745; Calderón Alzati, El DF y otros problemas, *Nexos*, Octubre, 1997, pp. 53-64; a Rowland & P. Gordon, *Mexico City: No Longer a Leviathan? The Megacity in Latin America...*, pp. 173-203.

In 1980 and 1990, the conurbation of 10 municipalities took place and between 1990 and 1995, 11 more merged into the urban sprawl. Thus, the process of expansion of the urban sprawl is in terms of the displacement of population and industrial activities towards the outer "rings", while the service sector consolidates itself in the areas.[14]

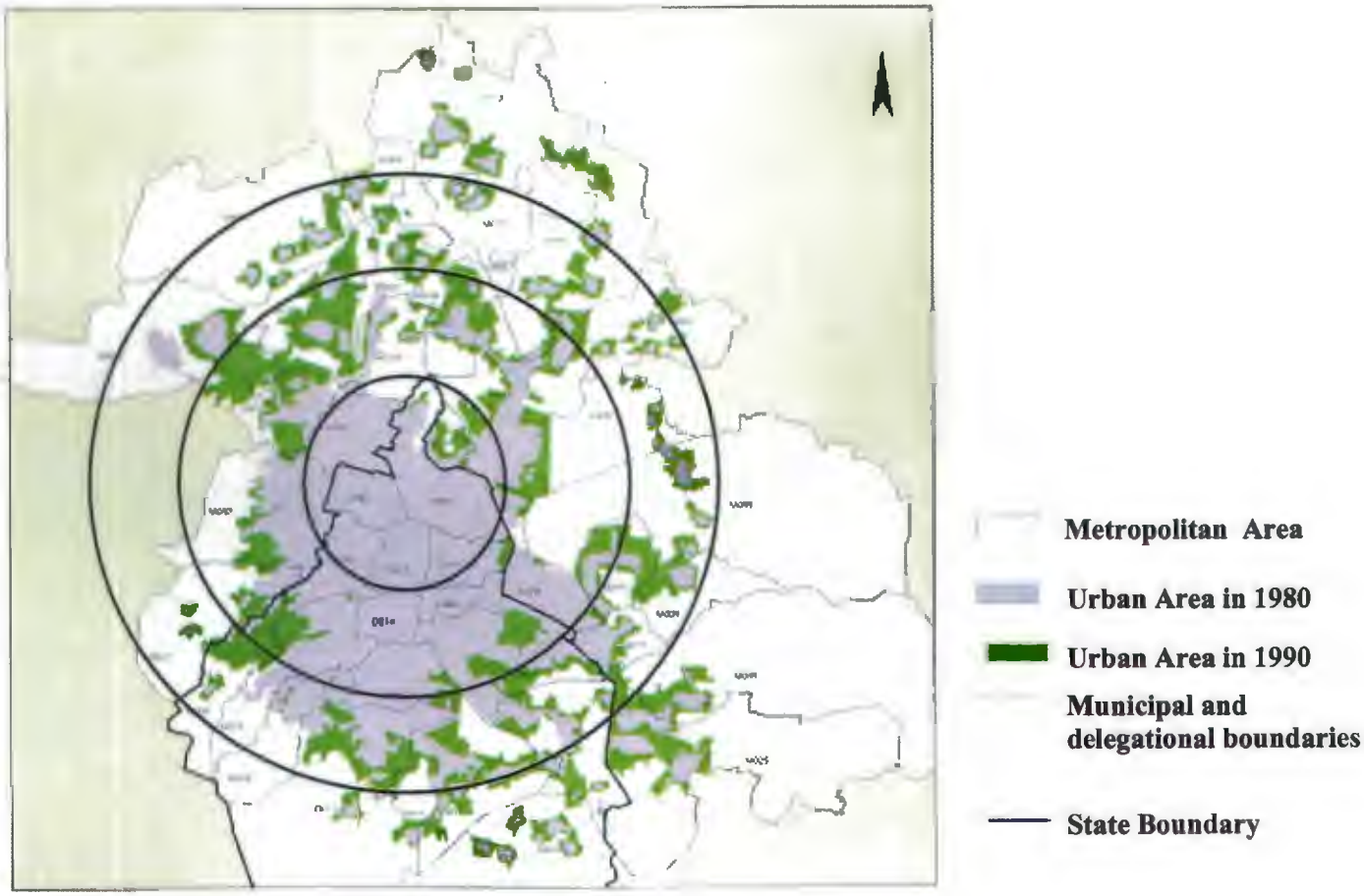
On reaching its level of saturation, neighbourhoods with apparent urban saturation become potential expellers of the population reaching adulthood. These adults do not find housing space or supply when they form their own families (a factor that influences the fact that the average age is lower in the State of Mexico than it is in the Federal District).

As seen in Section 3.8.2, in speaking about the megalopolis in crisis, peripheral population in the adjacent municipalities along with a reduction of housing in the central area has prompted urban sprawl to overextend itself over last decades.

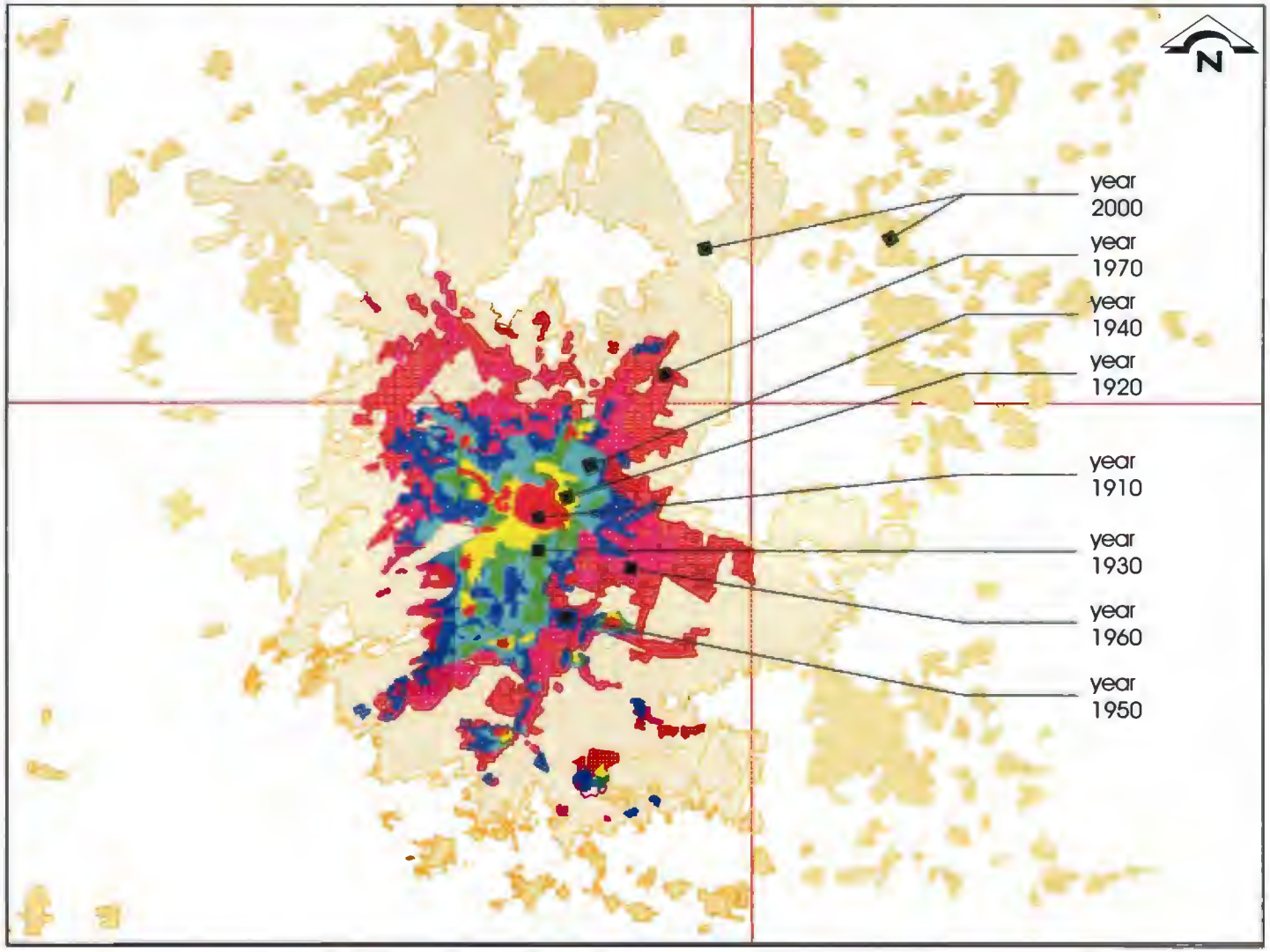
[14]This is concurrent with the fact that a large part of migratory flows are inter-metropolitan and instead of migration, it is more like "moving". See M. E. Negrete Salas, Migración, *La Ciudad de México en el fin del segundo milenio...*, pp. 265-278.

MAP 4.2

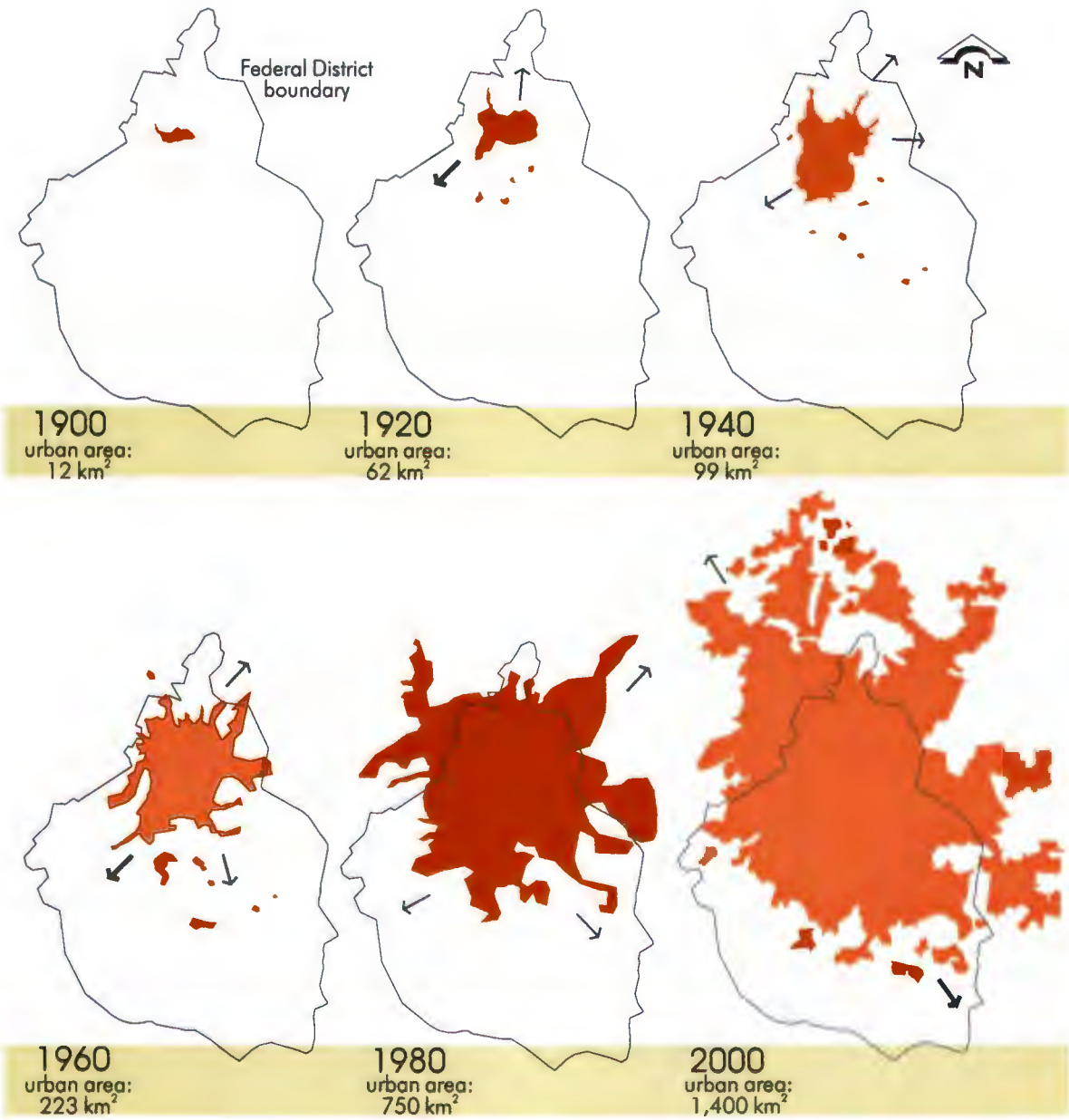
Urban Area Growth in Mexico City, 1980 - 1990



SOURCE: CONAPO. *Escenarios demográficos y urbanos de la Ciudad de México, 1990 - 2010*, México, 1999. Furthermore, the graph shows the urban rings defined in the first part of this chapter.



Map 4.3. Growth of Urban Sprawl.
Source: Own elaboration based on material provided by Ciudad Futura Desarrollo Urbano.



Map 4.4. Urban Growth.
Source: Own elaboration based on Gamboa de Buen, p. 47-56, and on material provided by Ciudad Futura Desarrollo Urbano.

At present, as a consequence of its accelerated population growth, the adjacent municipalities of the State of Mexico occupy most of the area of the Metropolitan Zone of Mexico City. The geographic configuration of the Mexico Basin and the growth of the Metropolitan Transport System have been two of the main factors that have contributed to this rapid expansion.

In geographical and orographic terms or the availability of space and characteristics, the highest possibility of urban expansion is found towards the northeast and southeast of the City. However, urban growth to the north is limited.

4.4 The Economic Dynamics of the City

This section aims to prove, through measurements of Gross Domestic Product (GNP), GNP per capita, employment and other variables that help in measuring the degrees of specialisation and diversification of an economy, its relevant importance and therefore the strategic role that Mexico City plays for the country as a whole.

4.4.1 GNP per Capita in Mexico City and Municipal Distribution

Originally, the most important economic processes have taken place in the outskirts of the Federal District. As a result of the centralisation processes of political decisions and financial resources, the industrialisation of the Mexico Basin manifested itself first in the capital city. Meanwhile, mainly agricultural activities predominated in the municipalities of the State of Mexico, which are now adjacent.

In view of all of the above, the GNP per capita in the Federal District has historically been higher than that of the rest of the states in Mexico, including the State of Mexico. However, given the integration of adjacent municipalities into the Metropolitan Zone and consequently its entry into industrialisation processes in detriment of primary activities, it comes as no surprise that the municipalities with the highest participation in the GNP of the

State of Mexico are Ecatepec, Naucalpan, Nezahualcoyotl, Tlalnepantla and Cuautitlán Izcalli, which are some of those that already form part of the metropolitan zone. Furthermore, they have already consolidated themselves or are in the process of urban consolidation.

Although the GNP per capita of the total number of adjacent municipalities is still much lower than that of the Federal District, the development of a larger service sector and more economic integration of recently conurbated municipalities over the next few years will set the conditions for this gap to narrow down significantly.

TABLE 4.6
Adjacent Municipalities:
Participation in the State of Mexico Total GNP, 1993

ACOLMAN	0.38%	ECATEPEC	11.63%	TEOLOYUCAN	0.41%
ATENCO	0.17%	HUIXQUILUCAN	2.14%	TEOTIHUACAN	0.28%
ATIZAPAN DE ZARAGOZA	4.24%	IXTAPALUCA	1.33%	TEPETLAOXTOC	0.12%
COACALCO DE BERRIOZABAL	1.96%	JALTENCO	0.25%	TEPOTZOTLAN	0.40%
CUAUTITLAN	0.51%	MELCHOR OCAMPO	0.25%	TEXCOCO	1.47%
CHALCO	2.29%	NAUCALPAN DE JUAREZ	10.69%	TLALNEPANTLA DE BAZ	8.78%
CHIAUTLA	0.12%	NEZAHUALCOYOTL	14.45%	TULTEPEC	0.49%
CHICOLOAPAN	0.53%	NEXTLALPAN	0.10%	TULTITLAN	2.47%
CHICONCUAC	0.12%	NICOLAS ROMERO	1.71%	ZUMPANGO	0.65%
CHIMALHUACAN	1.99%	PAPALOTLA	0.02%	CUAUTITLAN IZCALLI	4.92%
PAZ, LA	1.33%	TECAMAC	1.36%	VALLE DE CHALCO SOLIDARIDAD	0.75%

Total participation of adjacent municipalities in the GNP of the State of Mexico: 78.30%
Total GNP of the State of Mexico, 1993 (Thousand pesos): 119, 493, 914.
SOURCE: The participation of each municipality was obtained by taking into account estimates from the UNAM Centro de Estudios Económicos that were developed using 1993 GNP data (INEGI, SCNM, 1988-1993).

TABLE 4.7

Mexico City GNP per capita[15], 1999

	TOTAL GNP (1999, Millions of dollars)	% Of National GNP	POPULATION (1999, millions of people)	% Of National Population	GNP per capita (dollars)	Multiple of the National Rate
Federal District	97,543	22.79%	8.9	8.95%	11,005	2.54
Adjacent municipalities	34,746	8.12%	9.3	9.43%	3,721	0.86
MCMZ	**132,289**	**31%**	**18.2**	**18.38%**	**7,269**	**1.68**

SOURCE: Table is by author and based on data from TABLE 4.6.

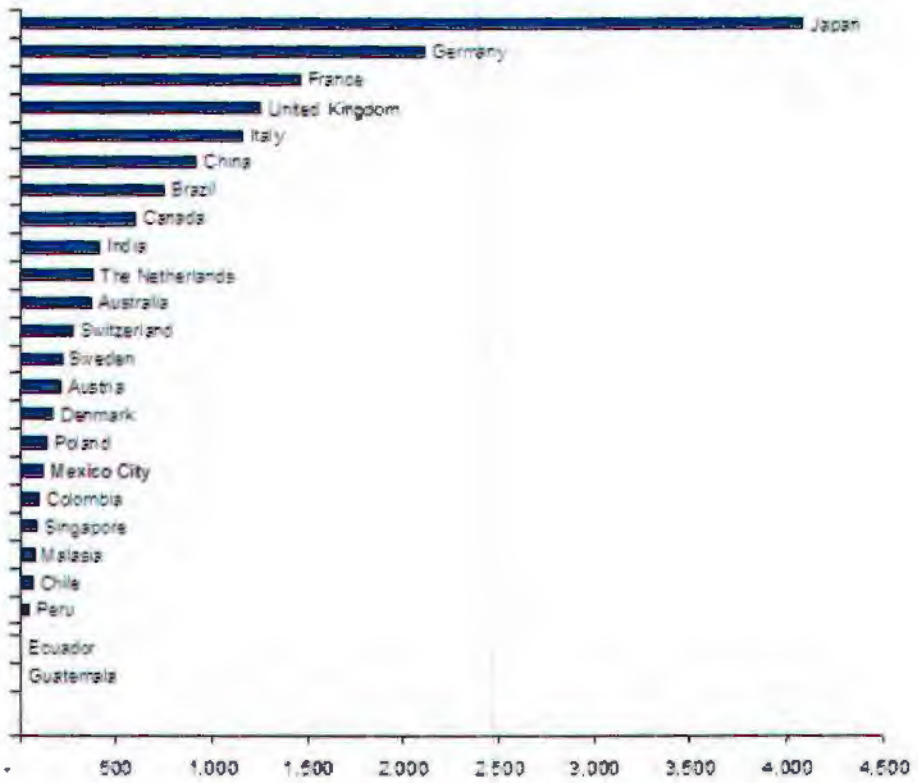
[15]This corresponds to the Mexico City Metropolitan Zone (MCMZ). The estimated GNP per capita of the City was based on several approximations of the GNP of the Federal District and the GNP of the State of Mexico in 1999. The state GNP data from the Sistema de Cuentas Nacionales de México (SCNM), 1993 - 1996 and the rates of national economic growth estimated by the Finance Ministry (SHCP) for 1997, 1998 and 1999 (supposing that the economic growth of both areas between 1996 and 1999 were very similar to that of the national economy) were taken into consideration. To later make international comparisons, the results obtained were converted into 1999 dollars, according to the information provided by the SHCP. Once the corresponding GNPs were estimated, the rates of the percentage of the participation of adjacent municipalities of Mexico City were added to the total GNP of the Federal District to obtain the GNP for Mexico City. Lastly, the GNP per capita was obtained by considering the demographic hypothesis used in this paper (18.3 millions inhabitants).

4.4.2 The Size of Mexico City (MCMZ) Economy

Aside from the inter-regional unbalance that exists in Mexico City in terms of GNP and GNP per capita, the general dynamics of productive activities supported by a historical framework of administrative centralisation has made its relative importance stand just over 30% of the GNP of the rest of the country.

This means that the size of the City's economy is equivalent to that of many national economies in the world (see GRAPH 4.12 below). This is sufficient reason to consider that its health in terms of sustainability and competitiveness has strategic attributes for Mexico as a whole.

GRAPH 4.12
MCMZ: International Comparison GNP (USD, billions)



SOURCE: *World Development Report 1999/2000*, World Bank, 1999.

When compared to state economies in Mexico, the economy that is closest to that of the City in terms of relative importance is that of Nuevo Leon. Its participation is almost five times less than that of Mexico City.

GRAPH 4.13: MCMZ: Relative position in Terms of Absolute GNP (millions of US)

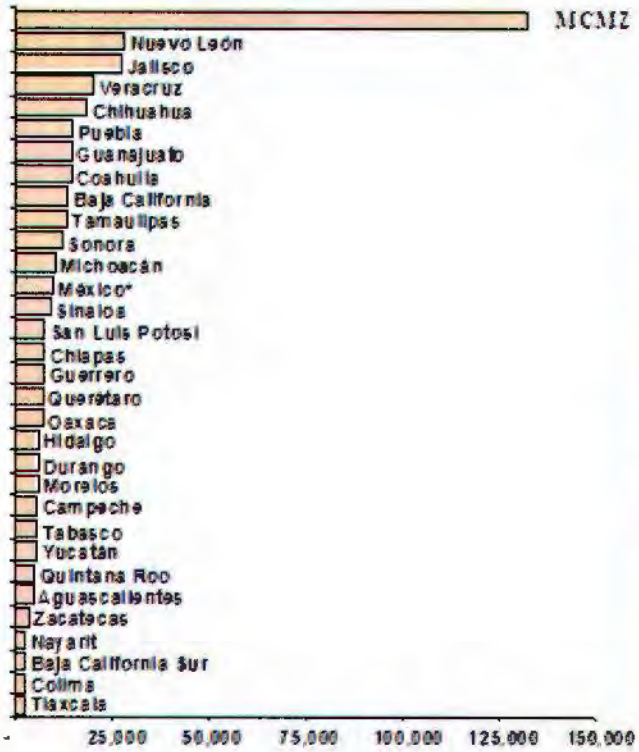
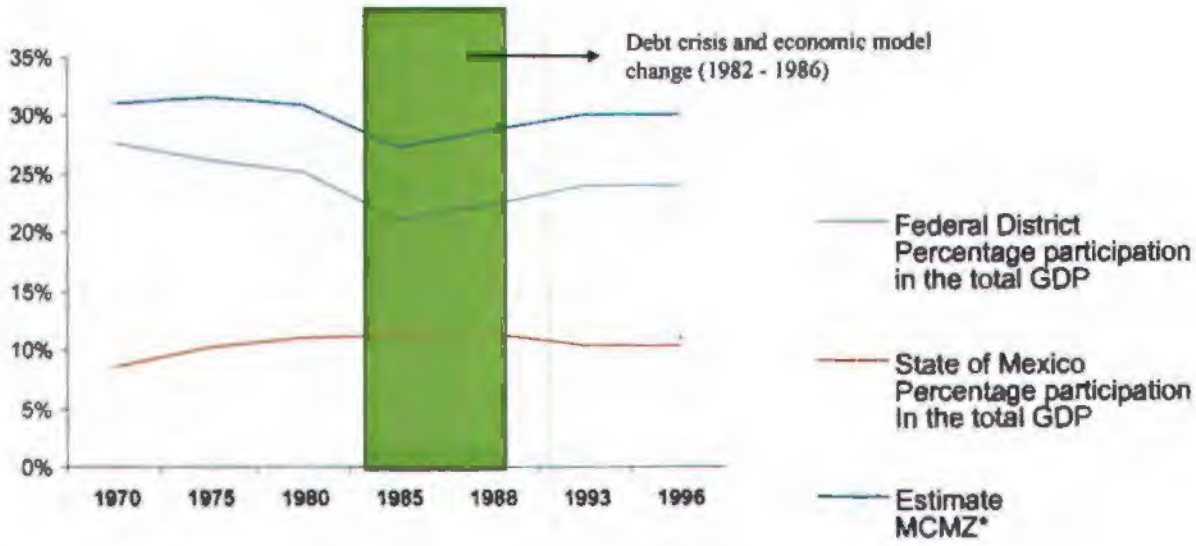


TABLE 4.8: MCMZ: Percentage of Participation in Terms of Absolute GNP

MCMZ	30.87%	Guerrero	1.68%
Nuevo León	6.61%	Querétaro	1.64%
Jalisco	6.40%	Oaxaca	1.60%
Veracruz	4.70%	Hidalgo	1.38%
Chihuahua	4.22%	Durango	1.34%
Puebla	3.41%	Morelos	1.32%
Guanajuato	3.32%	Campeche	1.31%
Coahuila	3.29%	Tabasco	1.28%
Baja California	3.16%	Yucatán	1.26%
Tamaulipas	3.02%	Quintana Roo	1.21%
Sonora	2.77%	Aguascalientes	1.10%
Michoacán	2.31%	Zacatecas	0.82%
México*	2.25%	Nayarit	0.56%
Sinaloa	2.09%	Baja California Sur	0.54%
San Luis Potosí	1.76%	Colima	0.53%
Chiapas	1.74%	Tlaxcala	0.52%

SOURCE: Graph is by author, and is based on data from the *Sistema de Cuentas Nacionales de México*, México, INEGI, 1990.

GRAPH 4.14
MCMZ: Participation of the City's Economic Activity in National GNP: Historic Evolution, 1970 - 1996



SOURCE: Graph is by author, and is based on the SCNM, 1993 and 1999.

*The estimate is based on data of the Federal District and State of Mexico GNP for the corresponding years, the year of the conurbation of new municipalities and the current participation of each in the GNP of the State of Mexico. The figure that corresponds to the Federal District coincides with those mentioned by the Federal District Finance Secretariat. See Alcántara, 2000.

In terms of the GNP per capita, if one considers that this variable is distorted by petroleum industry in Campeche and that the Federal District is part of the City phenomenon, then the area studied holds the first place nation-wide.

It is important to stress the crucial turning point that arises with the 1982 debt crisis because from this moment on, the City's economic activity embarks on a rearrangement and reorientation towards the service sector.[16]

[16]A. Rowland & P. Gordon, *Mexico City: No Longer a Leviathan?. The Megacity in Latin America...*, pp. 173-203.

The period between 1940 and 1970 was characterised by the high concentration of business corporations in Mexico City, which was promoted by the policies of industrial stimulation of the time (as seen in Section 3.8.2). Between 1930 and 1960, concentration in terms of manufacturing units in Mexico City compared to national levels grew from 6.8 % to 29.9%. In the 1930s, the industries that stood out were traditional ones such as paper, printing and publishing; machinery and metal products; food, beverages and tobacco; and textiles, clothing and footwear. In the 1970s, the paper, chemical, machinery and other industries represented 60% of the national production.[17]

However, since the 1970s and especially with the 1976 exchange rate crisis, the model of Industrialisation through Import Substitution began to show structural flaws. Between 1980 and 1988, a policy of progressive open trade was implemented as a result of the 1982 economic crisis. In Mexico City, this resulted in a negative growth rate and a lower participation in the national GNP. Its participation in the number of industrial establishments plummeted from 28.1% to 22.6%. The most affected industrial subsector in Mexico City was that of machinery and metallic products.[18]

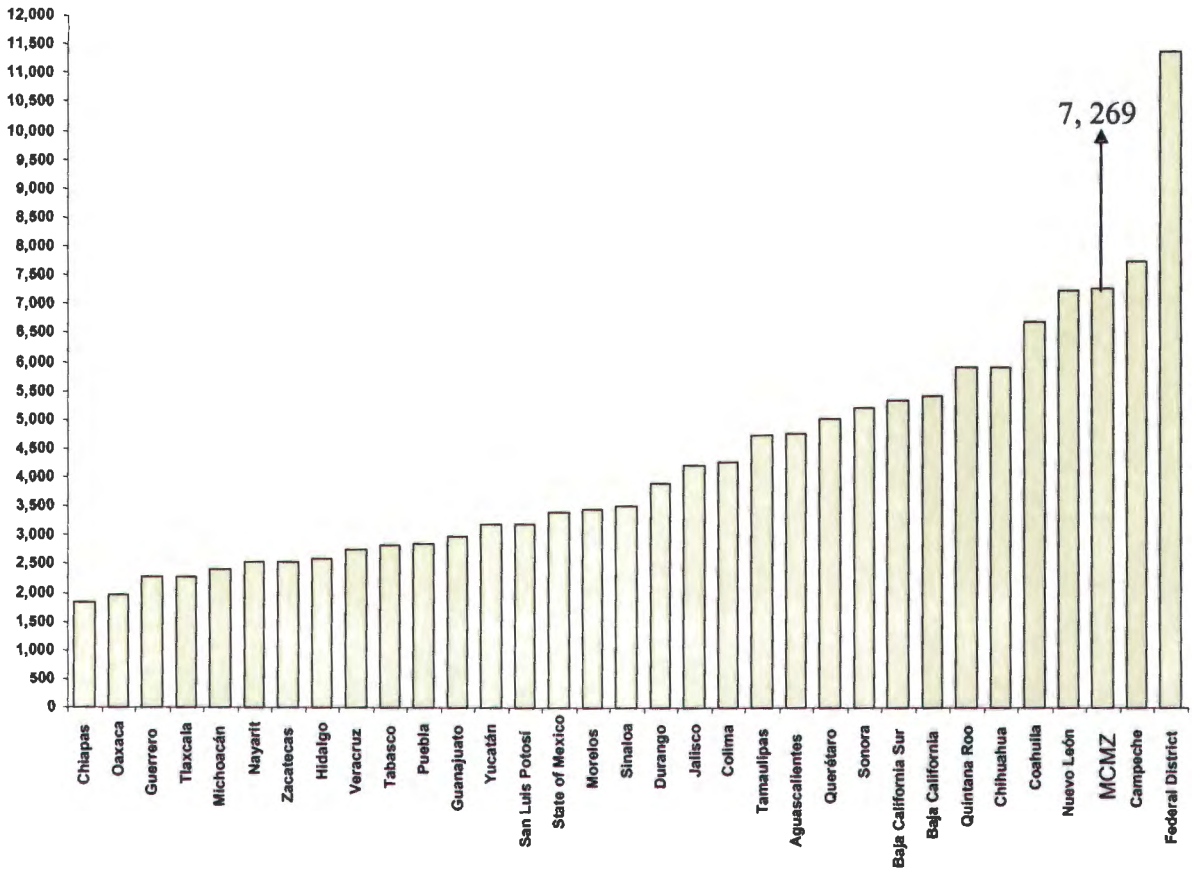
From 1988 on, the national economy saw itself fully immersed in a neo-liberal model. The results for Mexico City were for the most part similar to the dynamics of the nation. Especially in the service sector, more specialisation and dynamism was apparent when compared to national levels. This sector thus became the new axis for the economic dynamism of the City. The GNP of the service sector in Mexico City grew at an annual rate of 5.6% between 1988 and 1993, while in the rest of the country it grew 2.8%.[19]

[17]G. Garza & C. Ruiz Chiapetto, La Ciudad de México en el Sistema Urbano Nacional, *La Ciudad de México en el fin del segundo milenio...*, pp. 229-236.
[18]G. Garza & C. Ruiz Chiapetto, La Ciudad de México en el Sistema Urbano Nacional, *La Ciudad de México en el fin del segundo milenio...*, pp. 233-234.
[19]*Ibidem.*

As part of the trend towards a greater service sector in the economy, the concentration of services for producers and wholesale commerce stands out. However, it must be taken into account that large part of the growth in the service sector is due to the creation of small business and service establishments, which is one of people's main survival strategies in the face of economic crises.

GRAPH 4.15

MCMZ: National Comparison
(Income per Capita)



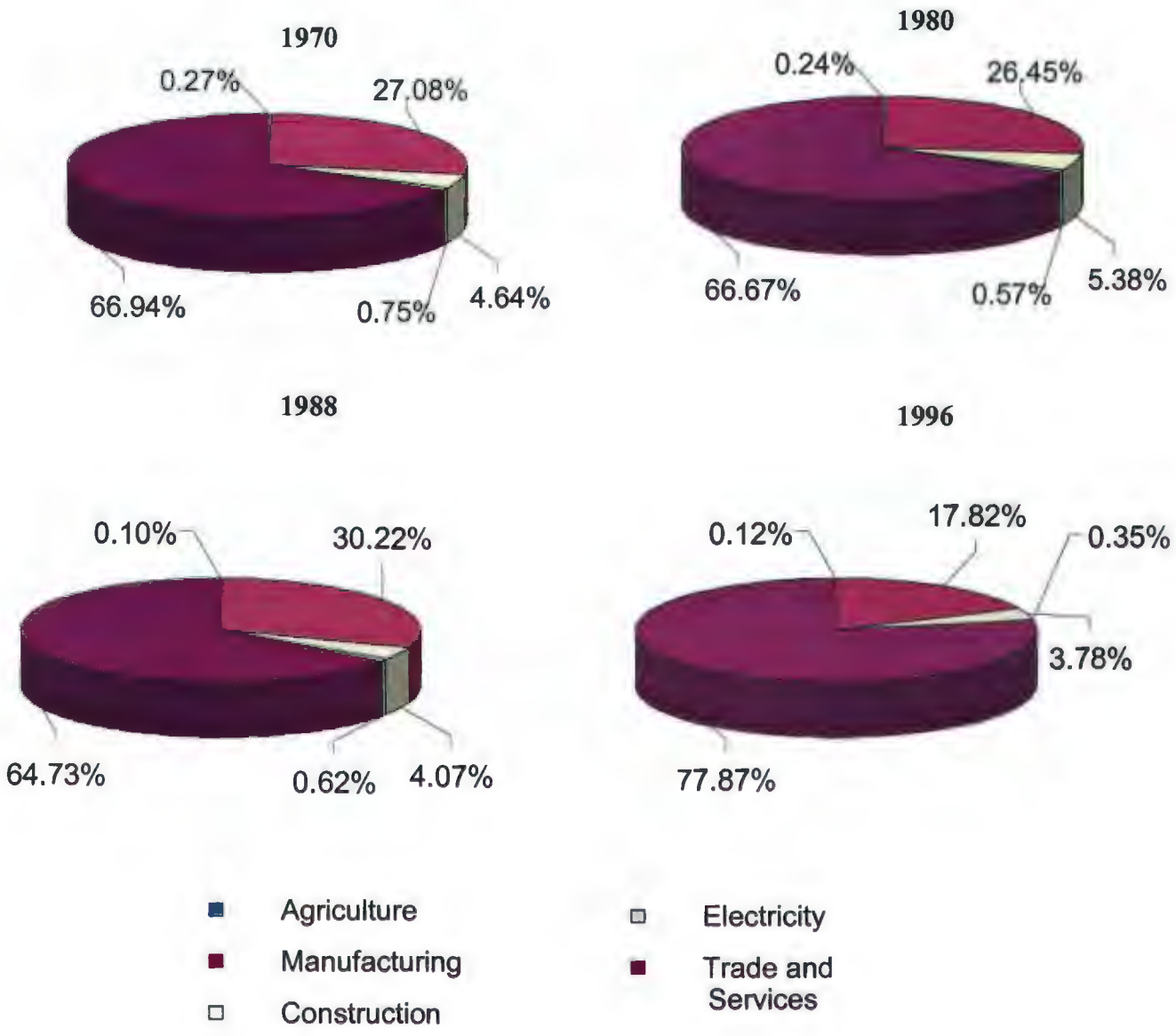
SOURCE: Graph is by author, and is based on data from the *Sistema de Cuentas Nacionales de México,* México, INEGI, 1999.

4.4.3 Breakdown by Sector and Levels of Productivity

Closely linked to the regional distribution of the economic activity in the City is the breakdown by sectors of said activities. The development of important industrial zones in the outer rings, mainly in those corresponding to adjacent municipalities, has made the inner delegations of the Federal District concentrate the economic activities in the service sector. As a whole, Mexico City represents a significant participation in the commerce and service sectors.

Excluding the agricultural and mining sectors, the percent of distribution of the economic activity of services, trade and industry in the Federal District clearly shows that this area has consolidated itself as an important sector for the exchange of goods and services. Most of the trade is concentrated in a few delegations in the centre of the City, such as Cuauhtemoc, Miguel Hidalgo, Benito Juárez and Iztapalapa. This shows that these delegations are further ahead in the process of development than are adjacent municipalities with a higher relative industrial participation as in the cases of Naucalpan and Tlalnepantla.

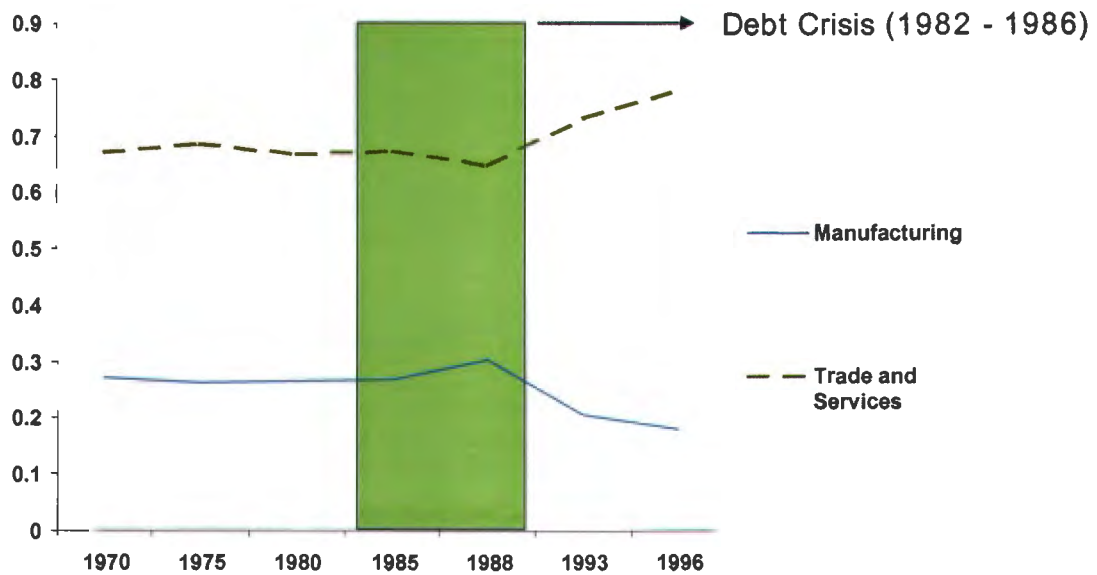
GRAPH 4.16
Breakdown by Sectors of Economic Activity in the Federal District: Historic Evolution, 1970 to 1996



SOURCE: Graph is by author, and is based on data from the *Sistema de Cuentas Nacionales de México*, México, INEGI, 1993 y 1999.

With the information presented in the Graph 4.16, the following comparison shows the historic evolution of the manufacturing, commerce and service sectors in the Federal District. As can be seen, from 1970 to the mid-eighties, both have a relatively stable participation, with the service sector prevailing over the manufacturing sector. However, from this moment on, or as of the economic crisis of the 80s, one can observe a trend in which the manufacturing sector loses participation while the service sector gains.

GRAPH 4.17
Historic Evolution of the Manufacturing and Service Sectors in the Federal District, 1970 to 1996



SOURCE: Graph is by author, and is based on data from the *Sistema de Cuentas Nacionales de México*, México, INEGI, 1993 y 1999.

The activities that stand out for their levels of specialisation[20] in the Federal District are the financial, professional, entertainment and medical services. While there may be manufacturing industries with high levels of specialisation such as in chemicals, textiles, some foods and some metal-mechanical products in this area, the State of Mexico has a larger number of industries that turn out to be important for its economy.

The adjacent State of Mexico is important in almost all fields of the metal-mechanics, textiles, non-metal mineral-based products, some chemicals and some food sub-sectors. In contrast, the service sector has some subsectors with a certain degree of specialisation, but there are not as many as there are in the Federal District.

It is also important to observe the historic evolution of the indexes of specialisation in both regions. Both in the Federal District and in the State of Mexico, the activities with some degree of specialisation in 1993 have sustained it since 1970. This shows that despite the opening of the economy that begun with Mexico's entry to the GATT in 1986, most of them were able to preserve their relative importance.

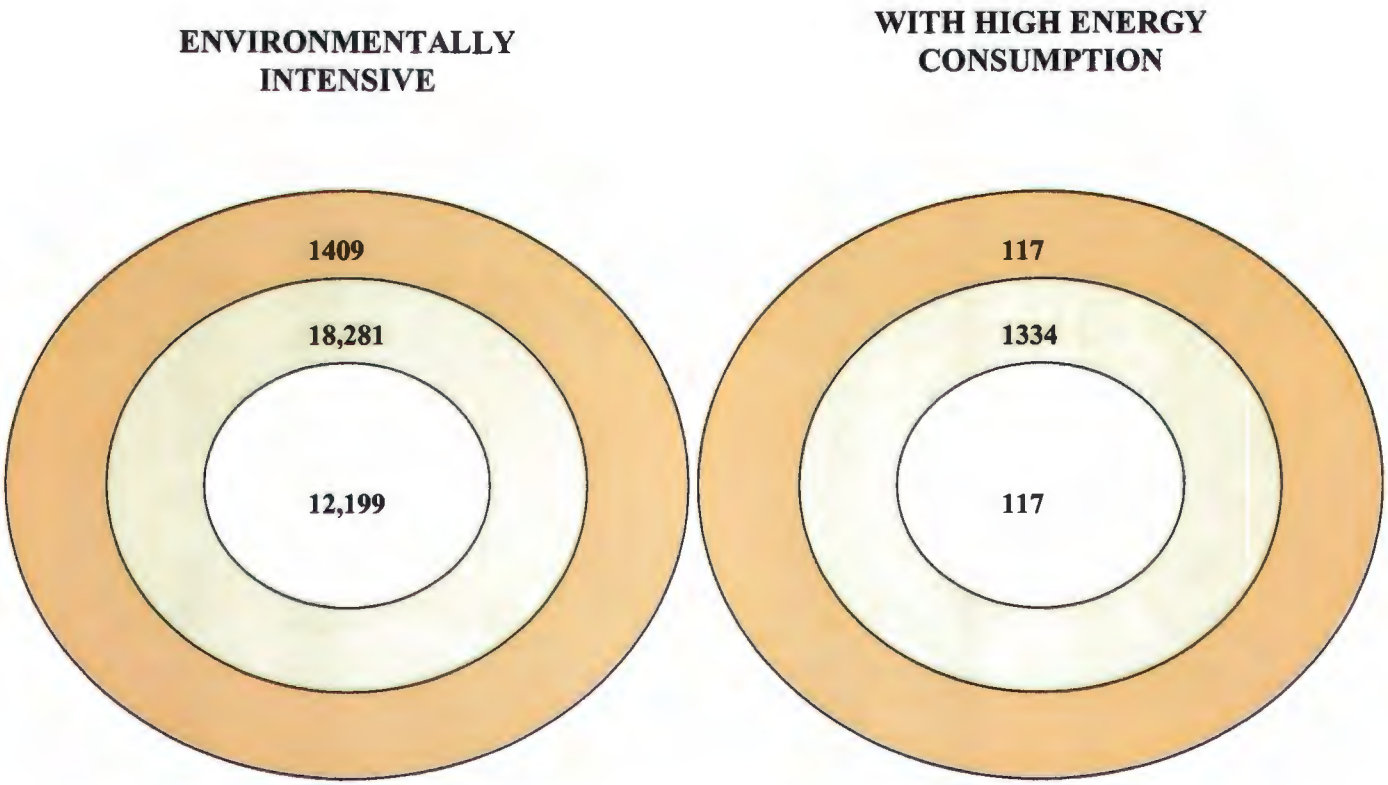
It is important to point out that the aforementioned industries characterised by high environmental impact or "intensity" are mainly those of machinery and equipment, food and beverages, iron and steel, cellulose and paper, chemical and petrochemistry and the sub-sectors in the chemical industry. In the case of the industries with the highest energy consumption, the automotive and parts, iron and steel, chemical, cement production, cellulose and paper, glass, beverage, rubber, tobacco and basic non-ferrous industries stand out.

Making a spatial analysis by means of urban rings, it is confirmed that most of the high environmental impact industries and those with the highest energy consumption are found in the second urban ring, in which most of the industrial activity of the City is concentrated.

[20] Specialisation is determined by the following formula: $(GNP_{ij} / GNP_{in}) / (GNP_{hj} / GNP_{hj})$ where "i" refers to a certain economic activity, "j" refers to a certain state, "n" refers to the national level, and "h" refers to a certain economic sector. More details about specialisation indexes, as well as its values are presented in Appendix A.

It is important to remember that the second urban ring comprises municipalities such as Ecatepec (wide industrial diversity), Cuautitlán Izcalli (automotive and plastics industries) and Tultitlán (automotive and plastics industries).

FIGURE 4.3
Number of Environmentally Intensive Industrial Establishments and those with the Highest Energy Consumption, According to "Urban Rings", 1993



SOURCE: Figure by author and based on *Estadísticas del Medio Ambiente del Distrito Federal y Zona Metropolitana*, México, 1999, INEGI /SEMARNAP, 1999.
*Iron and steel, chemicals, cement, mining, cellulose and paper, glass, beverages, automotive, rubber, basic non-ferrous metals and tobacco.

Both regions (the Federal District and the State of Mexico) have tended to diversify themselves more and more as time goes by[21]. In the case of the State of Mexico, this phenomenon is due to the importance most of the industries have in national economy. This inevitably leads to high levels of diversification, though they may be oriented towards industrial activity.

In the case of the Federal District, this phenomenon is due to the gradual loss of specialisation in some of its industries, which are generally not state-of-the-art in technological terms, to give way to a higher participation of the service sector and others that require high levels of technology.

In the case of the industries that have lost importance in the Federal District, those of soft drinks and carbonated beverages, machinery and non-electric equipment and structural metal products stand out. In contrast, professional services went from a specialisation index of 1.88 to 2.17 and financial services (with high technological requirements) went from 1.34 to 1.98. These processes are directly related to the increase in the diversification of economic activities in both regions.

This trend is confirmed when comparing the levels of productivity in the Federal District and the State of Mexico, in the different sectors of the economy[22]. The curves presented are the result of adding data from both states.

[21] Details about diversification indexes and their values can be found in Luiselli C. y. Domínguez J. C. *Indices de Diversificación para la ZMCM.* Mimeo. México, 2001.
[22] *Ibid.*

For example, in the case of the agricultural sector, productivity in the Federal District is very low in comparison to that of other states. Meanwhile, the State of Mexico shows a better situation in this respect due to the participation many municipalities that have yet to become conurbated to the metropolitan zone have in this sector. Anyway, if the production of the State of Mexico is compared to that which corresponds to the regression curve, its level of productivity is visibly below those expected in view of its infrastructure and degree of technological development.

In the case of the manufacturing sector, the Federal District and the State of Mexico hold a clearly advantageous position in comparison to other states in the country. Even Nuevo León and Jalisco are well behind the two regions that form the Metropolitan Zone of Mexico City.

Although the State of Mexico has a larger number of industries with high indexes of specialisation in comparison to the Federal District, the latter shows higher levels of productivity. This points to processes of technological modernisation in which its economic activities are found and those of scale economies generated by the consolidation of its urbanisation in most of its delegations.

In the mining sector, it is observed that the productivity of neither the State of Mexico nor the Federal District can be compared to that of states with more natural resources for mining as in the cases of Durango or Coahuila.

One of the most outstanding sectors is that of communications and transportation. Analysis of the productivity in the Federal District and the State of Mexico confirms that the City has consolidated itself as the great node of communications and transportation in the country. In the case of the Federal District, one of the factors with decisive influence is the presence of the Mexico City International Airport, which has become the point of connection par excellence for most destinations in the country and currently brings almost 20 million passengers a year. As to this same topic, the position of the State of Mexico is deceiving because it has very little of its population in this sector, though in terms of productivity it is far above other federative entities.

In the case of the financial sector, the Federal District holds the topmost position with levels of productivity far above those of any other state in the country. The Federal District is followed by Nuevo León, Jalisco and the State of Mexico. The latter again has levels of productivity that are well above the curve of regression shown.

The same occurs in the service sector as does in the manufacturing sector. On paper, the Federal District is the confirmed node for providing services, especially for those that require more infrastructure and technological development as in the case of professional services. The State of Mexico is in second place, especially with the participation of the adjacent municipalities of Mexico City. Its notable role in this sector is due to the relative importance entertainment services, educational services and trade have in its economy. Far behind these two regions are Jalisco and Nuevo León. This shows that thanks to the process of political and economic decentralisation, these two regions have become important poles of national development, but are still secondary to the importance of Mexico City.

4.4.4 Work Force

As explained in Section 3.8.2, during the expansion and consolidation of the Industrialisation through Import Substitution model (ISI): ca. 1930 – 1975. The dynamism and diversification of the industrial activities in the capital contributed to the fact that the secondary sector incorporated significant number of the work force at an accelerated tempo. This scenario noticeably changed in the late 70s with the depletion of the substitution model and the subsequent start-up of a strategy of external-oriented development.[23]

TABLE 4.9
Percentage of Distribution of Working Population in Mexico City

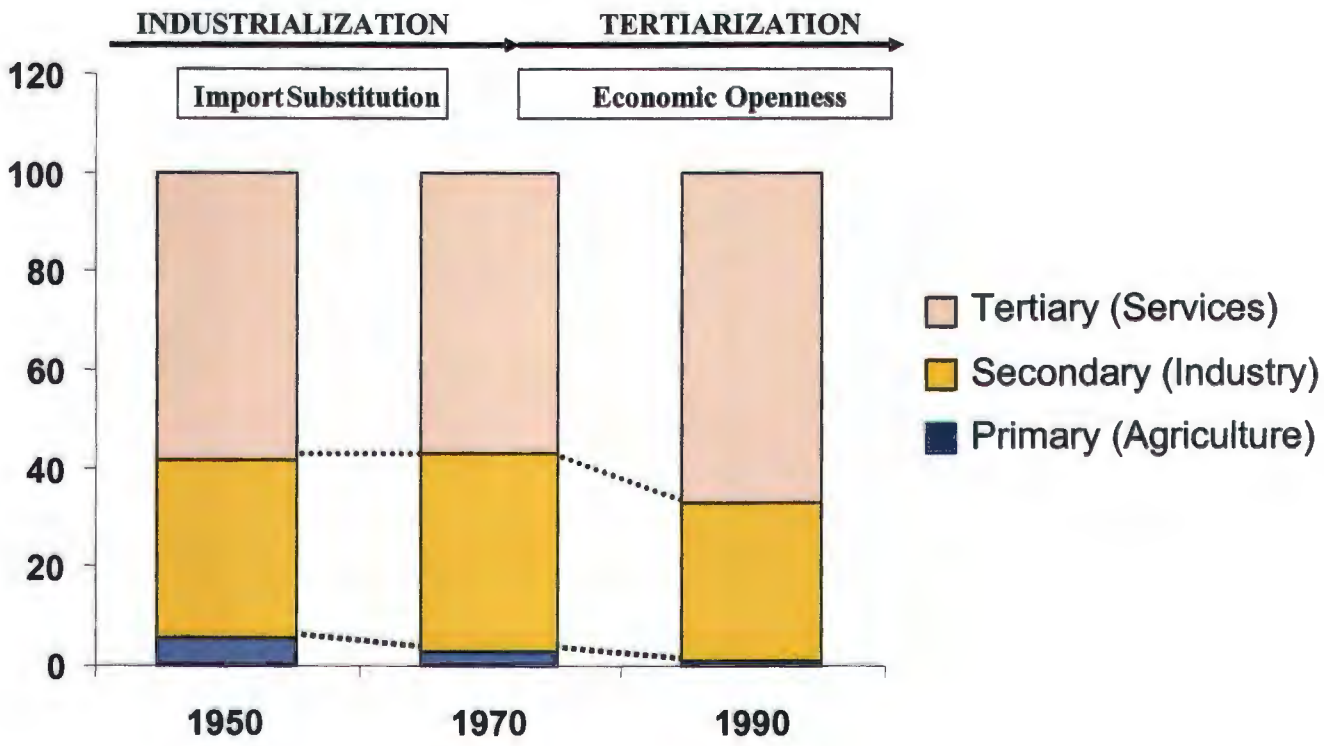
	1995	1996	1997	1998 (3rd Quarter)
Agriculture, livestock, forestry, hunting and fishing	0,4	0,6	0,6	0,3
Mining and Electricity Industries	0,8	1,0	0,7	0,8
Manufacturing	18,8	18,5	19,3	20,3
Construction	3,9	3,2	3,4	4,0
Commerce	22,0	22,4	21,5	21,4
Services	39,6	40,2	40,4	39,7
Communications and Transportation	6,9	6,5	6,8	6,8
Government	7,5	7,5	7,2	6,7
U.S. Occupy	0,1	0,1	0,1	-

SOURCE: *Indicadores de Empleo y Desempleo*, México, INEGI, October, 1998.

[23]B. García & O. Oliveira, El Marcado de Trabajo 1930-1998, *La Ciudad de México en el fin del segundo milenio...*, pp. 279-286.

As can be seen in Table 4.9, the work force in Mexico City is presently characterised by a strong concentration in the services and commerce sectors. Again, this is consistent with the pattern identified throughout this chapter, according to which the City forms the main node for service providers nation-wide, a vocation that became more important with the new model of an open economy.

GRAPH 4.18
Working Population in Mexico City by Sector of Activities, 1950 to 1990



SOURCE: Graph is by author, and based on data from B. García & O. Oliveira, El Marcado de Trabajo 1930-1998, *La Ciudad de México en el fin del segundo milenio...*, pp. 279-286.

If the distribution of the work force in Mexico City is compared to that of the rest of the urban areas in the country, both are very similar. However, in the case of other urban areas, the importance of the agricultural sector, construction and manufacturing industries is greater. In the case of services and trade, the sum of both sectors comes to 61.1% in Mexico City and 58.4% in other urban areas.

TABLE 4.10
Percentage of Distribution of Working Population in Urban Areas of Mexico

	1995	1996	1997	1998 (3rd Quarter)
Agriculture, livestock, forestry, hunting and fishing	1,2	1,3	1,2	1,1
Mining and Electricity Industries	0,9	1,0	0,9	0,8
Manufacturing	20,4	20,5	21,1	22,3
Construction	5,2	4,6	4,4	5,1
Commerce	21,6	21,6	21,1	21,0
Services	38,0	38,5	38,7	37,4
Communications and Transportation	6,2	5,9	6,1	6,0
Government	6,1	6,2	6,0	5,8
U.S. Occupy	0,4	0,4	0,5	0,5

SOURCE: *Indicadores de Empleo y Desempleo*, México: INEGI October, 1998.

In addition to the breakdown by sectors of the work force, it is important to analyse the regional distribution of the work force; since regionally unequal processes of evolution in economic activities and demographic phenomena bring about situations that are just as unequal in terms of working population in an urban area.

During the years of the consolidation of the process of substitution and industrial diversification (1950 - 1970), the industrial establishments and the working population gradually gravitated towards the municipalities in the State of Mexico that became part of the metropolitan zone in this period. This trend continued until the years of lesser industrial dynamism (1970 - 1990), when most recently conurbated municipalities were about the only ones to show relative expansion in the working EAP (Economically Active Population) in the secondary sector. All of the above shows the link between the process of metropolisation and the spatial location of manufacturing companies and their workers.[24]

At present, the delegations with the highest proportions of working population (from 46.5% to 52% of the population) are Tlalpan, Coyoacán, Benito Juárez, Cuauhtémoc, Álvaro Obregón, Magdalena Contreras and Cuajimalpa. Meanwhile, the municipalities of Acolman, Tecámac and Atenco have ranges of 31.32% to 39.59%.

It is also interesting to note that differences in the proportions of the working population significantly vary when distinction of gender and of municipality or delegation is made simultaneously. In the case of the Federal District, central municipalities have the highest proportions of women in the working population, followed by some adjacent municipalities. However, these proportions tend to decline, the further the municipalities are from the central area.

In the case of the working population in the Federal District, the opposite occurs. The highest proportions are found in the most peripheral municipalities and the lowest in the central delegations.

[24]B. García & O. Oliveira, El Marcado de Trabajo 1930-1998, *La Ciudad de México en el fin del segundo milenio...*, pp. 279-286

4.5 Considerations about Economic Globalization

Throughout this chapter, the importance of the progressive economic opening process that initiated in the decade of the 80s will be considered. This process resulted in a re-composition of productive activity in Mexico City. The new correlation of economic forces, such as the emergence of new poles of economic development in the north of the country, has made the megalopolis's role nation-wide fall more and more on providing professional, educational and specialised services, and not on the production of primary and secondary sector goods. Although this issue will be seen in depth in chapter 5.1, it is worth mentioning some important data related to the economic dynamics, which is already indissoluble from the process of globalization.

In 1992, Mexico City made up 24% of total exports and 49.5% of manufactured exports made by non-bonded assembly plants or "maquiladoras". By 1997 this proportion fell somewhat: to 21.9% and 41.5% respectively. [25] The manufacturing companies in the megalopolis considered the increased of foreign market share for their products. This situation was not entirely successful because Mexico City lost market share for its manufactured exports. Other cities in the national urban system, not including border towns, had greater competitive advantages to export their manufactured goods.[26]

On the other hand, the liberalisation of the national financial system as a necessary consequence of an open trade system and its expansion and modernisation through electronics and data processing have been distinctive characteristics of the sector, in the specific case of Mexico City. An example of this phenomenon is the tendency to broaden the range and the number of financial intermediaries.

These re-conversions are the result of the demise of the Industrialisation through Import Substitution (ISI) model and imply the insertion of Mexico City into economic

[25]H. Millán, Exports And Services in Globalization, Mexico City at the end of second millennium..., pp. 195-201.
[26]H. Millán, Exportaciones Y Servicios Financieros en la Globalización, *La Ciudad de México en el fin del segundo milenio...*, pp. 195-201.

globalization processes. These processes are characterised by "tertiarisation" (services) and the industrial re-deployment of developed economies and the consequent flow of direct foreign investment to emergent countries. Meanwhile, financial markets expand worldwide and technological advances, which allow global productive process management to appear.

Thus, tendencies of a worldwide economic globalization are expected to increase not only in terms of trade, but also in the financial, labour and political realms, All of this may continue to fortify Mexico City's new role, not only at in the country but world-wide. In this sense, it is worth distinguishing a megalopolis from a "World City". As mentioned in this chapter, the concentration to high value added economic activities, together with physical expansion until reaching continuity with Toluca Metropolitan Zone, has placed Mexico City in the category of a megalopolis. However, the term "World City" more than dimension and regional impact, alludes to its possible links and relations with other core cities in the world. For instance Shanghai, Mumbay[27], Singapore, Jakarta, New Delhi, Cairo, Sao Paulo and Rio de Janeiro boast the title of a megalopolis, but this does not mean that all of them can be considered authentic "World Cities". Thus, one of Mexico City's challenges is to leave behind its condition of megalopolis to become a "World City".

The role of large cities is essential in articulating global market production. Large cities are where most investments are made. Large urban areas generate 73% of GNP in middle income level and 85% in high income countries. The agglomeration economies present in many urban areas are the source of important increases in the productivity of many economic activities. Proximity of economic activities increases the ease with which knowledge is transferred and, lest it be forgotten, new information industries demand a large amount of qualified labour, which can only be found in such large cities.

However, looking towards the new millennium, it should be noted that cities will face two opposing forces at the same time. On one hand, resources and central government policies that have an effect on cities will lessen with globalization. On the other hand, internal forces that strengthen economies of scale, will come into being. As mentioned, in

[27] Formerly Bombay

discussing a megalopolis and its regional context, every extensive network requires a suitable distribution centre. Therefore, a higher participation in the trade and service sector, as well as in the processes of technical change that will take place in Mexico City ,(MCMZ) will strengthen its place among truly global cities.

The market potential, inherent to the size of its population and its high GNP per capita, compared to the rest of the cities in the country, is a positive factor to attain the economies of scale needed for efficient and profitable supply of some services, such as those related to information technology. Although it cannot be considered "primary" in the world city system, its role as a link between other minor Latin American cities and the main cities in the world gives it the not at all despicable category of "secondary", seen in depth in section 5.1.

Exchange relations between Mexico City and the rest of the world are largely established with the United States and to a lesser degree with Latin America and Europe. It interacts with world cities such as New York, London and Tokyo; in specific markets with some dominating metropolitan centres, such as Chicago; with other links of dominant regional links of global management such as Paris, Frankfurt and Amsterdam; with some regional centres such as Madrid, Sao Paulo and Buenos Aires, and with other cities with a minor urban hierarchy. Therefore, though it is not a dominant node in the world, Mexico City is a part of the global network of cities and can aspire to World City "*status*".[28]

[28]J. Iracheta Carroll, *Globalization and Air Flows, Mexico City at the End of Second Millennium...*, pp. 321-332. About the same theme, see also section 4.1 of this work.

TABLE 4.11

Mexico City: International Cargo Movements, 1997

International Cargo Arrivals, 1997		International Cargo Departures, 1997	
Miami	13.32%	Los Angeles	17.46%
Paris	11.12%	Miami	10.51%
Amsterdam	10.85%	New York	10.20%
Los Angeles	8.61%	Paris	8.18%
Dayton Ohio	7.00%	Houston	5.82%
Rio de Janeiro	5.88%	Frankfurt	5.34%
Frankfurt	4.48%	Amsterdam	2.81%
Madrid	4.13%	Sao Paulo	2.71%
Sao Paulo	3.73%	Santiago	2.67%
Houston	3.71%	Madrid	2.49%
Luxembourg	3.67%	Cincinnati	2.40%
New York	3.26%	Atlanta	2.38%
Cincinnati	2.33%	Dayton Ohio	2.32%
Santiago	1.96%	Chicago	2.19%
San Jose	1.64%	San Jose	2.14%
Guatemala	1.59%	Panama	2.12%
London	1.36%	Guatemala	2.04%
Dallas	1.32%	Dallas	2.00%
Chicago	1.19%	Tokyo	1.98%
Lima	1.15%	Luxembourg	1.39%
Atlanta	1.12%	London	1.29%
		Toronto	1.13%
		Havana	1.09%
OTHERS	6.57%	OTHERS	7.33%

SOURCE: *General Directorate of Civil Aeronautics*, Mexico, 1997.

TABLE 4.12
Mexico City: International Passenger Movements, 1997

International Passenger Arrivals, 1997		Passenger International Departure, 1997	
Los Angeles	13.36%	Los Angeles	12.56%
Houston	9.87%	Houston	9.72%
Dallas	8.74%	Dallas	9.39%
Miami	8.51%	Miami	8.88%
New York	7.10%	New York	6.46%
Chicago	6.55%	Chicago	6.36%
Madrid	4.08%	Madrid	4.17%
San Francisco	2.84%	San Francisco	2.71%
Atlanta	2.78%	Frankfurt	2.61%
Paris	2.52%	Paris	2.55%
San Jose	2.40%	Atlanta	2.54%
Frankfurt	2.39%	San Jose	2.29%
Guatemala	2.17%	San Antonio	2.10%
San Antonio	1.93%	Havana	1.95%
Havana	1.80%	Guatemala	1.88%
Phoenix	1.58%	London	1.77%
London	1.57%	Phoenix	1.68%
Toronto	1.52%	Toronto	1.65%
Santiago	1.38%	Santiago	1.41%
San Diego	1.27%	Panama	1.30%
Amsterdam	1.25%	San Diego	1.28%
San Salvador	1.22%	Detroit	1.26%
Detroit	1.15%	Washington	1.20%
Panama	1.14%	Amsterdam	1.17%
Las Vegas	1.08%	Las Vegas	1.08%
Washington	1.08%	Bogota	1.01%
Lima	1.01%	Lima	1.00%
OTHERS	7.71%	OTHERS	7.99%

SOURCE: *General Directorate of Civil Aeronautics*, México, 1997.

It is important to point out this new economic "vocation" turns out to be favourable to increase Mexico City sustainability levels because services, unlike traditional industries, are not productive activities with a great environmental impact. Additionally, as mentioned in other sections, insertion into the global city system gives Mexico City access to certain technological advances, especially in the area of information technology. These technologies could help solve certain problems, such pollution (fewer displacements), housing (freeing up office space) and all the variables mentioned of sustainability (more monitoring) in general.

Another positive factor for sustainable development of "globalized" cities, such as Mexico City, that is needed to face a context of limited financial resources will be the openness to change that new generations have. Thus, the social participation processes necessary to reach higher levels of urban sustainability levels will take place in a more suitable atmosphere. Examples of this phenomenon have already been found worldwide, such as the case of 288 Swedish municipalities that have been involved in Agenda 21-related work, recognising the need to link social conditions with those of environmental and economic development.

4.6 Economic Growth Perspectives of Mexico City

4.6.1 Productive Performance

Taking into account that due to re-conversion towards a larger participation of the services and commerce sectors, Mexico City could maintain its importance regarding national economy over the next decades. A 4% growth rate of the GNP in Mexico City was expected to be the average from 2000 to 2030. This is possible assuming the following:

1) The long term average rate of economic nation-wide will oscillate between 4.5% and 5%. Said increase is "distributed" among the states in such way that the interregional differences of the GNP per capita are lowered by 15% from the present situation (measured

by the variation coefficient of the GNP per capita for each state). The Federal District as such grows 3.5% a year.

2) The participation of adjacent municipalities in the State of Mexico's GNP increases from 78.3% to 90%, by the effect of either economic growth or because new municipalities are added to the metropolitan zone. Therefore, they grow at a slightly higher rate of 5%.

TABLE 4.13
GNP Projections and GNP per Capita for the Federal District and Adjacent Municipalities, 2000 to 2030

	1999	2010	2020	2030	AGR 1999 -2020
	GNP (USD, millions)				
Federal District	97,543	137,594	194,090	273,783	3.50%
Adjacent Municipalities	34,746	57,177.87	94,092.55	154,839.77	5.11%
MCMZ	132,289	195,752.42	289,661.89	428,623	4.00%
	POPULATION				
MCMZ	18,213,596	21,454,400	23,872,454	26,411,448	1.25%
	GNP PER CÁPITA				
MCMZ	7,263	9,124	12,134	16,229	2.72%

SOURCE: Table is by author, and is based on data from the *Sistema de Cuentas Nacionales de México,* México, INEGI, 1993 y 1999, and the assumptions described on this section.

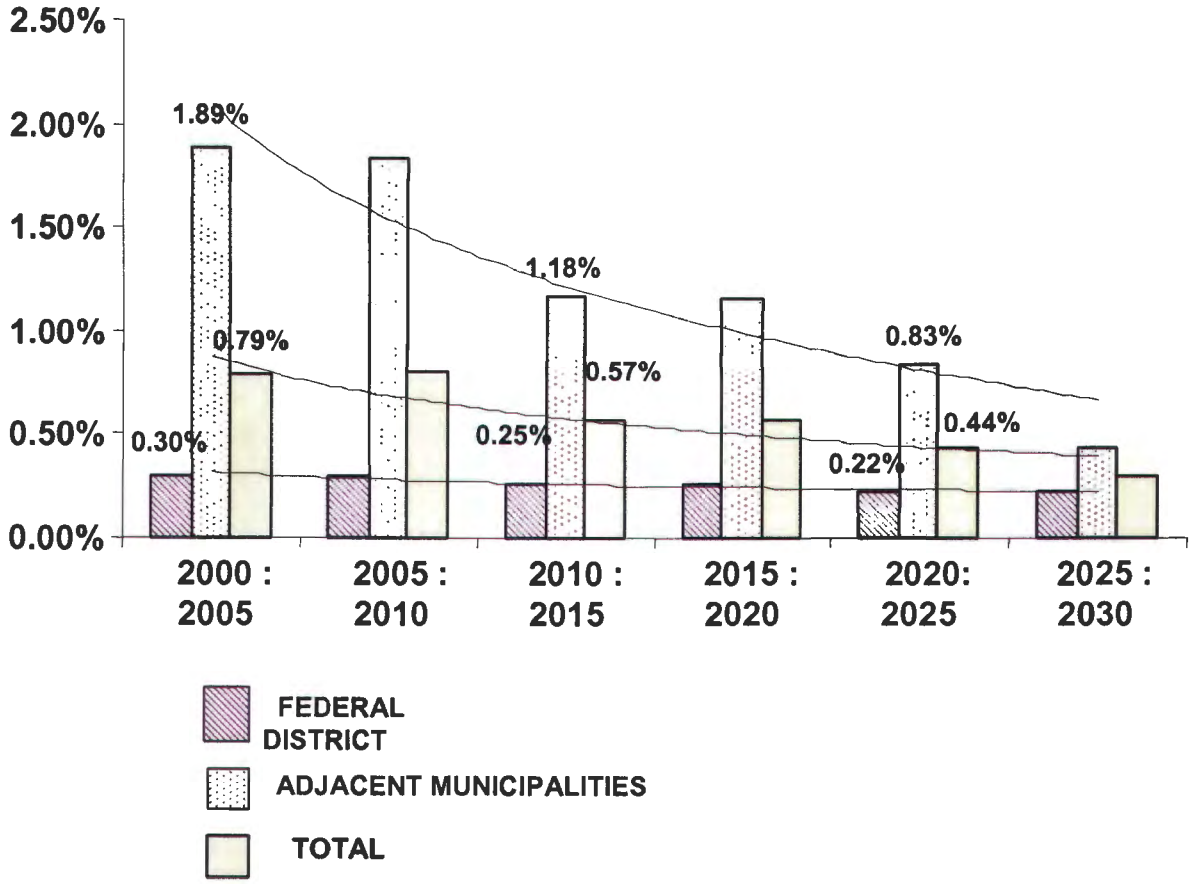
It is also important to make certain estimates to forecast the number of economical units or bussines[29] which will be in the City over a span of thirty years, because of the many variables of sustainability to be analysed further on and that are related to these results.

In this context, the growth rate of the number of economic units is expected to show a similar behaviour to the growth rate of population. This means that it tends to decrease as a consequence of the evolution of its own demographic variables and of the supposed increases in productivity per each economic unit. (Economic growth rates are expected to be much higher than demographic growth rates.)

[29] An economic unit is equivalent to a single business unit or "firm".

GRAPH 4.19

MCMZ: Estimated Growth Rates of Number of Economic Units, 2000 - 2025



SOURCE: Figure is by author.

4.7 The Crisis of Environmental Sustainability in Mexico City

We now turn to the analysis of the main ecological variables of the MCMZ with regard to this sustainability prospects, as expected the results are quite worrisome. After this analysis it will be quite obvious that an enormous effort will be needed to correct unsustainable path.

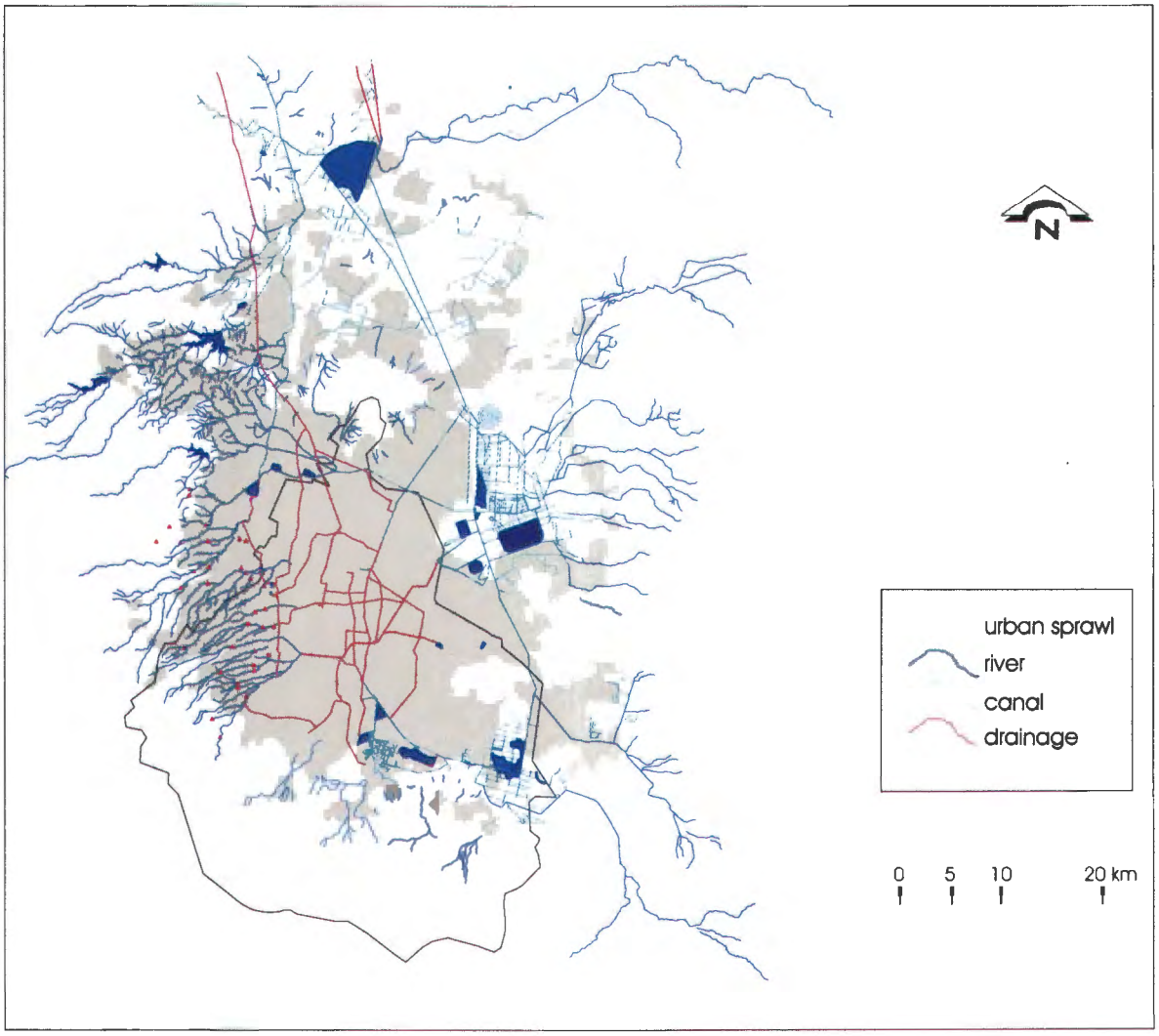
4.7.1 Water Balance

Developing countries face the challenge of fulfilling two agendas that have been established worldwide. The first is the "old agenda" which has to do with increasing water service coverage and the second is the "new agenda", which is concerned about the level of water quality and overall environmental sustainability.[30]

In the case of Mexico City, the biggest problem is the sustainability of water use or over-exploitation of the Mexico Basin aquifer, which cannot continue indefinitely due to the subsidence (sinking) problems in the city (In some zones in the south-eastern part of the Federal District reach 35 cm., a year.)[31] (see Map 4.5). Meanwhile, in terms of water extraction, the deeper the extraction, the more expensive the process.

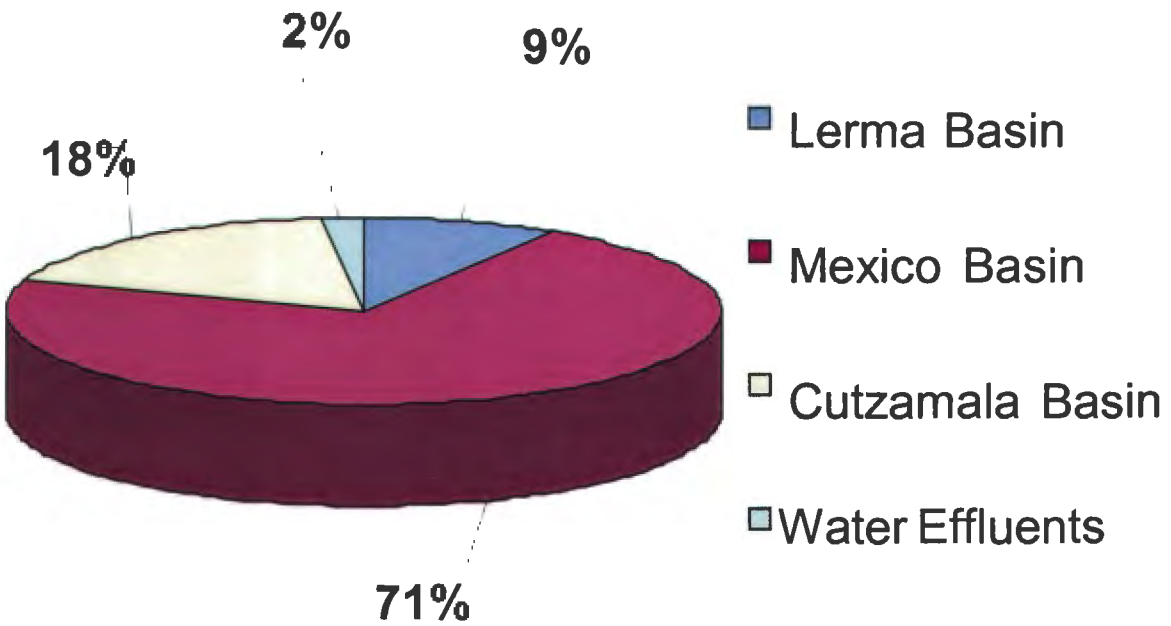
Although a significant amount of the Mexico City water supply comes from external water sources, mainly from the Lerma Basin and the Cutzamala River to the West, exploitation of resources in these areas is limited due to its physical availability. Furthermore, there are financial restrictions, due to the cost-distance ratio, and other political obstacles involved in bringing a resource that is outside Federal District jurisdiction.

[30]I. Seralgedin, Water Supply, Sanitation, and Environmental Sustainability, *The Financing Challenge*, Washington, D.C: World Bank, August 1995.
[31]In the Historical Centre of Mexico City, sinking has reached between 8 and 10 meters. See H. Merino, Sistema Hidráulico, *La Ciudad de México en el fin del segundo milenio...*, pp. 344-351.



Map 4.5. Year 2000: The Megalopolis Basic Hydrology.
Source: Own elaboration based on material provided by Ciudad Futura Desarrollo Urbano.

GRAPH 4.20
Water Supply by Source of Extraction, 1998



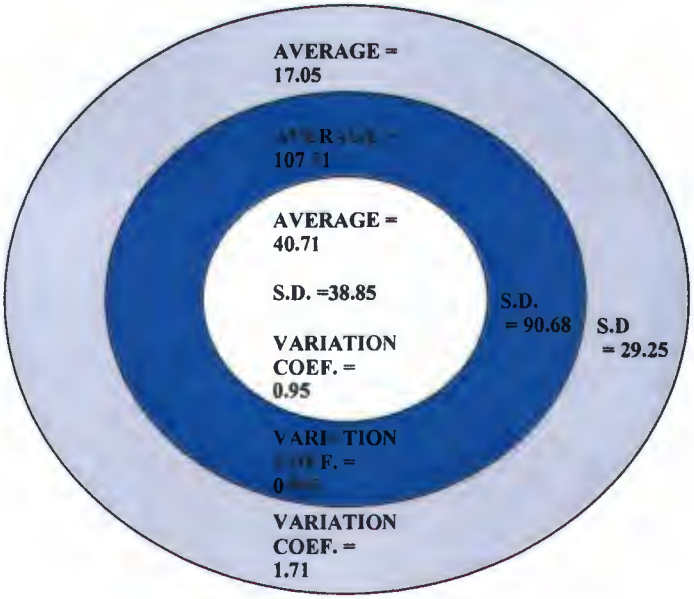
SOURCE: Graph is by author, and is based on environmental statistics from the Federal District and the Mexico City Metropolitan Zone, 1999, Mexico, INEGI /SEMARNAP, 1999.

In the face of this dilemma, the challenge in terms of sustainability consists of implementing policies that aim for a balance between the water supply and demand, without imposing non-sustainable measures, such as exploiting the aquiferous beyond its capacity to renew itself. Moreover, though it is possible that part of this resource may be obtained from the Tecolutla and Amacuzac rivers[32] in the future, this kind of measure is not desirable because of political implications and financial costs since these sources are located at lower elevations than that of Mexico City.

[32] J. Beristain, *Los Retos de la Ciudad de México en el Umbral del Siglo XXI,* ITAM, 1999.

FIGURE 4.4

Average Daily Volume of Water Extraction (m^3/day), According to "Urban Rings", 1996



SOURCE: Figure is by author, and is based on statistics from the Federal District and Metropolitan Zone, 1999, Mexico: INEGI /SEMARNAP, 1999.

PROBLEMS RELATED TO WATER SUPPLY

It is important to recognise factors that affect water supply, limiting it and restricting the attention drawn to growing demand in Mexico City.[33] The main factors include the low capacity for aquifers to renew themselves, the low rate of waste water recycling and the considerable proportion of water that is lost due to leaks in the water supply system.

In the specific case of the Federal District, the main recharging zones are found in the natural reserves to the south of the city, in the Cuajimalpa, Milpa Alta, Magdalena Contreras, Tlalpan and Tláhuac delegations. In these areas there is a large ecological reserve that covers 71,000 hectares, 64,410 of which form the recharging area of the Mexico Basin aquifer. It is also estimated that the average level of rainfall in these zones come to 1,200 mm a year – equivalent to just over 770 million cubic meters a year. This figure equals 30% of total demand for water in the city and 54% of the extraction of the Mexico Basin aquifer. However, the ongoing growth of the urban sprawl, a result of the urban form in the shape of rings that follow an "evolving" growth model, has brought about changes in the land use of areas that were originally forested or used for agricultural purposes. Thus it worsens the problem of water seepage and evaporation. Therefore, only 18 % is used for the renewal of the aquifers.

Another serious problem, which is also a consequence of the proliferation of human settlements, has been the erosion and deterioration of soil surrounding the different rivers that form in the higher areas of the Mexico Basin. A good example is the case of the eleven rivers to the east and the Compañía River, which are located in the Texcoco sub-basin, in the State of Mexico.

[33]Around 97% of the Federal District Population and 87% of that of the State of Mexico is estimated to have water services. Nevertheless, there are many deficiencies in supply and the associated problems worsen every day. See J. Gamboa, *Ciudad de México. Una Visión,* México: Fondo de Cultura Económica, 1994.

TABLE 4.14

Mexico City: Water-Related Services Coverage and Existing Infrastructure, 2000

		Federal District	Adjacent Municipilaties
Population	Inhab.	8,703,400	9,604,827
Surface	km2	1,504	3,230
Urban Area	km2	646	826
Urban Density	Inhab/km2	13,482	11,631
Stacking Index	Inhab/viv	4	5
Households	Houses	2,005,084	2,001,006
Houses with Water	Houses	1,962,977	1,838,924
Houses with Drainage	Houses	1,830,642	1,456,732
Inhabitants with Water	Inhab	8,244,504	8,826,836
Inhabitants with Drainage	Inhab	7,688,695	6,992,314
Drinkable Water Primary Net	km	875	937
Drinkable Water Secondary Net	km	11,953	12,797
Aqueducts and Conduction Lines	km	758	812
Intakes	Intakes	1,900,000	2,034,202
Lerma Wells	well	227	-
Valley of Mexico Wells	well	367	400
Regulation Tanks	tanks	380	240
Pumping Plants	plant	173	120
Potability Plants	plant	16	1
Chlorine Plants	plant	14	10
Drainage Primary Net	km	1,370	400
Area served by water conduits	km2	458	82
Storm Tanks	tank	11	1
Pumping Tanks	plant	172	122
Endowment	l/inhab/day	368	315
Demand	m3/s	37	35
TOTAL DEMAND	**m3/s**	**72.09**	

SOURCE: H. Merino, *Hydraulic System, Mexico City at the end of the Second Millennium...*, p. 346.

It is important to stress that the proportion of water used in Mexico City and that subsequently becomes residual or wastewater stands at 70%. This is the equivalent to just over 1,700 million cubic meters a year. However, because of the low recycling rate, only 194 millions of cubic meters are treated for reuse in the industry or for other urban uses for which potable water is not required.

TABLE 4.15
Infrastructure for Treated Wastewater

Distribution Net	783 Km
Treatment Plants (Secondary Level)	17
Average Flow of Production	800 litres /seg
Treatment Plants (Tertiary Level)	4
Average Flow of Production	3,000 litres/ seg
Pumping Plants for Treated Water	18
Capacity	2,400 litres/seg
Storage Tanks	18
Capacity	42,000 m3

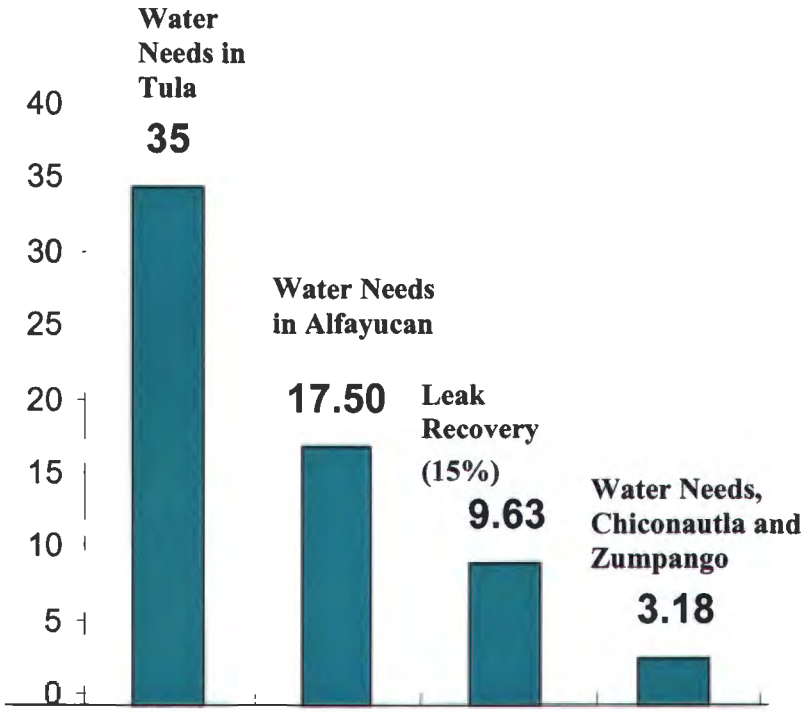
Source: J. Beristain, *Los Retos de la Ciudad en el Umbral del Siglo XXI*, Mexico, ITAM, 1999
*Concessions of Water Treatment Plants: Vallejo, Ciudad Deportiva, Coyoacan and San Juan de Aragón.

Reaching a better proportion of treated and reused water in the city is one of the guiding principles of a change toward a new hydraulic model. In other words, to counter draining wastewater and importing from external sources, viable options are needed to have water treated and reused without having to be extracted from the Mexico Basin.

Unfortunately, one of the factors hindering this option is the need, as pronounced in several presidential decrees, to supply water to different irrigation districts located in the states of Mexico and Hidalgo. In other words, each cubic meter of water that is treated and reused in the city means one cubic meter less to irrigate these districts. Therefore, one of the important measures that should be undertaken is the modernisation of agricultural methods in these areas or even a change to activities that require lower water consumption. Thus, it would be possible to increase the reuse of water in the city, without generating political and social conflicts in other areas of the country. As shown in Graphic 4.21, wastewater that is used for agricultural purposes in the irrigation district of Tula alone represents just over half of the water consumption in all of Mexico City.

Finally, one of the most serious problems that must be solved is that of leakage in the Mexico City water and drainage system. To a large degree, this problem is due to subsidence, the result of uncontrolled urban sprawl and a long history of using Mexico Basin aquifers. The subsidence of Mexico City has caused significant deterioration in most of the hydraulic infrastructure. For the sake of illustration, one example is that certain portions of the Great Drainage Canal (40 m3/s), north of the Texcoco Federal Zone, show changes in its inclination from what it was originally. This gives us an idea of the damage sinking has also had on the internal network. As shown in Graphic 4.21, just repairing leaks could save almost 10 cubic meters of water per second.

GRAPH 4.21
Water Needs in Different Irrigation Districts in Comparison to Water Leaks in Mexico City (m^3 / sec.)



Source: Graph is by author, and is based on statistics provided by the National Water Commission, 2001.

These problems not only undermine the capacity of water supply in Mexico City, but they also represent a major security issue for the population. A change in inclination of a work as important as the Great Drainage Canal increases the risk of flooding during the rainy season. The wastewater that needs to be displaced flows back into the City. Various fragments of the drainage system, such as the Central Transmitter (200 m3/s) and the West Transmitter (16 m3/s), reveal serious maintenance problems which brings about flooding in different parts of the city. Likewise, pavement and changes in land use along the slopes of the mountain system that surrounds the Basin of Mexico have increased the water flow to the urban area, making regulating water difficult.

Additionally, it is important to stress that the problem of leakage, as well as being caused by the gradual sinking of the city, is also the result using the wrong hydraulic model, which contributes to poor maintenance of the city's hydraulic infrastructure.

THE IMPORTANCE OF RESTORATION OF THE TEXCOCO LAKE FOR THE BALANCE OF WATER IN THE CITY

The natural process of water run-off has been drastically altered in the high and low areas of the Texcoco sub-basin, due to the loss of soil content as well as to modifications to natural river-banks and the introduction of large amounts of wastewater.

Thus, the Texcoco Lake Restoration project is directly related to the balance of water in Mexico City.[34] This project will significantly contribute to the increase in the reuse of wastewater in Mexico City and the rate of rate aquifer renewal in the Mexico Basin.

[34]For more information about the deterioration process of Texcoco Lake, See E. Ezcurra *et. al., The Basin of Mexico. Critical Environmental Issues and Sustainability*, United Nations, 1999.

While it is true that a certain degree of progress is evident in some of its stages, the project is still incipient and is far from reaching its goals and maximum potential. So far, rehabilitation work has only been completed in five minor lakes: Xalapango, Nabor Carrillo, Regulación Horaria, Churubusco and Recreativo.

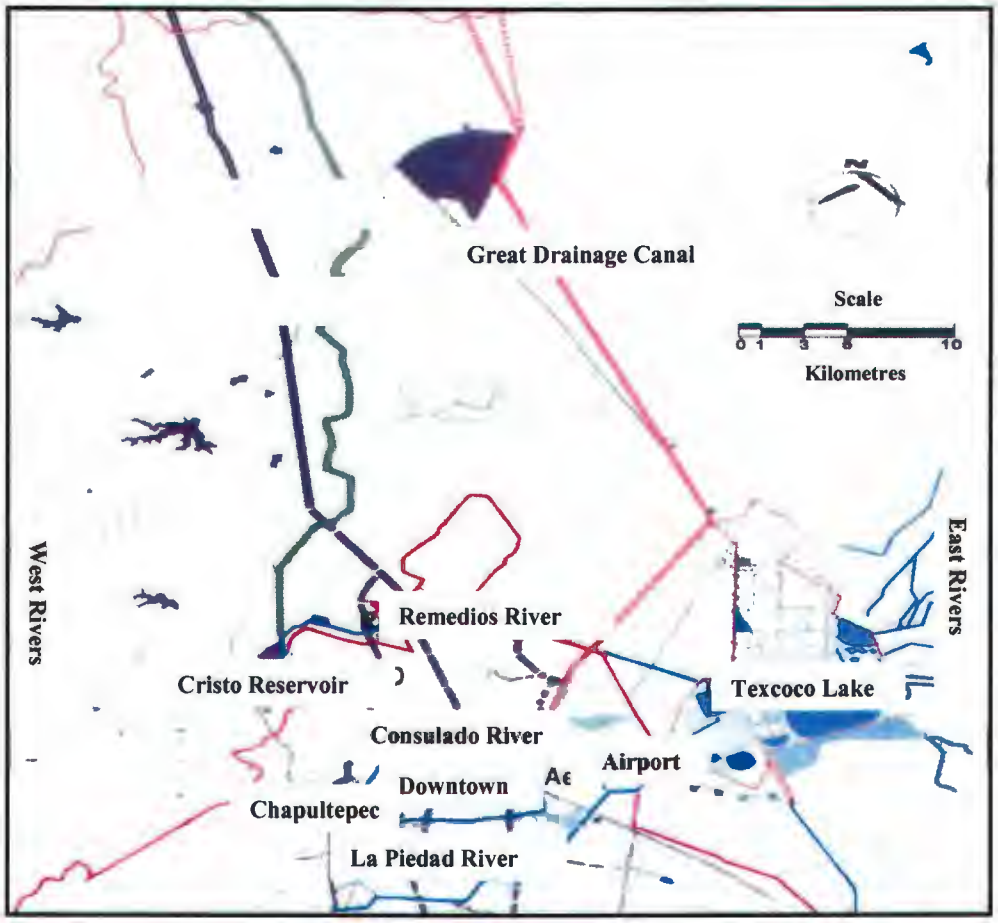
However, the completion of all the stages of the Texcoco ecological rescue project is vital to environmental sustainability in the Mexico Basin. Less extraction of subterranean water with better use of run-off water in the eastern part of the city and a better rate of water reuse could bring about lower levels of importing water from external western sources such as the Lerma and Cutzamala Basins.[35] Furthermore, improved the capacity of the renewal of Mexico Basin aquifers, as a result of more green areas and reforested areas in renewal zones, would be beneficial.

As part of Texcoco Lake rescue project, the eastern Teotihuacán, Papalotla, Xalapango, Coxcacoaco, Texcoco, Chapingo, San Bernardino, Santa Mónica and Coatepec rivers will be channelled into new lakes that are regulated. These lakes must also have the capacity for the temporary regulation that is needed for the increase in the volume of water flowing through the Oriente and Churubusco rivers, and the run-off water from the growth of urban sprawl. This means it must be able to go from 5 to 18 million m^3. Finally, the regulated lake must drain into the General Mexico Basin Drain, which in turn flows into the Great Canal Drainage system (see Map 4.6).

[35]As long as, as explained, the potential conflicts are solved between the different irrigation districts in the States of Mexico and Hidalgo.

MAP 4.6

Drainage System of the Mexico Basin



SOURCE: National Commission of Water, Mexico, 2001.

It is important to consider that channelled run-off water from the rivers east of the zone not only bring rainwater, but also bring wastewater from human settlements. Therefore, water that is collected for hydraulic regulation must be treated for later reuse or be injected into water-bearing mantles.

In addition to an increase in hydraulic capability, there is the possibility of rescuing new lacustrine areas around the Nabor Carrillo Lake, south–southeast of the Peñón–Texcoco highway. The lacustrine area will be made up of a system of an average of two-metre deep bodies of water, separated by parallel dikes with contour lines and supplied with treated wastewater at a secondary level.

The final system of bodies of water that is designed and the ecological rescue projects around said system could contribute to lower pollution by suspended particles, since it would regulate climate in the eastern part of Mexico City and increase the number of green areas per resident, among other benefits.

PROBLEMS RELATED TO WATER DEMAND

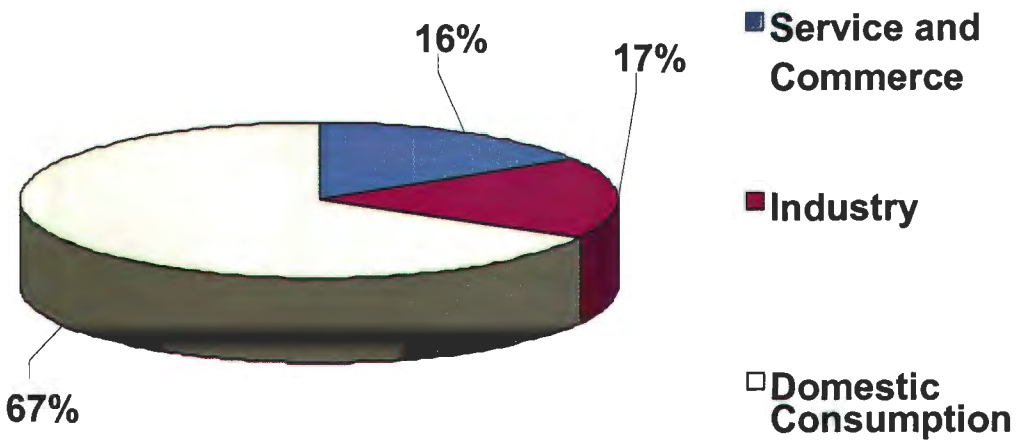
As in the case of flooding, it is important to point out that the problem of water supply in Mexico City is due to a *historically erroneous hydraulic model.*

As explained in section 4.1, stabilisation in the rate of population growth, resulting from the demographic transition expected, suggests that most supply problems were not due to increases in population. Instead, it is attributed to the evolution of a model of concentric urban rings that would bring about different sites demanding water in zones in which there is no suitable infrastructure for this purpose.

Thus, as will be explained later in detail, the challenge consists of bringing about an urban model in which a large urban centre is formed. Other urban sub-centres will gravitate towards said centre in such a way that will prevent the proliferation and dispersion of illegal settlements.

On the other hand, on analysing the distribution of water consumption in Mexico City based on units of said consumption, the importance of domestic demand compared to the demand of businesses, services and industry is evident. Despite the high level of economic activity in the City, it is inevitable for such a large population to generate such high levels of domestic consumption.

GRAPH 4.22
Distribution of Water Consumption by Type of User, 1998



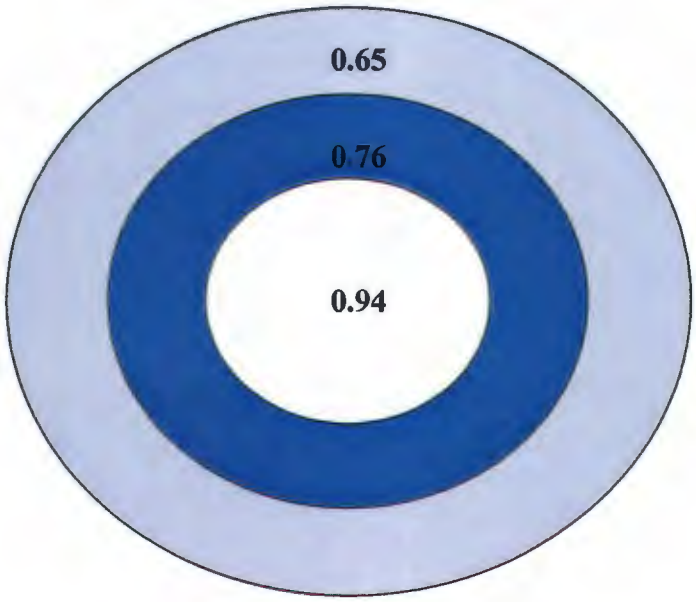
SOURCE: Graph is by author, and is based on Environmental Statistics from the Federal District and Metropolitan Zone, 1999, INEGI/SEMARNAP, 1999.

In view of this, the big challenge is to encourage less per capita consumption by means of awareness in water conservation, alternative technology (eco-technologies) and a reliable tariff system that reflects the true cost of supplying water in Mexico City.

As to this last point, it is important to stress that the difficulties associated with the corresponding charges, including the unpopularity of the highly variable "floating" quota system for consumption, include the existence of leaks in the distribution system and a

large number of illegal water taps that are not officially registered. As a result, a good part of this resource is used without being paid for.[36]

FIGURE 4.5
Average Collection per m^3 According to "Urban Rings", 1996
(Thousands of current pesos)



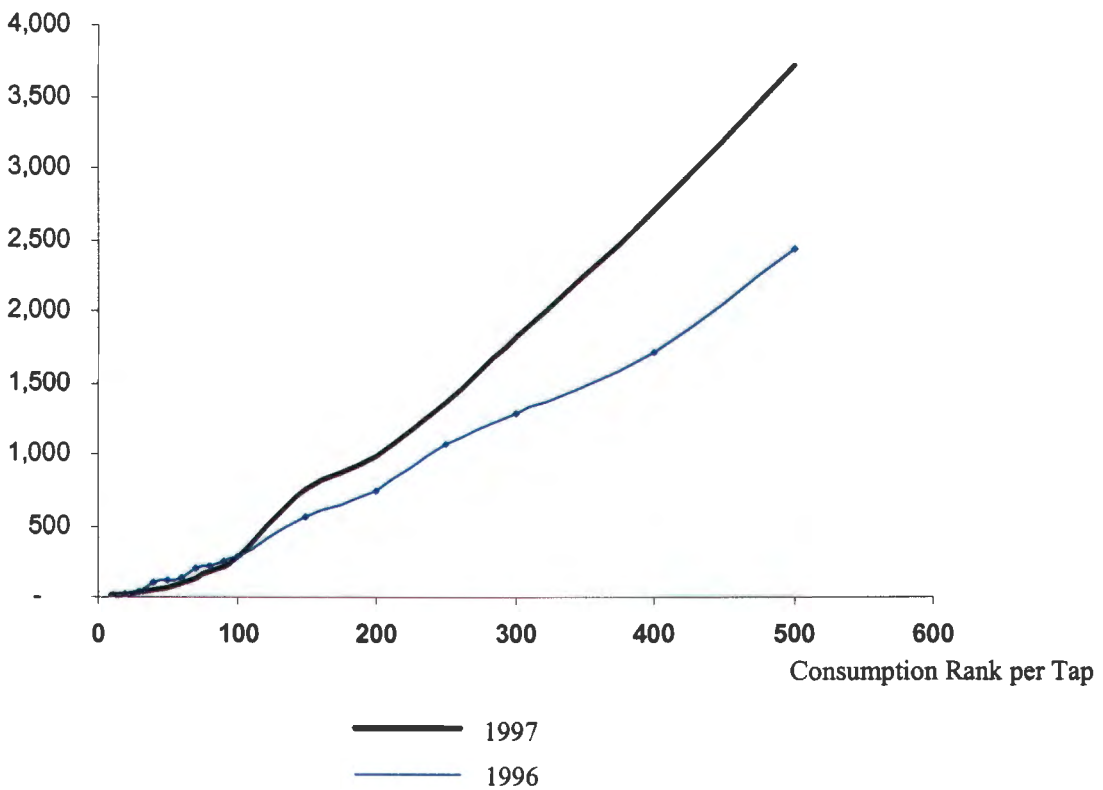
SOURCE: Figure is by author, and is based on Environmental Statistics from the Federal District and Metropolitan Zone, 1999, INEGI /SEMARNAP, 1999.

As mentioned in Section 3.6, the Porfirio Díaz administration marked great progress in terms of urbanisation and the building of infrastructure. In this sense, it is important to mention that since that time, there have been many attempts to establish a floating quota system based on the amount of water consumed by each residential, industrial, business or service (measured system) unit. However, continued growth of urban sprawl has meant that hard-won accomplishments are constantly being surpassed by increased water demand. In many cases, the complex tariff systems leading to sudden price hikes and the difficulties in installing and monitoring of meters have caused adopted policy measures to be abandoned. As a consequence, although slowly a pattern of users has emerged to increase the

[36]See *Programa para el Desarrollo del Distrito Federal,* 1995 – 2000, México: Poder Ejecutivo Federal,

measuring system, most of the water in the city is paid for by a system of fixed quotas which leads to inequality between users and lowers incentives for water conservation. This in turn, weakens the long-term financial health of the City's hydraulic system.

GRAPH 4.23
Structure of Tariffs for Consumption Range in the City



SOURCE: Graph is by author, and is based on Environmental Statistics from the Federal District and Metropolitan Zone, 1999, INEGI /SEMARNAP, Mexico, 1999.

4.7.2 Air Pollution

Since Mexico City is located in a closed basin that comprises most of the Federal District, as well as other federated states including Mexico, Hidalgo, Tlaxcala and Puebla, it fosters conditions that include intense winds and temperatures in the zone. In addition to this, the 18 million residents who generate 29 million legs of journeys daily cause many

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environmental problems, as in the case of thermal inversion with dangerous ozone levels. The main pollutants that represent a problem for the city are suspended particles such as sulphur dioxide, carbon monoxide, nitrogen and hydrocarbon oxides.

Each year it is estimated that pollution indirectly causes dozens of deaths. Due to respiratory problems millions of working days are lost, as well as make-up classes are given to thousands of children. (International Union of Public Transport, 1996).

TABLE 4.16
Mexico City: Inventory of Emissions, 1994 (Tons per year)

	TOTAL	%	Total Suspended Particles (PST)	óSulphur Dioxides (SO2)	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons
INDUSTRY	105,729	2.64%	6,323	26,053	9,433	31,518	32,824
SERVICES	413,013	10.30%	903	7,229	2,358	5,403	399,021
TRANSPORT	3,026,645	75.48%	18,968	12,185	2,346,350	91,725	554,936
SOIL AND VEGETATION	464,246	11.58%	425,420	-	-	-	38,979
TOTAL	4,009,629	100.00%	451,614	45,468	2,358,141	128,646	1,025,760

SOURCE: Table is by author, and is based on Environmental Statistics from the Federal District and Metropolitan Zone, 1999, INEGI/SEMARNAP, Mexico, 1999.

According to statistics, in 1994 and 1996 (Table 4.15 and 4.16), the transport sector was a major source of air pollution in Mexico City. Globally, this sector contributes just over 75% of total registered emissions.

TABLE 4.17
Mexico City: Inventory of Emissions, 1996
(Tons per Year)

	Industry	Service	Transport	Soil and Vegetation	Total
Total Suspended Particles (TSP	7.619,00	355,00	7.974,00		15.948,00
PM10 Particles			9.497,00	18.072,00	27.569,00
SO2	16.821,00	3.587,00	5.762,00		26.170,00
CO	10.345,00	4.526,00	2.086.938,00		2.101.809,00
NO2	29.448,00	11.006,00	117.928,00	500,00	158.882,00
HC	17.693,00	235.173,00	68.298,00	31.390,00	352.554,00
TOTAL	81.926,00	254.647,00	2.388.423,00	49.962,00	2.774.958,00

SOURCE: Table is by author, and is based on J. L. Lezama, *Degradación del Medio Ambiente, La Ciudad de México en el fin del segundo milenio...*, pp. 443-453.

As observed in comparing Table 4.15 and Table 4.16, it can be concluded that hydrocarbon emissions from automobiles, the evaporation of gasoline, industries and services, the commercialisation of LP gas, as well as the paint use and application, have substantially decreased. In this context, one important factor is implementing a policy to install technologies to recover gasoline vapours in gasoline stations in the Mexico City metropolitan zone.

However, though the level of suspended particles decreased between 1989 and 1994, levels rose above the norm for a few days in 1996.

Regarding sulphur dioxide, it is worth mentioning that it is one of the pollutants that has been controlled effectively. This is mainly due to PEMEX's reformulation of combustion fuels, natural gas substituting combustion fuel in several thermoelectric plants, the closure of the "*18 de Marzo*" refinery, and a reduction of sulphur in diesel fuel, among other measures.[37]

It is also important to stress that carbon monoxide and nitrogen dioxide levels have been kept under control. However, in the case of the former, levels have reached over two million tons a year and the risks this substance poses to health are still uncertain. Moreover, in the case of the second, even though it has not exceeded permissible health limits, this chemical is one of the main precursors of ozone levels.

In summary, low volume levels of polluting emissions registered between 1994 and 1996 were the result of measures that included the implementation of the PICCA (Integrated Program Against Atmospheric Pollution 1990) and the PROAIRE (Program to Improve the Air Quality of Mexico City), which is still in force. However, HC continues to emit high volumes and NOX is produced in sufficient amounts to form photochemicals. Thus, it must be stated that ozone levels still violate standards more than 60% of the days a year.[38]

[37]J. J. Lezama, Degradación del Medio Ambiente, *La Ciudad de México en el fin del segundo milenio...*, pp. 443-453.
[38]J. J. Lezama, Contaminación del Aire, *La Ciudad de México en el fin del segundo milenio...*, pp. 461-468.

4.7.3 Transportation and Road Systems

THE PROBLEM OF THE TRANSPORTATION MODAL MIX

Parallel to problems of environmental pollution, Mexico City also has some serious road congestion and transit problems. Being the main population centre and the most important economic area of the country, especially for business and service industries, it brings important challenges in terms of roads and transit.

These challenges have become more pronounced due to the uncontrolled urban sprawl of the last few decades. This situation has created a situation in which urban lines – that actually does persist in the city – do not follow any planning. In many cases, building new means of transportation was a determining factor in giving way to the growth of urban sprawl. On surpassing the formally established limits because of the high demand for housing, the city's growth overflowed into a formal and informal urbanisation of municipalities adjacent to the Federal District.

By the end of the 90s, there were almost 4 million automobiles in the city (see Graph 4.27), of which (87.5%) circulate in the Federal District. As mentioned in a previous section and according to the latest statistics available,[39] travelling demands in Mexico City[40] grew to almost 21 million trips a day in 1994. This is equivalent to approximately 29 million transfers via other means of transportation to reach a final destination.[41] Using Federal District delegations and adjacent municipalities in the State of Mexico as a reference, Mexico City population that year stood at close to 16.5 million people. This means a daily demand of 1.28 daily trips per person and 1.77 transfers per person, distributed among different means of transportation as shown in Graph 4.23.

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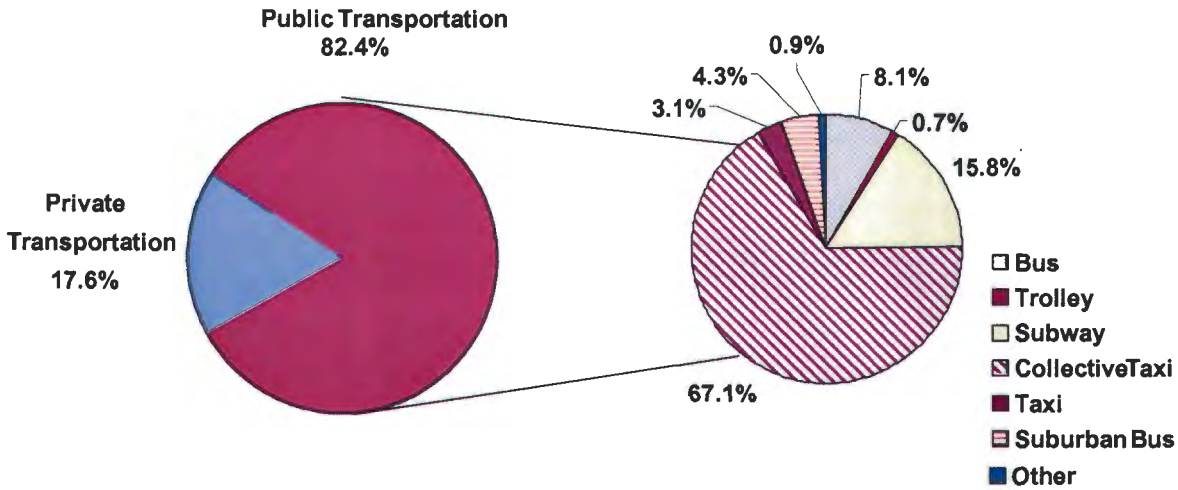
[39]COMETRAVI, *Estudio Integral de Transporte y Calidad del Aire en la Zona Metropolitana del Valle de México. Diagnóstico de las Condiciones de Transporte y sus Implicaciones sobre la Calidad del Aire,* 1999.
[40]In this case, the numbers refer to the "Metropolitan Zone of the Valley of México". COMETRAVI, *Estudio Integral de Transporte y Calidad del Aire en la Zona Metropolitana del Valle de México. Diagnóstico de las Condiciones de Transporte y sus Implicaciones sobre la Calidad del Aire,* 1999.

GRAPH 4.24
Transportation Modal Mix of the Daily Demand of Transfers in Mexico City



SOURCE: Graph is by author, and is based on statistics from COMETRAVI, Mexico, 1999.

This transportation modal mix shows the result of a lower participation of high capacity public transportation (subway, buses, trolley buses and streetcars) over the last three decades.

[41]A trip can be divided into various segments when a person uses several means of transportation to complete a single trip.

TABLE 4.18

Participation of Large and Small Capacity Means of Transportation. High anf Low capacity of Trips in Mexico City: 1966-1995 (%)

VEHICLE CAPACITY	1966	1972	1979	1983	1985	1989	1995
Low: taxis, small buses, and private automobiles	10.7	31.5	32.2	32.1	29	50	73.8
High: subway, buses, Trolley buses and urban trains	89.3	66.6	65.5	67.2	54	50	24.9
TOTAL	100	100	100	100	100	100	100

SOURCE: B. Navarro Benítez & S. Bacelis Roldán, El Metro como Sistema de Transportación Masiva, *La Ciudad de México en el fin del segundo milenio...*, pp. 378-383.

This makes the movement of people and goods in the city inefficient, resulting in longer travel times, which, as shown in Table 3.18, can be up to 50 minutes in the case of public transportation and the 35 minutes in the case of private transportation.

TABLE 4.19
Mexico City: Trip Time in Minutes per Person According to Type of Transport, 1996

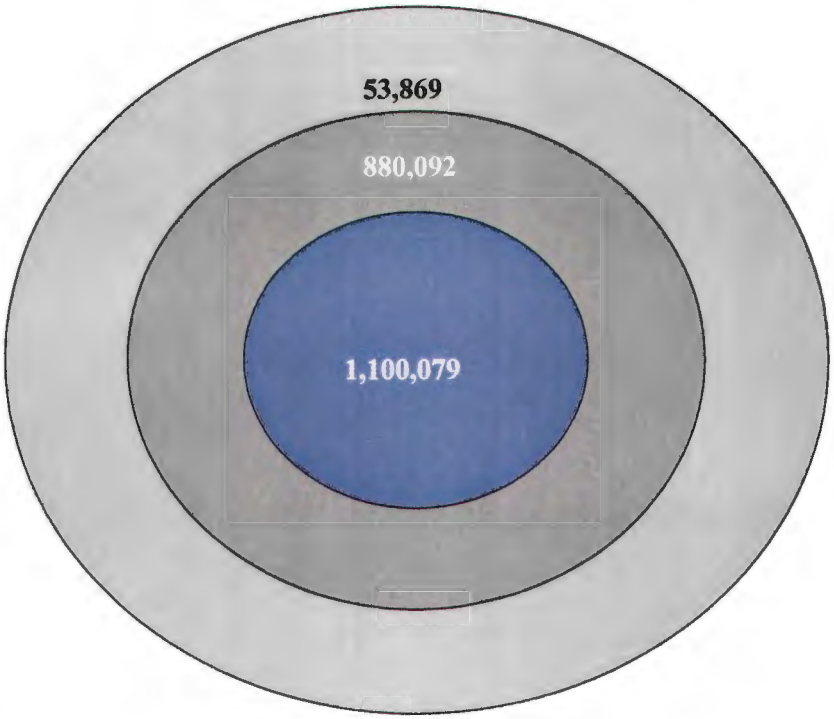
Means of Transportation	Federal District	State of Mexico	MCMZ
Public Transportation	44	57	50
Private Transportation	32	39	35
Mixed Transportation	74	84	79

SOURCE: COMETRAVI. *Diagnóstico de las Condiciones de Transporte y sus Implicaciones en la Calidad del Aire de la Ciudad de México,* Study No.1, Vol. 1, Mexico.

On the other hand, an analysis of the urban rings shows a high concentration of automobiles in the centre ring.

FIGURE 4.6

Distribution of Automobiles in "Urban Rings", 1997



SOURCE: Figure is by author, and is based on statistics from INEGI, Mexico, 1999.

PERSPECTIVES ON THE EVOLUTION OF THE TOTAL NUMBER OF PASSENGER CARS, 2000 – 2030

Over a thirty-year span, the number of passenger cars that circulate in Mexico City is expected to increase dramatically. If historic patterns of some countries worldwide – including Mexico – are studied, most countries show very similar curves and even though average rates of growth vary at different stages of periods analysed, these differences are related to the evolution of their respective economies.

Over the last few decades, the total number of passenger cars showed a marked growth in Korea while growth was lower in Brazil. The rest of the countries studied were much more uniform. However, on analysing a period from 1980 to 1990, it can be found that the

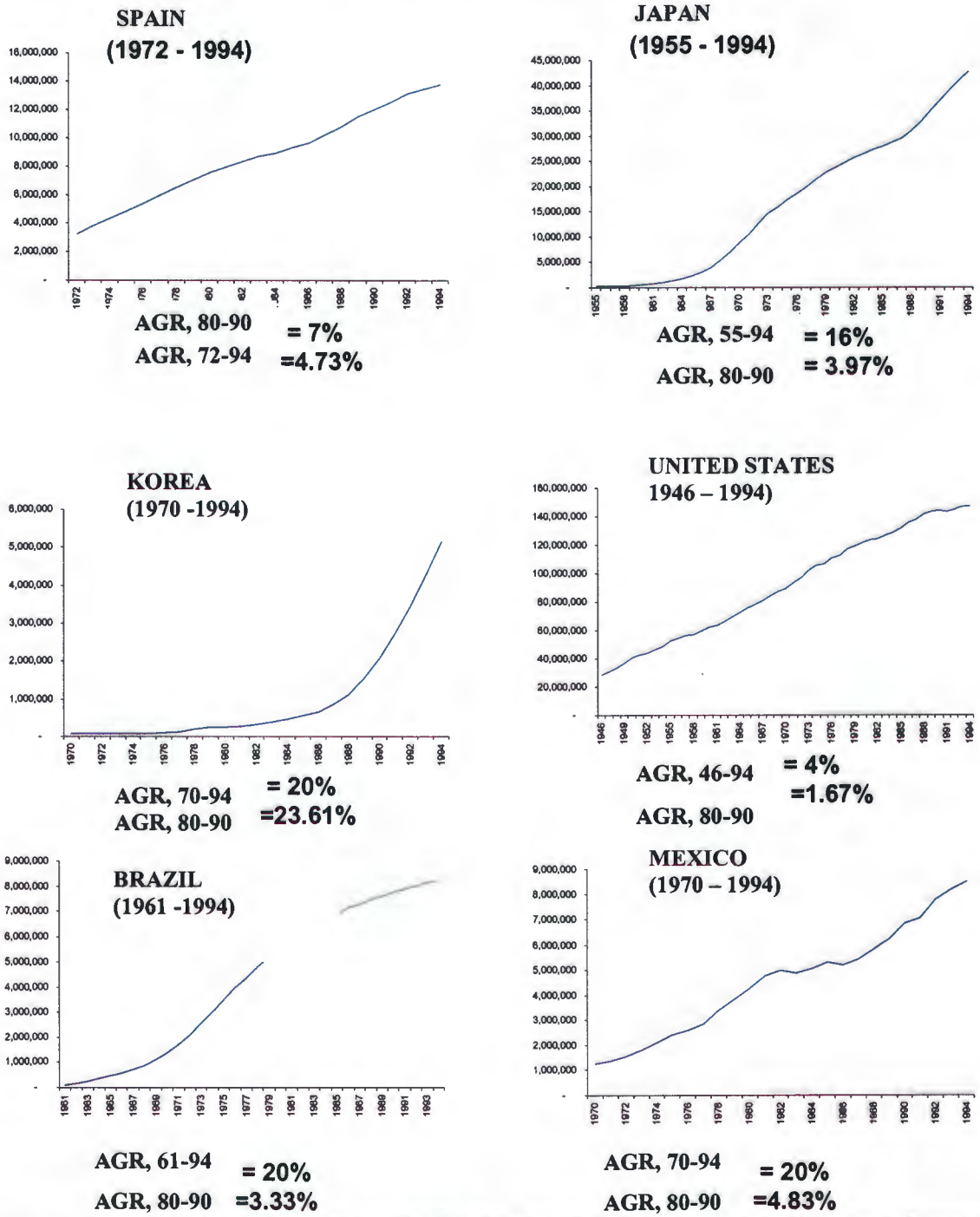
average annual rate of growth of the total number of automobiles had a correlation of 0.9 with the annual growth rate of Gross National Product (GNP) in real terms. To a great extent, this confirms the notion that the pattern of increases in the number of passenger cars is determined by the evolution of economic activity.

Worldwide, the number of automobiles is expected to double in the next 20 or 30 years to reach a total of 630 million vehicles. A good part of this growth will take place in developing countries and in Eastern Europe.[42]

[42] WHO, 1994.

GRAPH 4.25

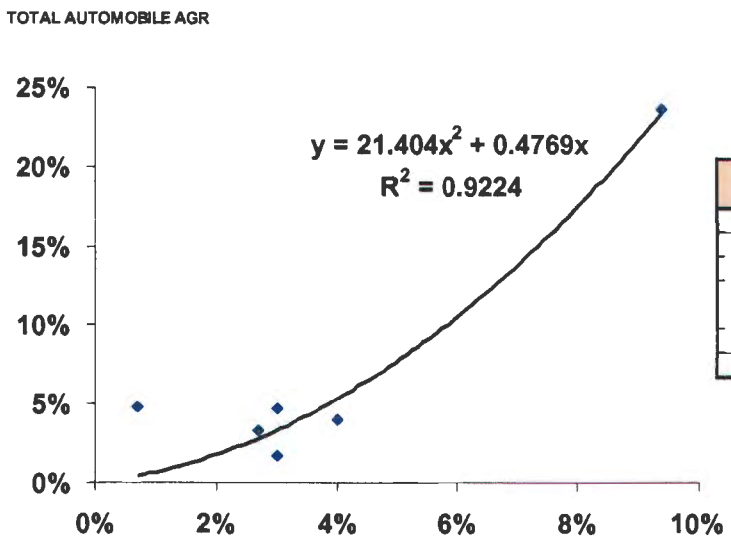
Automobile Penetration
(Number of Registered Passenger Automobiles - Several Countries)



SOURCE: Graph is by author, and is based on statistics from the AAMA (American Automobile Manufacturers Association), *World Motor Vehicle Data*, 1996. , using Excel 5.0

GRAPH 4.26

Relation between Economic Activity and Total Number of Automobiles (Several Countries)



	AUTOMOBILE	GNP
Spain	4.73%	3.00%
Japan	3.97%	4.00%
Korea	23.61%	9.40%
United States	1.67%	3.00%
Brasil	3.33%	2.70%
Mexico	4.83%	0.70%

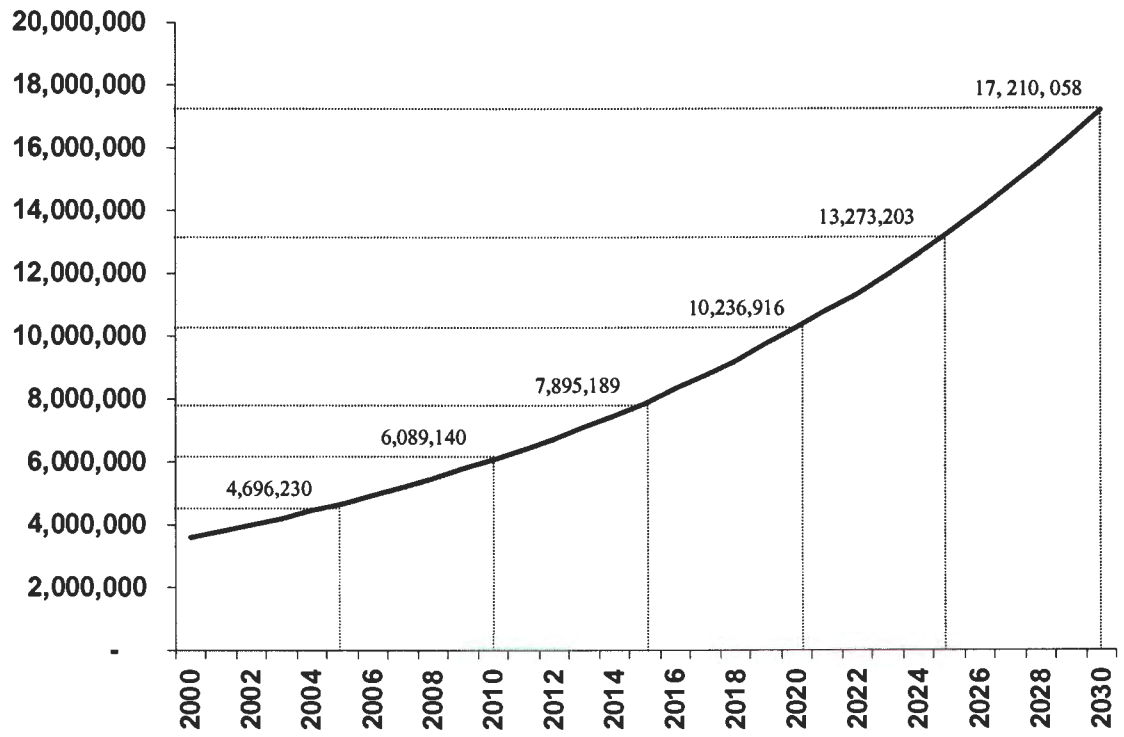
CORRELATION= 0.9

SOURCE: Graph is by author, and is based on statistics from the AAMA (American Automobile Manufacturers Association), *World Motor Vehicle Data*, 1996. The regression equation was estimated using Excel 5.0

If this ratio is applied to the case of Mexico City, the evolution of the number of private cars over a thirty-year span, will be as follows.

GRAPH 4.27

Projected Number of Personal Automobiles in Mexico City, 2000 to 2030

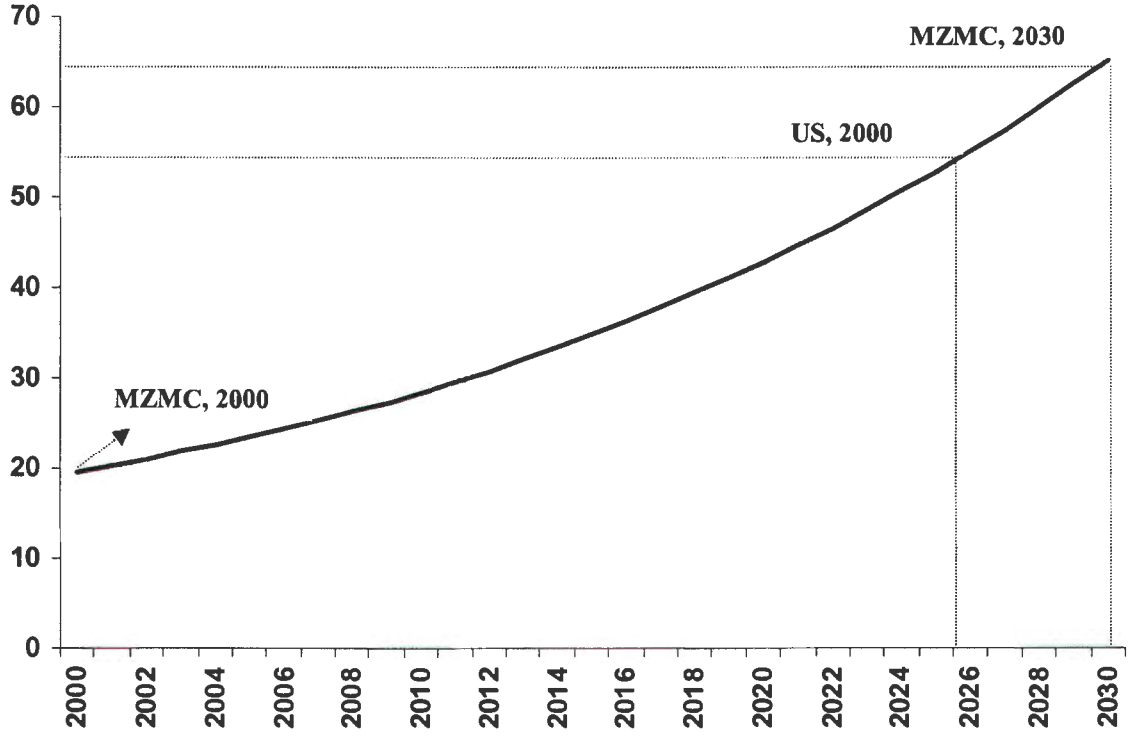


SOURCE: Graph is by author, and is based on statistics from the AAMA (American Automobile Manufacturers Association), *World Motor Vehicle Data*, 1996 and COMETRAVI, 1999.

Analysis of above results in relation to the total Mexico City population suggests that the statistics are not as unreasonable as they seem. At present, there are already countries, such as the United States, that have 57 cars for every 100 persons. This figure will surely grow over the next thirty years. Thus, the figure of 65 cars per 100 persons in Mexico City by the year 2030 is consistent with the level of expected economic growth.

GRAPH 4.28

Automobiles for each 100 Persons in Mexico City, 2000 to 2030



SOURCE: Graph is by author, and is based on statistics from the AAMA (American Automobile Manufacturers Association), *World Motor Vehicle Data*, 1996 and COMETRAVI, 1999.

ROAD INFRASTRUCTURE

Considered the centre of economic activity at the national level, Mexico City is also the main hub for inter-regional travel. As shown in Table 4.19, the city has highway access that joins the existing urban thoroughfares, but these are not enough to hold the volumes of traffic in transit, which is calculated at approximately 300,000 vehicles a day.

TABLE 4.20

Flow and Connections to Main Highway Access Points

HIGHWAY	DAILY VEHICLES	ROAD CONNECTIONS
México – Querétaro (toll)	27, 839	Periférico – Norte, Calz. Vallejo and Av. 100 Metros
México – Pachuca (toll) México – Pachuca (free)	16,860 33,198	Periférico, Northeast part, Insurgentes Norte and Circuito Interior
México – Puebla (toll) México – Puebla (free)	40,485 52,944	Ignacio Zaragoza, Ermita Iztapalapa and Periférico, East section
México – Cuernavaca (toll) México – Cuernavaca (free)	21,584 11,050	Tlalpan, Periférico Sur and Insurgentes Sur
México – Toluca (toll) México – Toluca (free)	22,460 59,700	Constituyentes, Palmas, Reforma,
TOTAL	**286,120**	

SOURCE: COMETRAVI, *Estudio Integral de Transporte y Calidad del Aire en la Zona Metropolitana del Valle de México. Diagnóstico de las Condiciones de Transporte y sus implicaciones sobre la Calidad del Aire*, 1999.

As a result of this design for inter-regional travel and for trips inside the City, there are roads with as many as 30,000 to 50,000 vehicles a day, as in case of Avenida Tláhuac, Calzada Ermita Iztapalapa, Paseo de la Reforma, Río Consulado, Eje 7 Sur, Eje 8 Sur, Avenida Churubusco and Calzada México-Xochimilco. Avenues with more than 50,000 vehicles a day include Calzada de Tlalpan, Viaducto Miguel Alemán, Calzada Ignacio

Zaragoza, Insurgentes Sur, Xola, Eje Central Lázaro Cárdenas, Río Consulado and Eje 7 Sur (see Map 4.7).

In terms of links to the business centre of Mexico City, there are many deficiencies, above all in those linking the Federal District and adjacent municipalities in the State of Mexico. For example, connectivity between both areas is restricted by the Sierra of Guadalupe, thus making access to the Coacalco, Tultitlán and Tlalnepantla municipalities deficient. Likewise, access to municipalities in the Cuautitlán Basin is limited to the Mexico–Queretaro highway and Tlalnepantla–Cuautitlán[43] highway, which in turn creates serious bottlenecks.

In the eastern part of Mexico City, the topography has allowed for the consolidation of greater road infrastructure in the municipalities of Ecatepec, Nezahualcóyotl, Texcoco and the Chalco Basin. However, these accomplishments are still not enough to satisfy the needs of, for example, Ecatepec, a municipality that according to the 1995 population census is the most populated municipality in the State of Mexico.[44]

In the future, finishing ring-like roads such as works like *Circuito Interior, Periférico* and the second outer *Periférico* will be required to satisfy the needs of mobility in Mexico City, along with a model of roadways that circle the area, which will be discussed in the last chapter of this thesis.paper. Regarding the second need, for example, the need to homogenise physical and operating conditions in the east and north by means of suitable planning for containment and for building overpasses stands out.[45]

[43]COMETRAVI, *Estudio Integral de Transporte y Calidad del Aire en la Zona Metropolitana del Valle de México. Diagnóstico de las Condiciones de Transporte y sus implicaciones sobre la Calidad del Aire,* 1999.
[44]*Ibid.*
[45]*Ibid.*

As shown in Table 4.20, there is an important gap between the road infrastructure that has been built and what was originally planned to satisfy the City's needs of mobility.

TABLE 4.21

Mexico City: Controlled Access Roads (km)

Roads	Planned Length	Constructed Length
Viaducto Miguel Alemán	16.8	11.8
Calzada de Tlalpan	17.2	14.4
Anillo Periférico	87.2	59.7
Circuito Interior	41.4	27.9
Radial Aquiles Serdán	9.4	3.6
Radial Río San Joaquín	5.4	5.4
Calzada Ignacio Zaragoza	14.1	9.6
Insurgentes	30.4	12.0
Gran Canal	10.0	8.0
TOTAL	**229.9**	**150.7**

SOURCE: Garza, México: 2000, p. 364.

Now, aside from the new road infrastructure that should be built to satisfy the demand of present and future travel, the conditions of the main intersections and thoroughfares must be improved. As shown in Table 4.21 and 4.22, most intersections show a service level of "F"[46], the worst possible conditions. Most thoroughfares have a service level of "C", which is also far from ideal ("A"). There are even some thoroughfares, as in the case of the Río San Joaquín, that received a "D", which means that the average speed along this route is 25 Km./hr.

[46] From "F" to "A" worst to optimal conditions.

TABLE 4.22

Level of Service on Main Intersections in Mexico City

CITY INTERSECTION	LEVEL OF SERVICE
Periférico / Centenario	F
Periférico / Autopista Peñón – Texcoco	F
Periférico / Av. Pantitlán	F
Carretera Libre México Puebla /Simón Bolivar	C
Periférico / Av. Xochiaca	F
Periférico / Blvd. Centro	F
Av. Texcoco / Ferrocarril del Sur	D
Av. Ignacio Zaragoza / Circuito Interior	F
Av. Central / Jardines de Morelos	E
Martín Carrera / Centenario	F
Ferrocarril Hidalgo / Talismán	F
Insurgentes Norte / Eje 2 Norte	G
Carretera Texcoco / Carretera México – Puebla	A
Av. Constituyentes / Acueducto	F
Periférico / Legaria	F
Marina Nacional / Circuito Interior	E
Vía Morelos / Av. Revolución	F
Insurgentes Norte / Montevideo	F
Av. 100 metros / Periférico Norte	D
Av. Gustavo Baz / Mario Colín	F
Aquiles Serdán / Calzada de las Armas	F
Av. Mario Colín / Circunvalación	F
Vía Morelos / Av. Morelos	F
Calzada Vallejo / Clave	D
Calzada Vallejo / Tequesquinahuac	F
Av. 1° de Mayo / Vía Gustavo Baz	F
Mariano Escobedo / Av. Marina Nacional	D
Mario Colín / Av. Toltecas	F
Aquiles Serdán / Eje 4 Norte	F
Río San Joaquín/ Ingenieros Militares	F

SOURCE: COMETRAVI, Comprehensive Study of Transportation and Air Quality in the Metropolitan Zone of the Mexico Basin. *Diagnosis of Transportation Conditions and Implications on the Air Quality*, 1999.

TABLE 4.23

Level of Service in Main Road Corridors of Mexico City

CITY STREET – ROAD CORRIDOR	LEVEL OF SERVICE
Insurgentes Norte – Vía Morelos – Av. Nacional	C
Av. 608 – Av. Carlos Hank González	C
Autopista México - Querétaro	D
Eje 1 y 2 Oriente – Centenario	C
Av. Mario Colín – Tlalnepantla – Tenayuca	C
Aquiles Serdán – Marina Nacional	C
Constituyentes – Carretera Federal México – Toluca	B
Cien Metros - Vallejo – Toluca – Del Durazno	A
Río San Joaquín	D
Carretera Federal México – Texcoco	B
Carretera Federal México – Puebla	B
Oceanía – Av. 602 – Autopista Peñón – Texcoco	B
Calzada Ignacio Zaragoza – Autopista México Puebla	C
Periférico Northwest	B

SOURCE: COMETRAVI, Comprehensive Study of Transportation and Air Quality in the Metropolitan Zone of the Mexico Basin. *Diagnosis of Transportation Conditions and Implications on the Air Quality*, 1999.

Map 4.7. Year 2000: The Megalopolis Main Urban Roads System.
Source: Own elaboration based on material provided by Ciudad Futura Desarrollo Urbano.

Aside from problems inherent to the conditions of the existing roadway infrastructure or the lack thereof, Mexico City suffers from serious problems of obstruction to roads for various reasons. Among these problems are the informal market stalls that line the streets, the incessant demonstrations that take place along city streets thus lengthening distances and travel times for vehicles.[47]

THE IMPORTANCE AND CHALLENGES OF THE METRO (SUBWAY) SYSTEM

For thirty years, the Metro (subway) network has placed itself as one of the leading axes of the entire transportation system in Mexico City:

> "Building new subway lines permitted a higher level of capacity for the Metro network as a main system of metropolitan transportation. Likewise, the structural vocation of said system was fulfilled by establishing institutional and regulatory measures, such as integrating fares for all means of transportation property of the Federal District; incorporating bus stops and bus depots to Metro stations; restructuring trolley buses and trolleys to link and feed that system."[48]

However, despite being one of the most important urban works nation-wide, the Collective Metro System (SCM) has shown a serious decline in the number of users over the past few years. In the mid-80s, promotion began for low-capacity means of transportation, such as collective taxis and meter-less taxis. This acted to the detriment of public transportation and consequently in detriment of the Metro as a structural axis of the metropolitan transportation system as well.

[47]COMETRAVI, Comprehensive Study of Transportation and Air Quality in the Metropolitan Zone of the Mexico Basin. *Diagnosis of Transportation Conditions and Implications on the Air Quality*, 1999.
[48]See B. Navarro y S. Bacelis, El Metro como Sistema de Transportación Masiva, *La Ciudad de México en el fin del Segundo Milenio...*, p. 379.

This trend continued well into the 90s but, neverthless the SCM was largely extended lately into the east of the City. There was also a booming growth of other means of transportation that have continued to compete with the Metro, such as taxis. "Thus, while a significant number of routes of collective transportation fulfil a feeding function to the Metro, but others compete by making parallel trips, completely or partially, jeopardising the potential securing of Metro users and distribution within the network..." [49]

TABLE 4.24

Evolution of Metro Infrastructure, 1969 - 1999

Years	Stations Opened	Annual Flow of Users (millions)	Kilometres in Use
1969 - 1972	48	389.1	41.40
1978 - 1982	32	1038	37.99
1983 - 1988	45	1476	60.95
1991 - 1994	29	1423	37.07
1994 - 1999	13	N/A	
TOTAL	**167**		**189.41**

SOURCE: Table is by author, and is based on G. Garza, coord.., *La Ciudad de México en el fin del segundo milenio*, México: Gobierno del Distrito Federal, El Colegio de México, 2000, 768 p.

The challenge for the SCM in the upcoming decades is to win back its role as a connecting axis of transportation in Mexico City, instead of other means of transportation that should act as feeders to the network. The population's needs of environmental protection and mobility force us to take on an emergency strategy so that the Metro may recover its levels of physical and functional integration, along with other choices for urban transportation.

[49] *Ibid.*

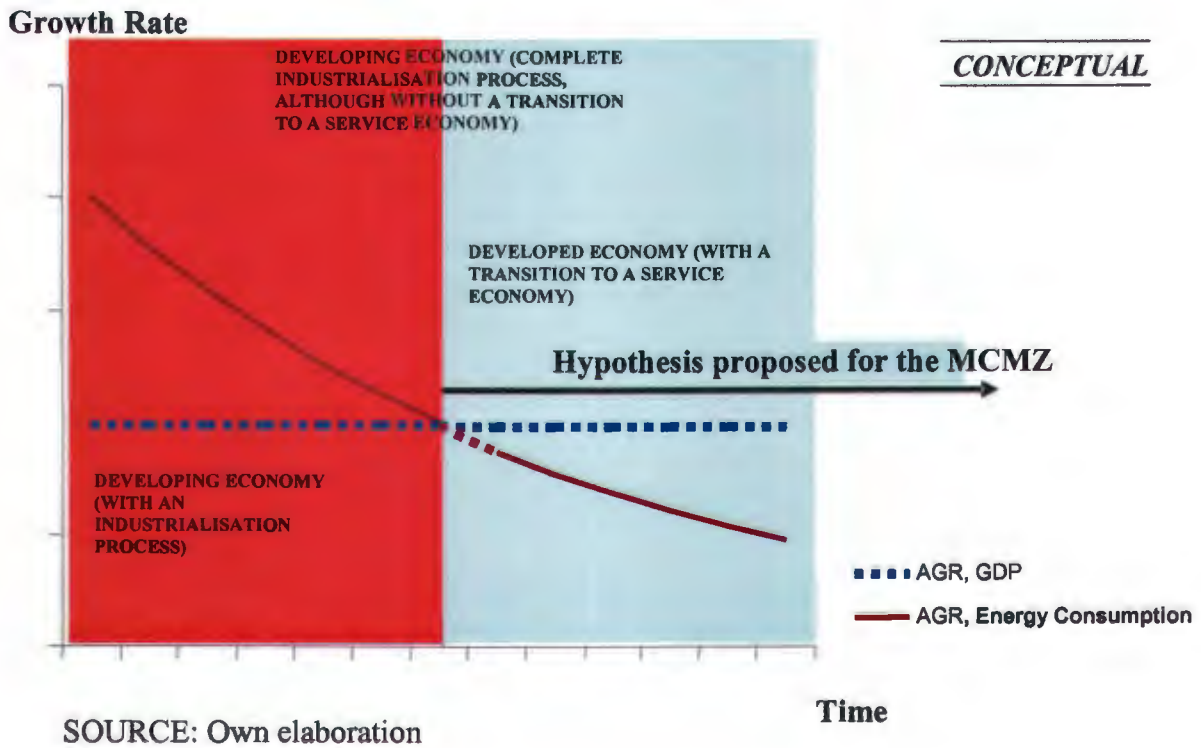
In view of this, it is important to remember that in looking towards the year 2030, expansion of the metro will take the system into the State of Mexico, to the west, to the south, to Xochimilco and Chalco.Therefore, institutional co-ordination between the authorities of this state and the Federal District – which has been practically absent in recent years – becomes imperative for the future.

4.7.4 Energy

WORLD TRENDS

The intensity of energy use, that is, the relationship between growth in the use of this resource and economic growth, constitutes one of the key variables of sustainability in any urban area. Worldwide, there is a trend towards more efficient use of energy, as well as greater penetration of increasingly cleaner forms.

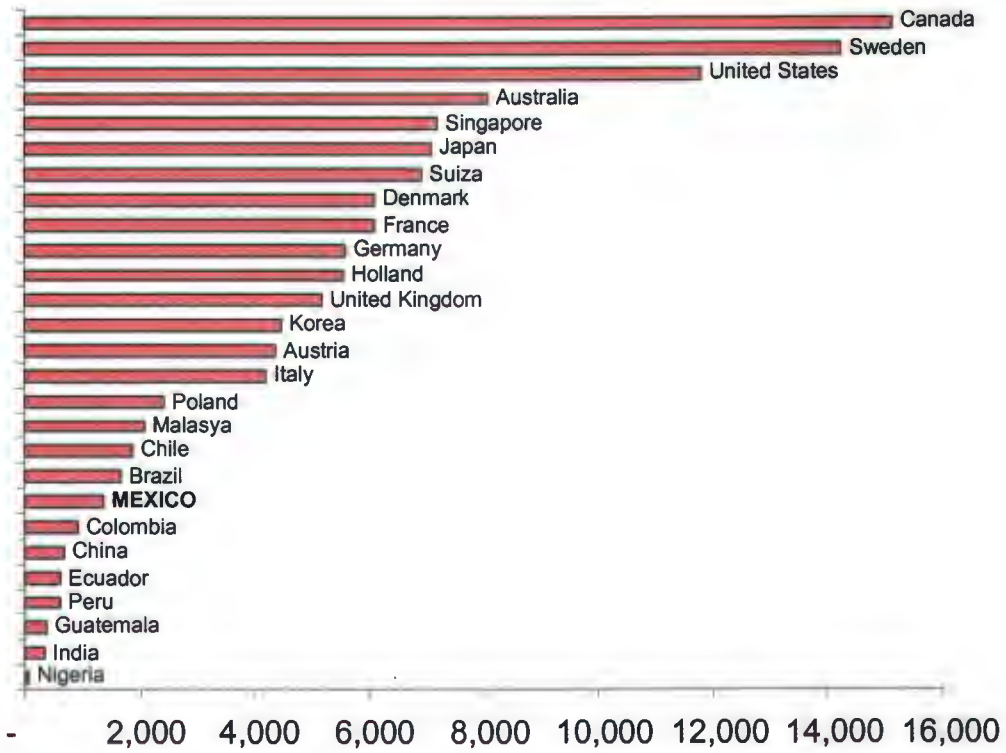
FIGURE 4.7
Stages in the Intensity of Energy Use in the Process of Economic Development



SOURCE: Own elaboration

Thus, in the last few decades, petroleum's participation has decreased substantially. This is due to the implementation of technologies that allow energy to be used more cleanly and efficiently; such implementation is directly related to the level of development of an economy (see Figure 4.7 and Graph 4.29). In this sense, the penetration of natural gas throughout the world is noteworthy, having risen from 17.5% of primary energy sources in 1970 to 23.5% in 1996.[50]

GRAPH 4.29
Per Capita Energy Consumption, 1996
(Kilowatt-Hour)



SOURCE: *Entering the 21st Century, World Development Report, 1999/2000*, Washington, D.C.: World Bank.

[50]*Prospectiva del Mercado de Gas Natural, 1997 - 2006*, Secretaría de Energía, México, 2000.

According to the International Energy Agency, it is estimated that during the next 15 years the use of natural gas will grow at a faster rate than any other fossil fuel, reaching 2.9 % annually, compared to petroleum at 2.1% and coal at 1.9%. Thus, the consumption of natural gas is expected to represent almost two thirds of the consumption of petroleum by the year 2010.

TABLE 4.25
Worldwide Consumption of Primary Energy, 1985 to 1996

Energy Source	1985	1990	1996
Petroleum	117,335.0	131,214.3	138,700.3
Coal	87,918.6	93,939.2	94,496.1
Natural Gas	62,404.3	74,001.7	82,546.9
Nuclear	16,001.9	21,633.2	26,012.6
Hydroelectric	7,293.4	7,929.8	9,131.4
World Total	**290,953**	**328,718**	**350,887**

SOURCE: *Statistical Review of World Energy*, 1997.

Worldwide, Mexico comes in fourteenth place in terms of proven natural gas reserves. During 1996, Mexico produced 85.2 MMm^3d, which represented 1.4% of the world's total, with an average annual rate, between 1990 and 1966, of 2.5%. In terms of consumption of natural gas, Mexico came in thirteenth place worldwide during 1996, since consumption rose to 86.2 MMm^3d.

The existence of this balance at the national level is important since natural gas is sold through ducts (pipes), which limits the integration into an international market. Thus, the market of greatest interest to Mexico is that of North America. With respect to this region, it is worth pointing out that the participation of natural gas (26.9%) is very similar to the one registered worldwide (23.5%).

TABLE 4.26

Consumption of Primary Energy in North America*, 1985 to 1996 (Petajoules)

Energy Source	1985	1990	1996
Petroleum	35,441.3	38,824.2	41,294.4
Coal	21,804.9	23,735.0	27,787.8
Natural Gas	19,799.4	21,319.2	22,788.8
Nuclear	5,015.8	7,381.3	8,754.6
Hydroelectric	2,223.2	2,181.3	2,579.1
World Total	84,285	93,441	103,205

*Includes Canada, the United States and Mexico
SOURCE: *Statistical Review of World Energy*, 1997.

With respect to bilateral trade between Mexico and the United States, in 1996 imports totalled 2.4 MMm^3d and exports reached 1 MMm^3d. Similarly, trade between Mexico and Canada has come to take place and the prospects for openness and free markets in this tri-national market are quite good, in light of structural and regulatory reform initiatives in the three member countries for the opening of their respective markets. It is also important to point out that Mexico has had a reserves/production relationship for 44 years, much longer than the United States and Canada, with nine and 13 years, respectively.

Thus, worldwide tendencies and, especially, the characteristics of North America's regional market guarantee that in the next few decades natural gas could reach a greater penetration in energy consumption in a competitive environment and free market, in national and international terms. In Mexico's case, this tendency would be reinforced by its reserves/production relationship.

MEXICO CITY'S ENERGY SITUATION

Commercial energy consumption accounts for 25% of the national total and 82% of this is made up by hydrocarbons and 18% by electricity.[51]

TABLE 4.27
Energy Production and Consumption in Mexico at the National Level, 1992 to 1997

	Primary energy destined for transformation according to its origin (Petajoules)					
	1992	1993	1994	1995	1996	1997
Coal	141.363	160.584	186.814	203.407	235.178	234.586
Crude Oil	2799.005	2854.523	2906.633	2711.962	2708.357	2714.419
Condensed	184.569	183.606	140.788	148.016	148.401	148.293
Non Associated Gas	163.412	128.139	144.934	141.554	158.462	146.075
Associated Gas	1106.78	1216.157	1330.598	1233.408	1288.931	1302.936
Hydroenergy	275.798	274.165	208.505	283.872	322.316	271.153
Geoenergy	61.342	61.417	58.221	58.459	58.729	56.075
Nucleus Energy	41.855	53.072	47.781	92.986	85.581	112.495
Wind Energy	0	0	0.042	0.062	0.051	0.041
TOTAL	**4,774**	**4,932**	**5,024**	**4,874**	**5,006**	**4,986**

	Production Volume of secondary energy according to its source (Petajoules)					
	1992	1993	1994	1995	1996	1997
Petroleum derivatives	3,010	3,090	3,142	3,032	3,025	2,924
Coke	56	53	55	59	60	58
Electricity	438	456	495	512	547	581
Natural Gas	923	996	1,035	996	1,077	1,106
Non energy products	213	204	261	138	123	194
TOTAL	**4,640**	**4,798**	**4,988**	**4,739**	**4,831**	**4,863**

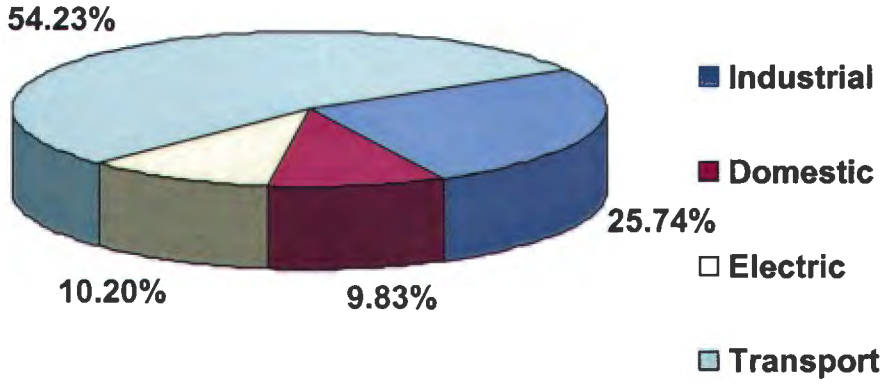
	Total final consumption of energy according to its origin					
	1992	1993	1994	1995	1996	1997
ENERGY CONSUMPTION	**3350.56**	**3431.082**	**3589.639**	**3564.185**	**3640.666**	**3713.423**
Residential. Commercial and public	769.681	795.964	822.936	816.12	837.896	840.302
Transport	1372.603	1403.333	1471.731	1399.082	1418.826	1478.14
Farming and Livestock	91.21	92.557	91.048	93.536	101.401	106.918
Industry and minning	1117.066	1139.228	1203.924	1255.447	1282.543	1288.063
NON ENERGY CONSUMPTION	**397.185**	**332.007**	**384.069**	**275.693**	**268.675**	**282.899**
PEMEX's Petrochemistry	289.855	258.546	271.519	240.709	230.757	229.563
Other sectors	107.33	73.461	112.55	34.984	37.918	53.336
TOTAL	**3,748**	**3,763**	**3,974**	**3,840**	**3,909**	**3,996**

SOURCE: Own elaboration, based on *Estadísticas del Medio Ambiente del Distrito Federal y Zona Metropolitana, 1999*, INEGI /SEMARNAP, 1999.

[51] J. Quintanilla, M. Bauer & Bernardo Navarro, Consumo y Abastecimiento de Hidrocarburos, *La Ciudad de México en el segundo milenio...*, pp. 352-361.

GRAPH 4.30

Consumption of Fuel in Mexico City by Sector, 1997



SOURCE: Own elaboration, based on J. Quintanilla, M. Bauer & Bernardo Navarro, Consumo y Abastecimiento de Hidrocarburos, La Ciudad de México en el segundo milenio..., pp. 352-361.

NATURAL GAS

Natural gas has significant advantages over the use of petroleum in terms of cleanliness, efficiency and availability of proven reserves. However, making its use more generalised requires the implementation of policies that promote an open and competitive market. In Mexico's concrete case, policies that give continuity to legal measures such as the reforms to the Statutory Law of Article 27 of the Constitution in the Area of Petroleum, the publication of the Law of the Energy Regulatory Commission (CRE, its Spanish acronym) and the publication of the Natural Gas Rules. With these measures, an attempt was made to initiate the liberalisation of the natural gas market, allowing the private sector's participation in the operation, transport, warehousing and distribution of this fuel.

In December of 1997 the CRE released the requirements for international bidding, the objective of which will be the acquisition of the necessary rights for offering the service of distribution of natural gas to the geographic zones of the Federal District and the conurbed municipalities.[52] This deregulation is expected to stimulate the use of natural gas in the domestic sector.

At the national level, the Ministry of Energy[53] predicts that the total consumption of dry natural gas will rise from 73.5 MMm^3d to a figure that oscillates between 191 MMm^3d and 168.9 MMm^3d by the year 2006. That is, an average annual rate between 9.7% and 11.19% (beginning in 1997) is expected. It is estimated that the biggest growth will take place in the electric sector, through the restructuring of numerous combined cycle plants, and in the industrial sector, followed by the residential, commercial and vehicular sectors. By the year 2010, its consumption at the national level is expected to grow by an average rate of 5%.

There are currently eight dry natural gas processing centres in the country, whose installed capacity, including bitter gas and sweet gas, is of as much as 195,584 MMm^3d. Similarly, the existing system of gas includes a gas duct system 11,877 kilometres long. This infrastructure allows for the connection of the production areas in the Gulf and the metropolitan areas of Mexico City, Guadalajara and Monterrey, among other cities.

[52] J. Quintanilla, M. Bauer y B. Navarro. *Consumo y Abastecimiento de Hidrocarburos* en H. Merino, Sistema Hidráulico. *La Ciudad de México en el segundo Milenio. ...*, pp. 358.
[53] J. Quintanilla, M. Bauer y B. Navarro, *Ibid.*, pp. 359-360

In terms of the composition of the demand for natural gas at the national level, the petroleum and industrial sectors stand out as the principal components.

TABLE 4.28

National Consumption of Natural Gas by Sector, 1991 to 1996

Sector	1991	1992	1993	1994	1995	1996
Electric	12,261.2	11,326.7	10,902.0	13,167.4	13,988.4	13,931.9
Petroleum	44,923.1	44,792.9	45,309.7	47,481.5	45,613.6	49,070.9
* Auto - consumption	32,730.9	32,972.6	34,553.7	34,547.8	33,355.9	34,241.1
* Raw Material	6,496.7	6,474.0	4,695.7	5,385.4	5,554.6	5,260.8
*Internal Recirculations	5,695.5	5,346.3	6,060.3	7,548.3	6,703.2	9,569.0
Industrial	24,210.9	24,494.0	22,746.9	23,304.7	25,655.0	27,070.0
Residential and Commercial	2,718.4	2,831.7	2,605.1	2,254.0	1,789.6	2,633.5
World Total	**84,114**	**83,445**	**81,564**	**86,208**	**87,047**	**92,706**

SOURCE: *Prospectiva del Mercado de Gas Natural, 1997 – 2006,* México, 2000.

Current consumption of natural gas in the Federal District totals approximately 1.1 million cubic metres and in the adjacent municipalities it is approximately 2 million cubic metres.[54]

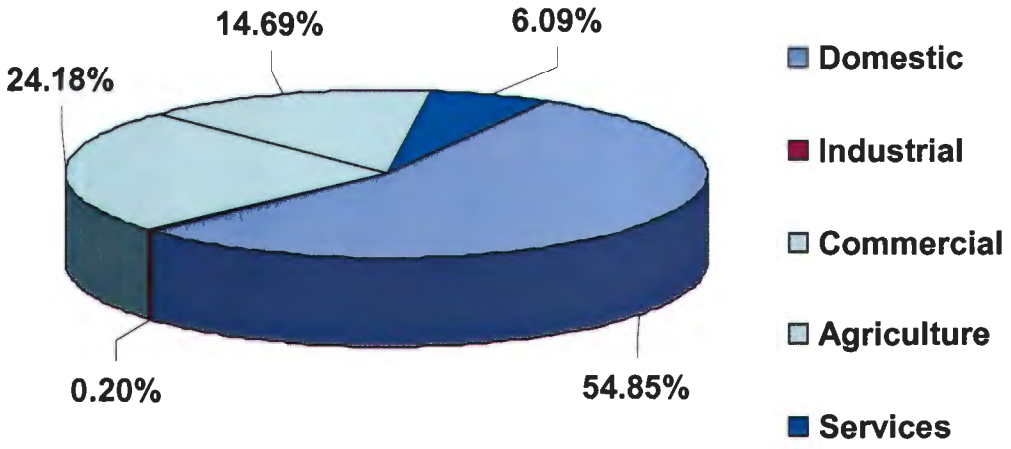
ELECTRICITY

In the Federal District more than 99.5% of the population is benefiting from electrical service, and, in the adjacent municipalities, 95%. This form of energy is also used in the delivery of services such as the pumping of drinking water and sewage, urban transport and traffic control, and in satisfying the electrical needs of a half-million small business and industries, more than 7,000 medium and large industries and close to four million homes in Mexico City.[55] It is necessary to add to the volume calculated exclusively for the Mexico City metropolitan area the energy used in the pumping of water through the Cutzamala System (15 cubic metres of water per second).

[54]J. Quintanilla, M. Bauer & Bernardo Navarro, Consumo y Abastecimiento de Hidrocarburos, La Ciudad de México en el segundo milenio..., pp. 352-361.

GRAPH 4.31

Mexico City: Consumption of Electricity by Sector, 1998



SOURCE: Comisión Federal de Electricidad, México, 1998.

For a number of reasons, especially those related to the city's atmospheric contamination problems, the supply of electrical energy should be done through the generation of energy from that of the centres of the Luz y Fuerza del Centro. Those which stand out include the thermal plant of Tula and the combined cycle plant in El Suaz, as well as the western region centres such as the hydroelectric plants of Infiernillo and Villita, or the thermal plant of Petacalco in Lázaro Cárdenas, the hydroelectric plants of Grijalva, the thermoelectric plant of Tuxpan and the nuclear energy plant of Laguna Verde.

4.7.5 Solid Waste

In terms of the management of solid waste, the ideal, defined by the international state of the art, is the encouragement of "integral management," understood as the balance between the quantity of solid wastes that are generated and the quantity of these wastes that can be suitably disposed of in landfills[56] or that can undergo some type of treatment process, whether it be recycling,[57] incineration,[58] with and without energy recovery, or composting, with the objective of reincorporating this material into different productive processes. Additionally, it is of course ideal that this balance be reached to a large extent through a reduction in the quantity of solid wastes that are generated, in such a way that the 3 R's are encouraged (reduction, reuse and recycling).

[56]Installations with engineering techniques that allow for the suitable confinement of solid wastes and which consist in the spreading, placement and compacting of wastes, covering them with dirt or other materials and controlling gasses and lixiviates to minimize the impact on public health and the environment.
[57]A process by which certain materials from the trash are separated, selected, classified, packed, warehoused and sold, in order to be reincorporated as raw materials for the productive cycle.
[58]Thermic treatment of wastes; energy is chemically attached to the material, transforming into caloric energy.

TABLE 4.29

Treatment of Solid Waste: International Comparisons

World Tendencies of Different Treatments (%)				
Country	**Landfills**	**Incineration**	**Composting**	**Recycling**
United States	73	14	1	12
Japan	27	25	2	46
Germany	52	30	3	15
France	48	40	10	2
Sweden	40	52	5	3
Mexico	Between 90 and 94	—	—	Between 6 and 10

SOURCE: *Cruzada por un México Limpio*, México: SEMARNAT, 2000.

Similarly, it is desirable that along with an *integral* management there be a *suitable* management of solid wastes --in terms of the prevention of the negative effect they can have on public health and the environment-- throughout their entire life cycle (collection, transport, transfer, treatment and final disposal). In this sense, the three harmful effects that should be avoided are the generation of lixiviates and their seeping into the subsoil, the proliferation of harmful fauna (rodents) and, finally, the emission of biogas.

Thus, with the objective of reaching truly integral, suitable management, the problem of solid wastes in Mexico City can be considered within the framework of four principal dimensions. In the first place, over the last few decades there has been a large increase in the amount of solid waste per inhabitant. It is worth mentioning, for example, that generation per capita was 0.37 kilos per day in 1950[59], and that that amount has now reached 1.8 kilos per day. Additionally, the composition of waste has changed drastically, in such a way that a large proportion is composed of products that are non-biodegradable or are considered to be slow in degrading, in such a way that non-biodegradable components have increased their participation from 5% to 40% of the total.

TABLE 4.30
Composition of Solid Waste in the Mexico City Metropolitan Area

Cardboard	5.360	Solid Plastic	4.330
Fine Wastes	1.210	Food Wastes	34.660
Rubber	0.200	Gerdening Wastes	5.120
Cans	1.580	Rag Material	0.640
Ferrous Material	1.390	Colored Glass	4.000
Non Ferrous Material	0.060	Transparent Glass	6.770
Paper	14.580	Others	10.490
Disposable Diapers	3.370		
Plastic Film	6.240	**TOTAL**	**100.000**

SOURCE: *Cruzada por un México Limpio*, 2000 based in Sancho y J. Cervera Rosiles G., *Situación actual del manejo integrado de los residuos sólidos en México*, SEDESOL, 1999.

[59]See E. Ezcurra, *et. al.*, *The Basin of Mexico. Critical Environmental Issues and Sustainability*, United Nations, 1999.

In the second place, the city faces the exhaustion of the capacity of sites for suitably depositing solid waste; a case which stands out is that of the eastern dam sanitary landfill, located in the federal zone of Lake Texcoco, which receives the largest portion of the solid waste collected in the Federal District (around 12,000 tons per day) and whose capacity cannot go on beyond 2004. Similarly, a factor which exacerbates the problems inherent to the suitable management of solid wastes in the city is the location of many trash deposits in areas that were originally located outside the city, but that have now been overcome by urban expansion, or in clandestine dumps.[60]

TABLE 4.31

Hectares of Landfills for Solid Waste in the City, by Delegation/Municipality

	LANDFILLS	CONTROLLED DUMPS	TOTAL
Atizapan de Zaragoza		5.7	5.7
Coacalco	4		4
Chicoloapan	1		1
Chimalhuacan		17	17
Ecatepec	3		3
Huehuetoca		4	4
Huixquilucan	1		1
Jaltenco		1.5	1.5
Melchor Ocampo		1	1
Naucalpan	40		40
Nezahualcoyotl	30		30
Nicolas Romero	3		3
Otumba		1	1
Ozumba		1	1
Tecamac	2		2
Temascalapa		1	1
Tenango del aire		1	1
Tepetlaoxtoc		2	2
Tepetlixpa		1.5	1.5
Tlamanalco		2	2
Tlalnepantla	9		9
Tultepec		1.5	1.5
Tultitlán	7		7
Zumpango		2.5	2.5
Cuautitlán Izcalli	7		7

SOURCE: E. W. Buttler, J. B. Pick & W. J. Hettrick, *Mexico and Mexico City in the World Economy*, USA: Westview Press, 2001, 388 p.

[60] Sites without any type of technical control and which tend to be empty lots, canyons, gullies, etc. E. Ezcurra, *et. al.*, *The Basin of Mexico. Critical Environmental Issues and Sustainability*, United Nations, 1999.

In the third place, the lack of a regulatory framework and the presence of "mafias" that take control of the trash in order to benefit from its commercial value in the context of the informal economy have limited the private sector's participation in the different stages of the life cycle of waste (recollection, transport, transfer, treatment and final disposal). This has led to a series of conflicts between the different parties involved: the government, citizens and trash collectors.[61]

Finally, there continues to be a problem with the distribution of powers between the Federal government, the Federal District government, the State of Mexico government, the delegations and the adjacent municipalities. At the federal level there is a regulatory void,[62] principally because Article 115 of the Constitution gives municipalities the power of offering cleaning services and the General Law of Ecological Balance and Environmental Protection (LGEEPA for its Spanish initials) gives the states the power of regulating the operation of said cleaning services, in such a way that the federal government has its hands tied, even though the LGEEPA gives it the power of preventing soil, water and air contamination.

On the other hand, the political differences between the governments of the Federal District and the State of Mexico have blocked the possibility of formulating regional solutions for the metropolis, which are vitally important for reaching an *integral*, *suitable* management of solid waste in all of Mexico City.

[61]G. Castillo, The emissions contributed to forming 5% of the ozone: data from the IMP, *La Jornada*, August 26, 1996.
[62]The only official Mexican norm currently in effect is the NOM – 083, which refers to the specifications for defining the location of a sanitary landfill.

4.7.6 Housing

There are three fundamental aspects related to this crucial variable. The first aspect is quantitative and refers to the provision of housing to meet the growing demand derived from the demographic evolution of the population and of the tendencies in income and the number of members that make up a family. The second aspect is qualitative and refers to the characteristics of housing foreseen in terms of urbanisation, basic public services and "ecological functionality."[63] Lastly, the third aspect, also qualitative, refers to the way demand is met in spatial terms, whether it is through the urban expansion or through densification or redensification of already existing urban areas.

With respect to the attention given to the demand for housing in Mexico City, although a large part of the existing deficit has been covered for several decades, there are still significant problems in terms of the amount of housing and its quality. A sizeable number of housing units have been financed with minimal resources and are located on land where there is uncertainty as to property rights. In this sense, the areas that currently have the largest deficit are in the State of Mexico, exactly in the zones with the greatest challenges for the future, derived from a greater population growth than in the rest of the city.

The problems mentioned are related, in turn, to the existence of cycles which consist of different phases of urban space expansion, followed by phases of densification of this space. The first is characterised by formal and informal appropriation of land and its suitability for increased preparation for urbanisation. The second is characterised by the construction of buildings and the execution of projects for basic infrastructure and roads.[64]

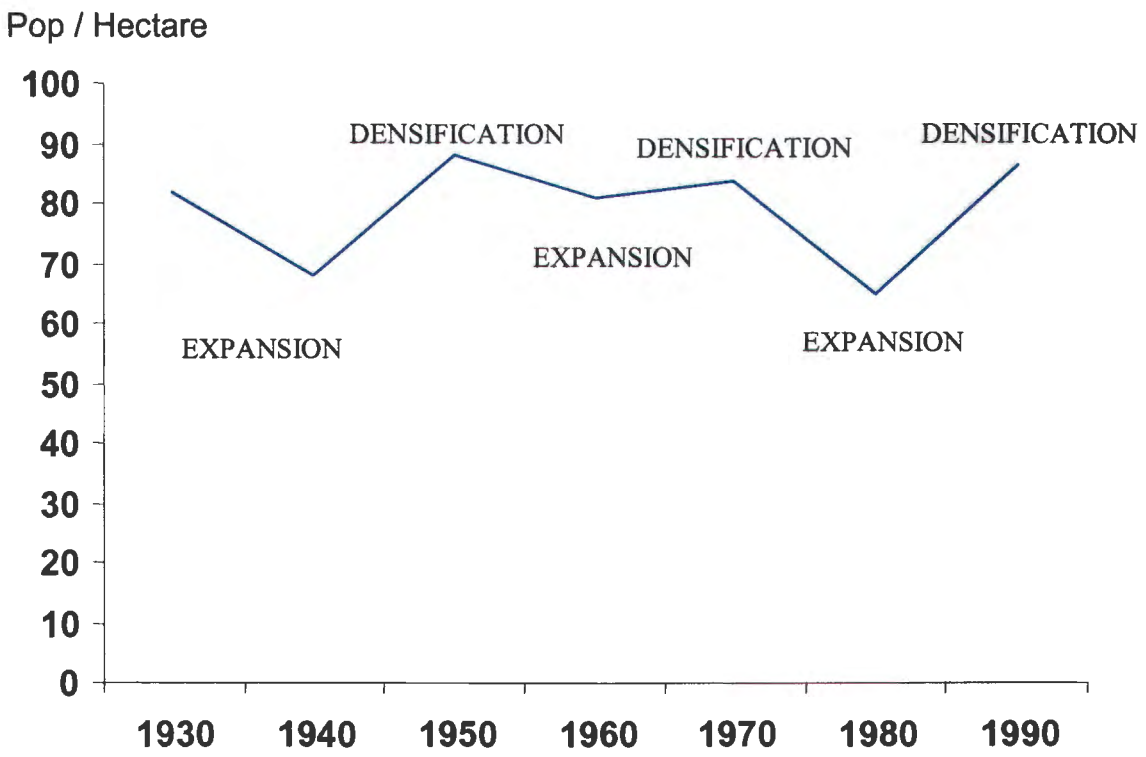
It is important to point out that the authorities' position is determinant in bringing about and prolonging each of the phases of expansion and densification of the urban area. Phases of expansion have been characterised by the existence of an unwritten policy to "let it be

[63]The term refers to the need for houses to be designed in a way which allows for savings, principally on water and energy.

done" and, the years of urban densification, by the selective application of policies of control and channelling of public investment.

Thus, population density is a determinant variable in the selection of zones where it is a priority to apply policies aimed at facilitating the provision of housing in the context of sustainability, that is, of urban densification and redensification. As is shown in Graph 4.32, in terms population per hectare, there is clearly a decreasing pattern that coincides with the delegations or adjacent municipalities that belong to the urban ring farthest from Mexico City downtown.

GRAPH 4.32
Population Density in the Delegations and Adjacent Municipalities of the City (Population/Hectare), 1990



SOURCE: Graph is by author, and is based on data from CONAPO. *Escenarios demográficos y urbanos de la ZMCM, 1990-2010,* Mexico: INEGI, 1995.

[64]A detailed description of these processes of expansion and densification can be found in A. Suárez, Escenarios Socioeconómicos y Espaciales de la Zona Metropolitana de la Ciudad de México, *El Mercado de Valores*, May, 2000 and Rakesh, 1984.

4.7.7 Green Areas

Taking into consideration the geomorphological characteristics of the Basin of Mexico described in the first chapter of this thesis, it is important to mention the current condition of green areas, as well as the imperious need to conserve and regenerate these areas in order to increase their availability index per inhabitant (see Map 4.8).

In the face of imminent urban expansion, the natural characteristics of the basin have changed in a nearly irreversible manner, the most outstanding examples being the degradation of lacustrine vegetation, as a consequence of the drying up of the lakes that characterised the basin's landscape, or the forests and scrubland characteristic of the alluvial deposits and the piedmonts, as well as the xerophyte scrubland characteristic of the driest parts of the basin.[65]

In consequence, the few pristine green areas that still remain within the city become loaded with special importance for their contribution, although marginal and incipient, to natural processes such as the recharging of aquifers, the regulation of weather, oxygenation and control of suspended particles.

In this sense, all space that is not used for housing, infrastructure or urban "furnishing", can be classified in five large categories: green areas for public use, areas with environmental value (gullies, canyons, runoffs and groves of trees found on urban land where the recharging of aquifers takes place), ecological recovery areas where it is necessary to implement programs to relocate human settlements and encourage conservation activities, rural agri-industrial production areas, and, finally, ecological preservation areas.[66]

Table 4.32 shows the current state of these categories, by delegation and in the case of some conurbed municipalities.

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[65] I. Pisanty Baruch, Ecosistemas y Áreas Verdes Urbanas, *La Ciudad de México en el fin del segundo milenio...*, pp. 475-482.
[66] *Ibidem*

By taking into account the category of "green areas", which is generally used for international benchmarking, it can be concluded that neither the Federal District delegations, nor the "conurbed" municipalities of the State of Mexico have an adequate indicator since both are far below 9 m^2 per person, which is the desirable value from an international point of view.

TABLE 4.32

Green Areas and Urban Surfaces, 1997
(Meters per person)

Delegation	Open Spaces	Green Areas	Ecological Recovery	Rural Agri – industrial production	Ecological Preservation
FEDERAL DISTRICT	4.5	3.7	4.9	27.00	62.3
Álvaro Obregón	7.2	29.7	2.8	0.00	27.2
Azcapotzalco	2.2	0.0	0.0	0.00	0.00
Benito Juárez	1.4	0.0	0.0	0.00	0.00
Coyoacán	4.6	4.2	0.0	0.00	0.00
Cuajimalpa	0.7	5.6	16.4	0.00	164.8
Cuauhtemoc	2.1	0.0	0.0	0.00	0.00
G.A. Madero	4.0	1.4	0.3	0.00	17.2
Iztacalco	7.4	0.5	0.0	0.00	0.00

(continues....)

SOURCE: I. Pisanty Baruch, Ecosistemas y Áreas Verdes Urbanas, *La Ciudad de México en el fin del segundo milenio...*, pp. 475-482.

TABLE 4.32 (continued)

Green Areas and Urban Surfaces, 1997
(Meters per person)

Delegation	Open Spaces	Green Areas	Ecological Recovery	Rural Agri – industrial production	Ecological Preservation
Iztapalapa	5.3	0.5	0.4	0.00	3.8
M. Contreras	1.7	1.6	8.0	10.38	186
Miguel Hidalgo	15.9	0.0	0.0	0.00	0.00
Milpa Alta	0.0	0.0	48.6	1515.95	1637.7
Tláhuac	17.0	0.0	20.2	199.38	92.4
Tlalpan	8.7	7.2	16.1	54.15	420.8
V. Carranza	3.5	0.1	0.0	0.00	0.00
Xochimilco	2.7	1.6	49.1	69.45	93.6

(continues….)

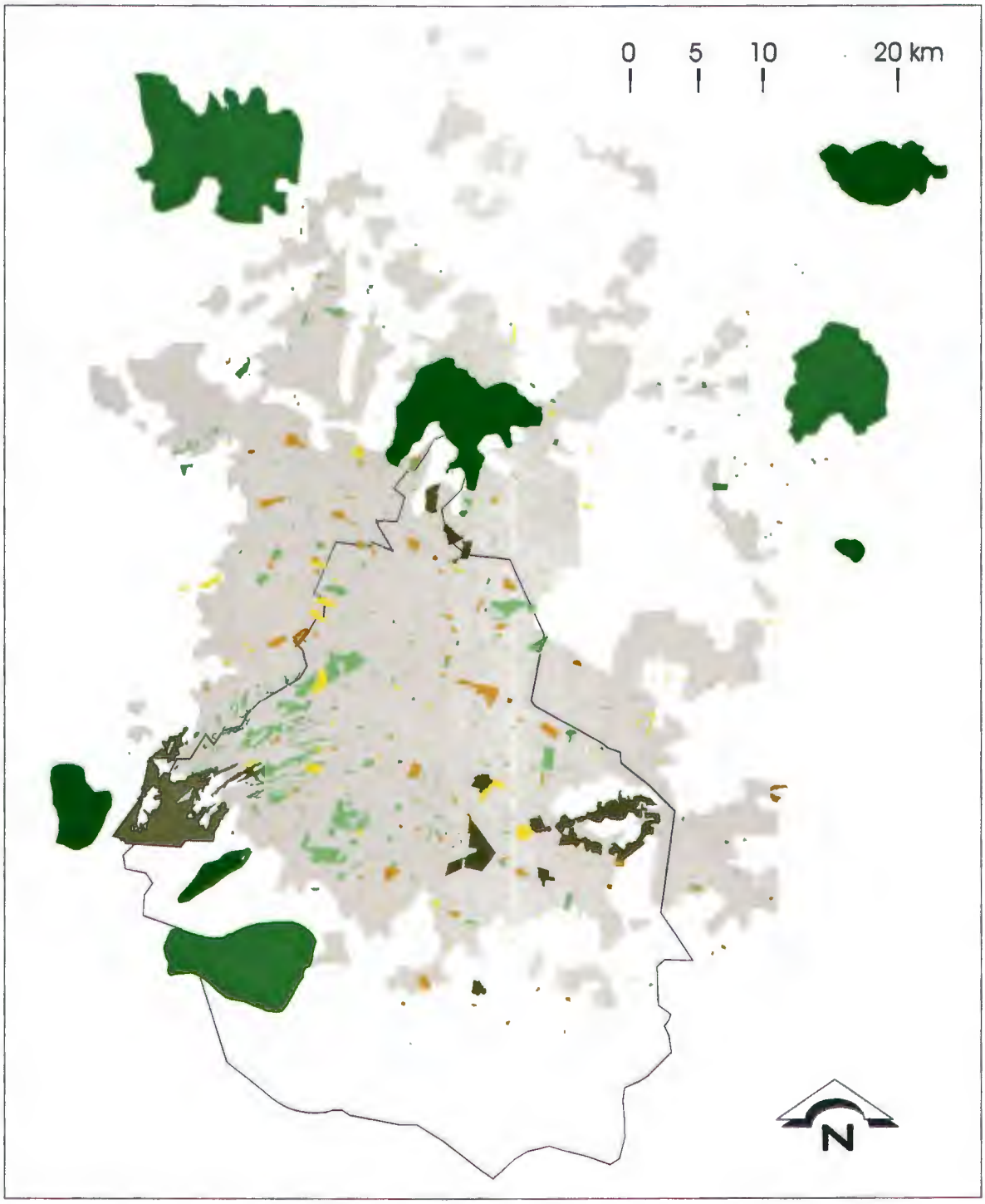
SOURCE: I. Pisanty Baruch, Ecosistemas y Áreas Verdes Urbanas, *La Ciudad de México en el fin del segundo milenio...*, pp. 475-482.

TABLE 4.32 (continued)

Green Areas and Urban Surfaces, 1997
(Meters per person)

Delegation	Open Spaces	Green Areas	Ecological Recovery	Rural Agri – industrial production	Ecological Preservation
STATE OF MEXICO	7.3	0.6	0.9	0.00	0.7
Acolman	0.00	0.00	0.0	0.00	0.00
Atizapán	0.00	0.00	15.3	0.00	0.00
Coacalco	1.9	1	0.00	0.00	0.00
Cuautitlán	0.00	0.00	0.00	0.00	0.00
Chalco	7.3	2.3	0.00	0.00	0.00
Chicoloapan	0.00	0.00	0.00	0.00	0.00
Chimalhuacán	.0.00	0.00	0.00	0.5	0.00
Ecatepec	8.1	0.5	0.00	0.00	0.00
Huixquilucan	1.1	0.00	0.00	0.00	30.8
Naucalpan	5.1	0.00	0.00	0.00	0.00
Nezahualcóyotl	2.5	0.5	0.00	0.00	0.00
La Paz	19.0	0.3	0.00	0.00	0.00
Texcoco	0.00	0.00	0.00	0.00	0.00
Tlalnepantla	10.1	0.2	0.00	0.00	0.00
Tultepec	0.00	0.00	0.00	0.00	0.00
Tultitlán	40.2	0.7	0.00	0.00	0.00
Cuautitlán Izacalli	0.00	0.00	0.00	0.00	0.00

SOURCE: I. Pisanty Baruch, Ecosistemas y Áreas Verdes Urbanas, *La Ciudad de México en el fin del segundo milenio...*, pp. 475-482.



Map 4.8. Year 2000: The Megalopolis Remaining Green Areas.
Source: Own elaboration based on material provided by Ciudad Futura Desarrollo Urbano.

Thus, we can conclude this chapter by saying that although the demographic and economic trends of the MCMZ are clearly pointing towards a positive stabilization neither its basic environmental variables nor its degree of urban and economic policies are moving to both sustainability and a "World City" status.

In the next chapter, we will discuss at lenght: what does imply globalization for Mexico City and what are the challenges ahead with regard to the environmental situation, we will first discuss the very content of the concept of "sustainability" and the peculiarities and analytical difficulties that conveys for the urban realm. From there, we move into the construction of seven quantitive indicators, each one for a critical sustainability variable: water, greenery, roads, air pollution, waste, housing and energy. Each one is complemented with policy prescription measures pointing to sustainability by the year 2030. A very simple and tentative exercise is also made into combining them all in a single indicator, as well as some rough measure of a "globalization index."

CHAPTER 5

TWO MAIN CHALLENGES TO THE MEGALOPOLIS IN THE 21ST CENTURY: TO BE BOTH GLOBAL AND SUSTAINABLE

A GLIMPSE TO THE FUTURE: 2030'

What forces will shape the city's new urban form? This is one of the most basic questions posed in this thesis. Of course, there will have to be internal forces at work such as demographics, environmental and socio-economic patterns. However, economic globalisation and the technological revolution (information, digitalisation, networking) will undoubtedly have the most powerful exogenous influence in the next thirty years.

What is the future of cities in general and what does Mexico City's future hold? Although these questions are impossible to answer in full, a general prospective analysis of Mexico City in thirty years should take into account the impact of technological advances on the corresponding social and economic systems, even if we can only point out a few inevitabilities and identify some of the trends that are already more or less well-established.[1]

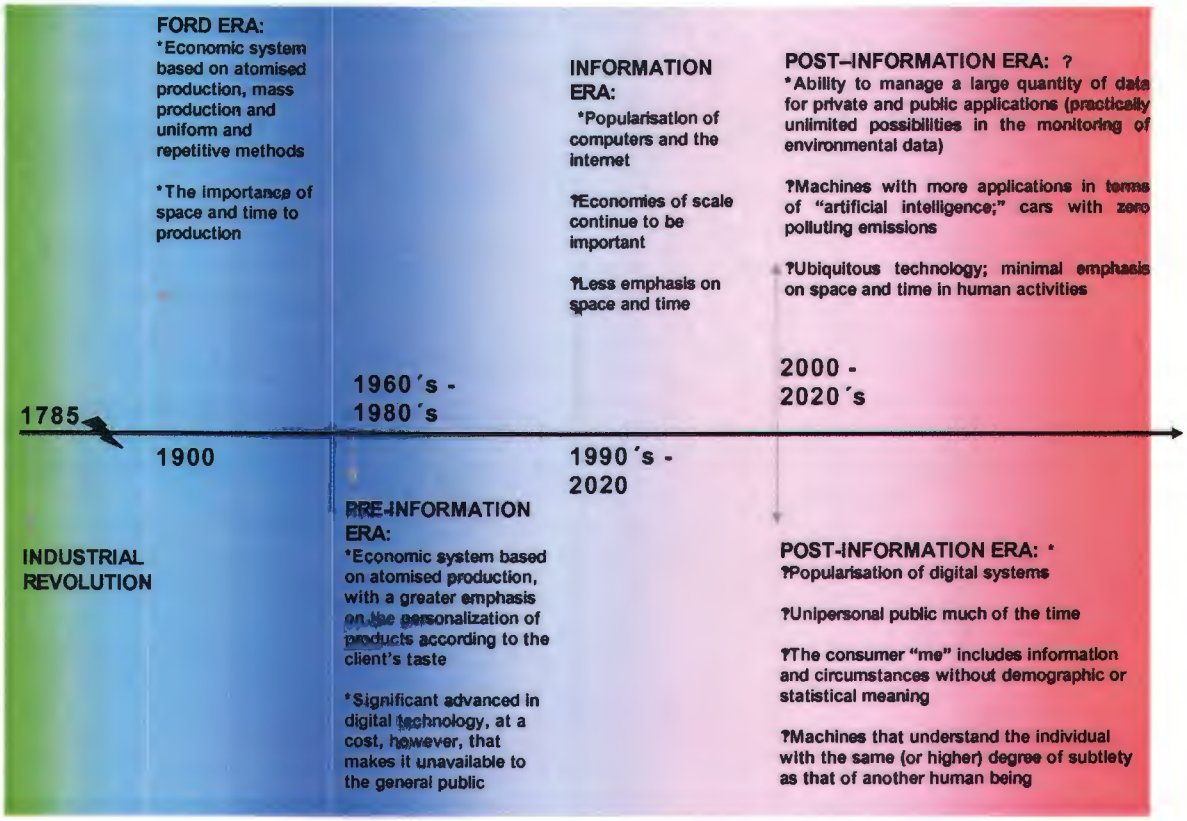
We know that in spite of current technological mutations and the demographic dynamics, cities will not vanish into an urban rural continuum. But at least we do know that they will continue to change along with the influence of the new economy and a society that is more interconnected through all types of action and communication networks. New technologies, especially those dealing with information and communication, will have a dramatic impact on cities, perhaps comparable to the impact that the automobile, the telephone and electricity had in the 20th century. These new technologies, led by the prodigy of microelectronics and lasers, may also affect the way we go about production, education, entertainment and transportation.

[1]Following Concheiro, Alonso and Julio Millán, to imagine the future, especially that of Mexico, it is convenient to employ "a suitable combination of reasoning and imagination". See Concheiro, Alonso and Julio Millán. *México 2030. Nuevo Siglo, Nuevo país*, Mexico, 2000, pp. 9.

During the next two or three decades, changes are expected to occur in such a way that communications, information and other areas of human activity will be driven by digital processing of all types of data. This phenomenon will allow information management to be carried out with greater flexibility and more applications, and in greater volume. Users, instead of producers, will be principally responsible for the creative process behind the presentation of images, sounds and textual data, since the former group will be able to mix these elements according to their tastes and receive massive and personalised information. There will be little difference between the distinct forms of media as we know them now: television, radio, cellular phones, etc. In the forthcoming digitalised era, information emitted will be transformed by the user according to his or her needs. As a consequence, the economies of the world will embark on a post-information era (see Figure 5.1).

Other, relevant technological changes will have a derived or indirect impact in cities, but these types of changes will have a cumulative effect. We are talking about the introduction of new materials and, of course, new genetic biotechnologies (based on the functional technology of recombinant DNA) and, on a larger scale, biotechnologies. What is done with energy --its sources, distribution and management-- will be very important. During the period we have chosen, up to the year 2030, a new variable will be the progress made in solar energy, which promises to be incremental, not revolutionary. All this should change the institutions of control, regulation (of markets) and property that govern social and economic life.

FIGURE 5.1
The Road Towards the Post-Information Era



SOURCE: Own elaboration based on N. Negroponte, *Being Digital*, New York: Alfred A. Knopf, 1995, p. 243.

Due to its relative intermediate state of development, Mexico and the MCMZ, will lag behind in their adaptation to these great technological changes that are already apparent in the more advanced countries. For Mexico City, much diminished demographic change will be as decisive as well as a new political era that is more democratic, citizen-oriented and responsible, that involves a more arduous decision-making process. Also to arise will be the possibility of Mexico successfully facing the challenges of a new specific economic model which will simultaneously shift its focus to the vast, profound globalisation process, in which cities are sure to play a decisive role as "nodes" of a vast network.[2] However,

[2] Most probably a profound departing of its integration within the north America economies.

Mexico City could run the risk of prolonging its stagnation by delinking itself from this network that it is knitting for the future. We believe this to be contrary to its interests due to the fact that since the beginning of Mesoamerican history this city has been the centre of our country and our national life. Its prosperity and primacy should not be understood in terms of an empire, but as an axis for a broader, more egalitarian modernization of our country as a whole.

These are the issues to be addressed in this chapter. It is not about arbitrarily predicting or projecting trends. Instead, it is simply (and perhaps this is enough) about elucidating and decoding already observable tendencies, which will inevitably influence urban form and city life for the future generation, and looking at these still undefined traits to at least anticipate real priorities. We should not repeat mistakes made in the past, when "planning" was carried out in such a short-term, incomplete way, that reality overwhelmed and laid to rest many urban programs that are now the cause of so many urban mishaps in the metropolitan area of Mexico City.

5.1 Globalization, Technology and the Urban Future

The 20th Century was an era of extremely rapid urbanisation worldwide. In the past two decades this trend abated somewhat with the exception of Africa and some developing areas in south Asia. Nevertheless, today we have a much more urbanised world than only two decades ago and most of the largest metropolitan areas are much more spread out than ever before. Within the present decade, for the first time ever the world will have more urban than rural dwellers.

In the 1950s and 60s the urban population grew most rapidly worldwide than the last three decades (Again, Africa and Central South Asia are exceptions). This can be explained by a combination of population and economic growth. Since then, urban growth in most countries can mostly be attributed to higher incomes and wider integration into the world economy. So, as we will see now, globalisation is also a very urban phenomenon.[3]

5.1.1 New Technologies, Cities and the Era of Networked Telecommunications

Every revolutionary period in the world has an essential component: the freeing up of information and knowledge. For example, the Renaissance, with all its creativity and progress, saw the diffusion of ideas through the printing press. The diffusion of ideas during the Enlightenment spurred the liberal revolutions, and the list goes on. The current era is beginning in a similar way. Life in the first century of the third millennium will see the progressive convergence of telecommunications, digitalized information and audiovisual interactivity. Information and knowledge will be the basis of a global, interconnected economy. In fact, we are already at the beginning of this era.[4]

The current revolution involving information, communications and an "interconnected society" is functional to the current globalisation process, in its economic, political and even cultural dimension. It has been the subject of innumerable descriptions and analysis,

[3]Sassen, Saskia, *Cities in a World Economy*, Fine Forge Press, Thousand Oaks Ca. 1994.
[4] C. Luiselli, *New Technologies of Urban Impact*, Mimeo. Mexico 2001.

of which the sociological perspective of M. Castells[5] and the technological viewpoint of Nicholas Negroponte[6] stand out. Here we will look at their implications for the urban realm, to visualize the challenges facing the Mexico City metropolitan zone. In the following section (5.1.3) we will examine the details and implications of the digital revolution in communications and information; and we will analyse their general impact, along with other technologies, in defining aspects of global society in the next 30 to 50 years. The emerging global society will be centred on knowledge and information; its elements will be integrated territorially into the world economy, and this will be organized through large cities that will have net articulating and leadership functions. A physiological metaphor might be apt: cities will be the neurons of globalisation and communications networks will be the dendrites, both making up the essential synapses.

As we will see in more detail in the following section (5.2), the new information technologies will make distances and territorial specificity less relevant for production and consumption. This will represent a great challenge to cities as we now know them. With respect to this question, J. Borja and M. Castells [7] discuss three large converging processes: globalisation, the digitalisation of society (especially through the Internet) and the generalized advance of world urbanization. These phenomena, acting in the same direction, will radically change the structure and functions of cities. This is why they propose that, at the same time that cities prepare to compete in the globalised world, this should be understood to include not only massive investment in information technology and developing skills related to knowledge and advanced services, but also making the environment sustainable and pleasant, reclaiming the "locality" and reinvigorating the culture of every city. Mexico City has a vigorous culture and is the largest Spanish speaking centre in the world. However, it is still far from being a "global player" in terms of information, knowledge and environmental sustainability.

[5]M. Castells, *The Information Age: Economy, Society and Culture*, 3 Volumes, London: Blacwell, 1997.
[6]*Ibidem.*
[7]J. Borja, & M. Castells, *Local and global: Management of Cities in the Information Age*, London: Earthscan, 1997, pp. 137, 234 y 248.

It should be stressed, then, that a necessary condition for actively engaging globalisation is to participate in the revolution of information and telecommunications, which allow an almost infinite number of interactive data transactions and messages to be transmitted almost instantaneously at an increasingly lower cost to any part of the world. In short, these factors "make" globalisation. This is why globalisation and a society of information and knowledge go hand in hand.

In the era of globalisation, knowledge and information technology will be the foundation of the economy and will profoundly influence the social order. Among the most noteworthy modes of information technology are microelectronics, as well as fibre optics and lasers, which allow for increasingly powerful computing and telecommunications platforms. This technology is allowing information to be digitalized, processed and put onto networks at a very low cost in any part of the world through the ubiquitous Internet, starting from the present world wide web "www". This is what will lead the way to dramatic changes in urban life, something which we have only begun to observe with the exponential growth of the Internet,[8] the most recent expression --although not the only one-- of these technological mutations that undoubtedly will more profoundly affect urban design and city life in a few more decades. At the same time, other technologies are being incorporated into this constellation of change, which will make for powerful and definitive social and even cultural synergy,[9] as we will see in the following section (5.1.3).

Thus, we should consider the digitalisation of information into discrete units of binary information or "bytes" (from "binary digits") as something revolutionary: It allows any kind of data, whether it be written, visual or oral, to be saved, compressed, mixed, codified, processed and retrieved through a variety of media, at times interactive, all interconnected in networks. Not only is this possible, but it can be done at an increasingly lower cost from any part of the world, a fact that has led to talk of "the death of distances."[10] The marginal cost of sending or receiving a byte anywhere is now close to zero. This is the "heart" of the

[8] See: http://www.mit-edu/people/mkgray/net/web-growth-summary.html.
[9] The main ones will be the diverse biotechnologies that fully take advantage of the human genome, nanotechnology, new composite materials and ceramics, superconductors and optoelectronics.
[10] F. Cairncross, *The Death of Distance: How the Communications Revolution Will Change Our Lives*, Boston: Harvard Business School Press, 1997.

current revolutionary transition to a society of knowledge and information. This is why it is also said that the classic functions of regulation and control of governments and nation states is clearly weakening in favour of the cities. In a notable parallel with the Renaissance, cities, and not nation states, are the governing entities in the global economy.

But in some way the very notion of place will be affected by the powerful penetration of information and digital technology. Set against the territorial dimension is an intangible, invisible, immaterial network. Virtual reality is juxtaposed upon concrete, tangible reality.

The progressive dematerialization of the economy and its equivalent spatial disconnection or deterritorialisation are fundamental to understanding this new reality. It is not only about bytes which, as N. Negroponte[11] says, are immaterial, but also about hard data that undoubtedly establish the level of dematerialization: From 1950 to 2000 the value of world economic production has tripled, while its material weight has remained the same. Moreover, while per capita consumption continues to grow rapidly, the intensity of the use of natural resources per unit of value or weight is declining. A clear example are the automobiles or domestic appliances that, on average, weigh less than half what they did 50 years ago. A fibre optic cable that weighs 65 kilograms can transmit more messages in terms of magnitude than a ton of copper cable. Both the processes of production recycling and consumption, as well as new materials, miniaturization, microelectronics and digitalised information technologies, point to a dematerialization process that will continue.[12]

[11]N. Negroponte, *Being Digital...*, pp. 14-17.
[12]L. Scarlett, *Doing More With Less: Dematerialization, an Unsung Environmental Triumph in Bailey,* New York: Ronald Ed. Earth Report, 2000 Ch. 3 , CEI Mc Graw Hill , p. 200

5.1.2 Cities and the Anatomy of Globalization

Globalisation is a highly ambiguous concept that has come to be excessively used and abused in recent years. But it is also an undeniable reality in the contemporary world, although it is a process still incomplete and highly unequal. Many of its dimensions, such as those dealing with economics, politics and culture, are clearly identifiable. All of these have to do with contemporary cities, which are its natural territory.

In terms of economics, evidence of an accelerated globalisation process is expressed through the forceful fact that international trade has grown more rapidly than national production. Growing even more rapidly than trade itself is the exchange of financial flows between countries, especially between a small group of cities. Thus, according to statistics from the World Trade Organization (WTO),[13] while foreign trade represented only 25% of the total world product, that number has now risen to 50% in the year 2000. This is, what is produced more and more in every country in the world is destined for the world market.

Furthermore, within world trade, the most dynamic area is the growth of services (communications, insurance, entertainment, health, consulting, among others), which are almost exclusively found in the largest cities. Globalisation of services is made possible by the direct investment of transnational companies.

Financial exchanges, such as portfolio investments, currency exchange and other operations, are thought to total more than the amazing figure of more than a trillion dollars a day. This number is 50 times greater than the amount of currency necessary for trade financing. Almost all of this incredible movement of capital takes place in the financial centres of the largest cities in the world. All this is made possible by the telecommunications revolution, which, as an immense network accessible in real time 24 hours a day, allows for the movement of enormous quantities of money every second and for the creation of financial instruments. It should be noted that direct foreign investment in the form of productive assets in developing countries is concentrated in a handful of

[13] *World Trade Organization; International Trade: Trends and Statistics*, Geneva 1999.

countries, of which Mexico comes in second place after China, with Brazil trailing closely behind.

Finally, one should keep in mind that production is increasingly organized, decided upon and controlled centrally by large transnational companies (TNC's) that also tend to homogenize the patterns of consumption and even generalizing contemporary cultural trends. These companies organize their activities and financing in head offices located in a few cities, where there is not only an abundance of finance capital, but also technological skills and easy communications. This financial capital moves quickly and opportunistically only to where security and maximum profits can be found. It takes the form of investment in plants and equipment, from high tech to light manufacturers. As mentioned, it has to do with a wide variety of services, from consulting businesses to entertaining and tourism events, from healthcare to legal consulting firms. It is, however, volatile and capricious. Thus, it forces governments (those of cities included) to act in a more businesslike fashion and to compete intensely amongst themselves in order to achieve a greater flow of resources, investment and foreign visitors. This is why the largest cities of the world often restructure their space or renew their central business districts (CBD) to attract said investment and visitors. Here, there is an important connection with the environment and sustainability: only safe, clean, green, unpolluted and environmentally attractive cities will sustain in the long term a significant flow every type of visitor and investor.[14]

Thus, a ferocious competition between different companies and economic agents is inherent to the globalisation process. This implies rapid deregulation and an increasingly more active role for markets in terms of resource allocation and decision-making, in place of national governments. In sum, globalisation is above all, the growing integration of markets. It is also a powerful mechanism of social, spatial and economic differentiation; in globalisation there are always many more losers than winners.[15]

[14]Beaurgard, *Theorizing the Global-local connection*, in Knox and Taylor, *Op. cit.*, 1995; S.Graham, & M. Simon, *Telecommunications and the City: Electronic Spaces, Urban Spaces*, London: Routledge, 1996.
[15]Habitat Report, 2001, Chapter 1, 2.

In its cultural expression, it should be emphasized that it is not only electronic information, but also the movement of goods and people themselves, that are globalising society. Culture, in its broadest sense, has always been associated with specific places and countries. This continues to be true, although at the same time it is also increasing true that we find all languages, and almost all the customs and ethnic groups, in a great number of places in the world. This phenomenon is becoming notably more widespread with international migration, one of the most dynamic forces of the contemporary world. Once again, this phenomenon is mostly associated with cities.

In politics, globalisation especially affects the concept of the sovereignty of nation states. These entities are less and less the one and only power in the societies they comprise. Issues such as regulation of the environment, international finance, migration, human rights protection, among others, are increasingly being associated with supra-national institutions and powers. Finally, it should be pointed out that the political impact of globalisation is still incomplete and very unequal. Many remain excluded from its benefits. Not only are the poorest, least educated groups excluded losers; all those who do not participate in the interconnected, digital, global society or economy are missing out on benefits.

GLOBALISATION AND THE WORLDWIDE URBAN SYSTEM

It is an accepted fact that in the last few years, cities and their regions have been much more capable than nation states at adapting to the rapid changes brought on by economic globalisation. The key role played by cities in achieving dynamic and competitive economies has been studied extensively.[16] The growing role of multinational companies in the world economy, in volume of trade and production as well as in technological innovation and telecommunications, is a key factor in distinguishing the role of certain cities in the global economy. Some cities are unambiguously the "centres of command functions", and thus have a high degree of internationalisation in their economic and governmental structure.[17] There are three of these "world" cities, as we shall see here: New

[16]S. Sassen , *The Global City: New York, London and Tokyo*, Princeton: Princeton University Press, 1991; *World Bank* 1991; Jacobs 1984 as cited in M. Cohen, *et. Al.*, 1996, pp. 1.
[17]S. Sassen , *The Global City: New York, London and Tokyo*..., pp. 18-24.

York, London and Tokyo. They hold a place as central "nodes" in a vast and growing network of cities of different hierarchal position. New York and London are large financial and commercial centres, but they also export their sophisticated services. Tokyo, additionally, is still a great manufacturing centre. While New York operates in a decentralized and multipolar context, Tokyo and London hold overwhelming weight in their respective island countries. London (and to some extent Tokyo) has a long history as a colonial and imperial capital. The three cities fight to maintain their superior position among world cities and compete with other cities for the huge amount of investment necessary for advanced telecommunications technologies such as "teleports," the massive fibre optic networks that further broaden bandwidth and allow for the incorporation of all technological advances. Intense financial relations (spurred by telecommunications) and the exchange of services and trade between the "big three" cities are also characteristic of their central role in the global economy.[18] After these three undisputed world cities (in many indicators Paris might also qualify), the classification of world cities is more ambiguous and subjective.[19] Undoubtedly, with globalisation has come intense competition to achieve the enviable status of the world city.

But the global economy is more than this; it is composed of a very extensive network of interconnected cities. We will work closely here with the models developed in the important work of Paul L. Knox and Peter J. Taylor.[20] One way of visualising cities is as a function of their attributes and world ranking (in terms of size, financial institutions, etc.); another is as a function of their ties and the density of their connections with other important "nodes" on the urban network.[21] There are four principle variables involved in the classification of cities in terms of their participation in the processes of globalisation:[22] as functions of their use as command centres, their financial markets, their size and extension of the service sector and their telecommunications infrastructure (a clear proxy of digitalisation). Here, the most powerful indicator would be the number of corporate

[18]S. Sassen , *The Global City: New York, London and Tokyo*, Princeton: Princeton University Press, 1991.
[19]UNCHS, 1996, pp. 21-22.
[20]P. Knox, P. & P. J. Taylor eds., *World Cities in a World System*, Cambridge: Cambridge University Press, 1995.
[21]Smith & Timberlake, in P. Knox, P. & P. J. Taylor eds., *World Cities in a World System.*
[22]J. R. Short J.R & Y. Kim, *Globalization and the City*, New York: Longman, 1999.

headquarters of large transnational companies located in different cities, since these are basic decision making centres. However, as Sassen[23] points out, this indicator has lost its weight since financial and technological aspects are increasingly more important. Furthermore, many transnational companies decentralise their decision making systems with new telecommunications at the level of certain regions or determined functions. Despite this fact, the use of this indicator puts New York, Tokyo and London at the top, although Paris should also be included. Mexico City is home to the headquarters of Mexican transnational companies,[24] but, more than anything else, it is regional centre for Latin America to a number of transnational companies and banks from the United States, Asia and Europe. In this respect, Mexico City leads Sao Paolo, although its true real competitors are Los Angeles and Miami.

Financial markets have grown enormously, diversified and become concentrated in no more than a dozen key cities. Judging by the indicators of the number of headquarters of the world's largest banks, services offered and stock exchange size according to market capitalisation, New York and London are clearly on top, being considered "Supranational Financial Centres;" Tokyo is considered only an "International Centre," and shares third place with Frankfurt, Paris, Zurich and Amsterdam. Within this system of classification, Mexico City stands out in a fourth group as a "Guest Centre," among cities such as Sao Paolo, Singapore, Hong Kong, Sydney, Rome and others. In terms of service production, including modern services such as entertainment, fashion and publicity, among others, New York, London and Tokyo are leaders. But, once again, Paris appears to be very close to sharing this status.[25] In terms of these variables, Mexico City seems to have little relevance. It is notably surpassed by far more minor cities such as Milan, Madrid or Singapore.

With respect to the highly strategic variable of telecommunications infrastructure (digitalisation), it is notable how this is an ongoing process that began around the early 90s with a race for principle cities of the world to "connect" via the new telecommunications

[23] S. Sassen , *The Global City: New York, London and Tokyo.*
[24]The leading companies are: Televisa (television and entertainment), T elmex (telephone), Bimbo (food) and state-owned PEMEX (oil).
[25]J. R. Short J.R & Y. Kim, *Globalization and the City...*, pp. 32-37.

technologies; this included penetration of the Internet, fibre optic hook-ups,[26] bandwidth availability and teleports, and the establishment of technopoles, or high technology centres.[27] It is clear that the construction of this telecommunications infrastructure will be critical to qualifying as a world city. Furthermore, the gap that results between "conventional" cities and those designated as primary nodes on the digital telecommunications network will be a decisive factor in terms of global competitiveness in only a few more years.[28] Here, again, the leaders in Latin America Mexico City and Sao Paolo are far behind, not only compared to the large cities of advanced countries, but also in relation to the great emerging cities of the Asia-Pacific region such as Seoul, Hong Kong, Singapore, Taipei, and Kuala Lumpur.

It would be apt to mention that the other way to analyse cities within globalisation --in terms of their ties and connections with other urban centres in the network of global cities. We will not take telecommunications into consideration here, since they were discussed in the previous paragraphs; instead we will look at air transport, a common category in all the large world cities.[29] We may conclude that international accessibility is increasingly important to globalisation and no other activity reflects this better than air transport. Thus, it is an excellent proxy of global connectivity since it includes the exchange of educated people with high incomes, merchandise with high added value and relevant information. Keeling[30] discusses the concept of "transport" in connection with World Cities and why (air) transport is crucial to the formation (and aspirations) of the new global economy due to the growing demand for interpersonal contacts in globalisation, rapid interurban connectivity, and its high correlation with emerging globalisation activities such as tourism and entertainment. Commercial passenger and cargo aviation has grown in an almost exponential manner in the last 20 years, at 5.1% annually, far more than general economic growth. This growth has not only occurred with air traffic, but also with routes that connect

[26]It is noteworthy that the city with the most fibre optic connections is Seoul, Korea.
[27]M. Castells & P. May, *Technopoles of the World: the Making of 21st Industrial Complexes*, London: Routledge, 1994.
[28]S.Graham, & M. Simon, *Telecommunications and the City: Electronic Spaces, Urban Spaces.*
[29]Ports are relevant only in cities which are also ports, but the three world cities no longer have the principle world ports. P. Knox & P. J. Taylor, eds., *World Cities in a World System.*
[30]D. Keeling, Transport and the World City paradigm in Taylor and Knox, *World Cities in a World System...*, pp. 40-41.

increasingly dense flows of passengers to important cities. The emergence of large aviation and transport hubs is a clear indicator of all this. The results are not surprising: the cities with the most passengers and routes[31] are London, Tokyo, and Paris, followed by Frankfurt, Hong Kong, Singapore and New York. The relatively inferior position held by New York can be explained by the fact that in the United States there are many other hub cities with global connectivity such as Chicago, Los Angeles, Miami, Denver, Atlanta and San Francisco. Singapore and Hong Kong's importance is a result of their function as regional "hubs."

This has a number of important implications for Mexico City. In terms of the volume of its air traffic, Mexico City's airport is among the twelve busiest in the world, leading all of Latin America and staying far ahead of Sao Paolo. However, as a regional hub for Latin America and the Caribbean, it competes with Miami and Los Angeles for the Pacific and with a number of cities in the United States –Dallas-Fort Worth, Houston, Denver, Chicago and Atlanta-- for Europe and the rest of North America. If Mexico does not modernize and enlarge its flight connectivity, it runs the risk of being pushed out of its position as a hub or global node.

THE PRIME CITIES OF MEXICO AND LATIN AMERICA

The primacy of New York, Tokyo and London as world cities before a vast network of global cities is clear. It is also clear that, in the intense competition to achieve this status, in Latin America the only cities that may eventually qualify are Mexico City and Sao Paolo. This is the case not only because of their large size and regional primacy, but also because of other attributes that we will discuss shortly. Only in a couple of decades will we be able to know if the two gigantic Latin American cities were able to overcome their sizeable problems and restrictions which, at the moment, not only impede them from joining the ranks of the "big three," but also situate them below many other smaller cities that are more prosperous and modern.

[31]According to *ICAO* (International Civil Aviation Organisation), London, 1998.

According to the methodology of Sassen, Knox and Taylor,[32] among others, and those specifically working on Latin America such as M. Pérez Negrete[33] and Parnereitier, [34] some cities in Latin America are beginning to take on specialized functions with respect to globalisation, although they are far from functioning as command centres. According to an "alpha, beta, gamma..." classification system established by the Globalization and World Cities Study Group,[35] certain Latin American metropolises such as Sao Paolo and Mexico City will be on the second or "beta" level. Cities like Buenos Aires, Santiago and Caracas will be on the third or "gama" level. All, however, will be part of the network of global cities and nodes on this network in their respective regions. The classification system is interesting, although it makes grave omissions such as not listing Tokyo in any category and omitting Bombay and New Delhi.

In the case of Sao Paolo and Mexico City, the two are far above the other cities in their category and above any other Latin American city. But Mexico leads Sao Paolo with 12% in the "world city formation" index, which, according to Sassen's[36] methodology, relates to financial centres, consulting businesses, attraction of foreign investment, high technology centres and regional communication centres, among others.

Sao Paolo and Mexico City are almost always mentioned, but in the context of a transition to becoming possible global cities. Certainly, they have the size and importance required in their respective regions. Not only do both have large dimensions, but they also have similar problems. Sao Paolo presides over a larger and more diverse region, and also has greater industrial density. Mexico City, on the other hand, is the capital of the country and the great centre of Hispano-American culture. It attracts more foreign investment and many more visitors; it is closer to the United States and more connected to the world.

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[32]S. Sassen, *The Global City: New York, London and Tokyo*; P. Knox & P. J. Taylor eds., *World Cities in a World System*.
[33]M. Pérez Negrete, ¿Megaciudades o Ciudades Globales? Rev. *Memoria* no. 156, México, Feb. 2002, pp. 8-10. y GAWC, *Globalization and World Cities Study Group* http://www.Lboro.ac.uk/gawc/
[34]C. Parnereitier, *La Ciudad de México en la red de Ciudades Globales*, Anuario de Estudios Urbanos, México: Universidad Autónoma Metropolitana, México, 2000, in M. Pérez Negrete, ¿Megaciudades o Ciudades Globales?, pp. 8-10.
[35]*Ibidem.*
[36]S. Sassen, *The Global City: New York, London, Tokyo.*

Sao Paolo plays an even more important role in its own region than does Mexico City. It has no competition whatsoever in South America, given that Rio De Janeiro is a function of its region and Buenos Aires lies in another region, and, in any case, is of a lower rank. In contrast, in terms of globalisation, Mexico City has to face the ferocious competition of Los Angeles in the Pacific and Miami in the Atlantic. The former monopolizes relations with the Pacific, California and the American west, while the latter primarily does the same with the rest of Latin America.

Thus Mexico City and Sao Paolo are still on the periphery of the global economy. Both clearly demonstrate one of the biggest problems with globalisation: the exclusion of the great majority of people from its benefits. Globalisation worsens an already existing unequal distribution of wealth and quality of life among the inhabitants of its cities. In both Sao Paolo and Mexico City (and in the rest of the Latin American cities mentioned) urban poverty is rampant, with segregation of the poor in "lost cities" and "favelas." Among the working population in both places, there is either extremely high unemployment or employment in "informal activities," where production and profits are extremely low.[37] Both cities have extremely high levels of pollution and their historic CBD's are deteriorating rapidly. In short, this is a case where globalisation increases social polarization.

5.1.3 World Cities and the Largest Cities in the World (Megacities)

It is interesting to note that the main cities might be much bigger as a result of the rapid urbanization that has taken place throughout the world, but those which were among the largest one, two or more centuries ago continue to be the majority. This is particularly true, not only for Mexico, but for all of Latin America, since the majority of the largest cities already existed from between the 16th and 18th centuries. Almost everywhere, in the last years of the 20th century, the majority of the largest cities seem to have consolidated their growth, and the medium and small cities were those which grew the most.

[37]P. Hall,& U. Pfeiffer, *Urban Future 21*, Chapters III and IV, London: E&FN Spon, 2000.

If we analyse the 15 largest cities in the world, we are able to observe that, with the exception of Lagos and Dhaka, lately all have grown at a much slower rate (UNCHS, 1996). This allows us to suppose that the greatest urban centres tend to consolidate themselves and that in about 15 years the most populated cities in the world will mostly be Asian. But as we saw previously, a large population does not necessarily lead to being considered a world city, as we can see in Table 5.1, which follows.

TABLE 5.1

The 15 Most Populated Cities in the World: 2000 and Projections for 2015 (in millions of habitants)

	2000	(2015)
1.- TOKYO (1)	26.4	26.4
2.- MEXICO (6)	18.2	19.2
3.- MUMBAY(2)	18.0	26.1
4.- S. PAOLO (5)	17.7	20.3
5.- NEW YORK (9)	16.6	17.4
6.- LAGOS (3)	13.4	23.2
7.- L. ANGELES (12)	13.1	14.1
8.-SHANGHAI (13)	12.9	14.6
9.-CALCUTTA (11)	12.9	17.2
10.-B. AIRES (13)	12.6	14.1
11.-DHAKA (4)	12.3	21.1
12.-KARACHI (7)	11.8	19.1
13.-DELHI (12)	11.7	16.8
14.-JAKARTA (10)	11.1	17.3
15.-OSAKA (19)	11.0	11.0

These numbers include metropolitan areas.
SOURCE: *Cities in a Globalizing World*, Table B1; *UNCHS*, Earthscan, London, 2001.

On the other hand, Asia's growing urban predominance is noteworthy[38]: China has 103 cities with populations over one million while India has 40. Additionally, while Europe no longer has a city amongst the 15 largest in the world, Asia has nine. Tokyo is one of the three "global" cities (along with London and New York) and will continue to be at the forefront of these. Similarly, the largest metropolises in North America will drop in rank compared to Asian ones; however, New York and especially Los Angeles will hold on to their important positions. Nonetheless, the United States and, to a lesser degree Canada, will continue to experience rapid urban growth (cities in the United States with the most growth are located especially in the Southwest).

For their part, the two great Latin American metropolises, Mexico City and Sao Paolo, will continue to be amongst the largest cities in the world, although they will fall in rank. This is due to the fact that in all of Latin America a so-called "Demographic Transition"[39] is in an already highly advanced stage. Latin America is now seeing the consolidation of its largest cities and metropolitan areas and the growth of numerous small and medium population centres. This is true in the case of Mexico, where the metropolitan areas of Monterrey and Guadalajara are being consolidated and where the fastest growing cities are the medium sized ones like Cancún, Irapuato or Tapachula. In Mexico the growth of cities along the border with the United States is notable. Places like Tijuana, Mexicali, Ciudad Juárez, Reynosa and Matamoros have undergone rapid growth spurred by migration to the United States, business opportunities provided by NAFTA and especially the installation at the border of in-bound assembly plants or *maquiladoras*.

Only the largest Latin American metropolises --Mexico City and Sao Paolo-- will hold on to their places amongst the 15 most populated places in the world, although they will be passed up by some of the cities in southern Asia and Africa. No other large Latin American city, not even Buenos Aires or Rio de Janeiro, will remain amongst the 15 largest, since

[38] UN CHS, 1996, *Ibidem.*

[39] As we saw in section 4.1, the demographic transition basically consists of the change from high mortality and fertility rates to low mortality rates, followed by low fertility rates. This has been taking place in Mexico and Latin America since the 70s. In Mexico, demographic growth has gone from almost 3.6% in 1970 to close to 1.6% in 2000.

they will be overtaken by the metropolises of central and southern Asia and by some of the largest African cities.

Another characteristic of the recent urban development that has taken place in the world is the notable resettling of the population and the production carried out within cities and in their metropolitan areas. In general, the reduced growth of the largest metropolises can be explained by the decentralization of production and the movement of the population towards close, peripheral minor cities. This has often led to the decline of CBD and to the formation of large central areas of influence, or core regions. In Mexico, this phenomenon is expressed by the growth around the metropolitan area of a "crown" formation of a number of cities such as Toluca, Cuernavaca, Puebla, Tlaxcala, Pachuca and the metropolitan area of Querétaro. A similar situation can be found in the region surrounding Sao Paolo in Brazil.

In the chapter 7, we will see how the Mexico City metropolitan area as a megalopolis might face the challenge of becoming a genuine "world city," not just another big city in the global era. However, we will first look at the other great challenge the city faces, one that is not distinct from its globalisation goal: that of environmental sustainability.

5.2 Implications of the Technological (Digital) Revolution for the MCMZ

5.2.1 The New Technological Revolution

We already saw at the beginning of this chapter that recognition of what has been called the New Industrial Revolution began by around the end of the 70s. Although its possible depth and initial impact were then exaggerated, and its components have not progressed at equal rates, nor have they lived up to their initial promise, we can say twenty plus years later that it was not a mistake to use the term "revolution." Undoubtedly, the accumulation of the most important scientific and technological innovations of the last decades of the century were made in the fields that constitute this phase of profound technological mutations and discontinuities: microelectronics, biotechnology and the advent of ecology as a mature science as well as the emergence of the new materials revolutions.

These fields in themselves and, to some degree, in conjunction, constitute the "triad" of the New Technological Revolution. They were considered, from about the end of the 70s to the beginning of the 90s, to be the basis of the contemporary technological revolution. In the early 90s the effect of microelectronics on communications and the applications of lasers, which, through the use of fibre optics and computational algorithms, allowed for the digitalisation of information, began what can be called a "second phase" of the New Technological Revolution, since microelectronics was energized by the possibilities of the presentation and display of digitalised information and especially by the possibilities of communications. For its part, biotechnology has advanced at a slower rate than expected, through DNA recombinant techniques and the recently completed decodification of the genetic code, the human genome which also is beginning to mature. The science of new materials is moving forward at a steady pace; however, a breakthrough that would lead to truly revolutionary progress in the critical area of superconductor materials –which are able to transport electricity without energy loss-- has not been possible. In the area of composite materials, interesting progress has been made, as has also been the case with plastics, steel and ceramics. In any event, we are able to confirm that the "triad" remains intact. The synergy between the new technologies can be better appreciated in robots than in any other

type of technology. Robots will increasingly use not only greater computer power, but will also require computing technologies to be operated and controlled at a distance; they will surely incorporate ceramics, superconductor materials and plastics, among others. However, Robots are another example of a technology that so far has failed to live up to its promise; but with the exponentially expanding capacity of computers and communications, as well as specific software driven technologies like virtual reality, artificial intelligence and voice recognition, the robotics presence in the manufacturing industry will undoubtedly become stronger. This will have a highly significant impact on, first of all, labour markets and second on the possibilities of control and decentralization of the manufacture of innumerable products. It is one of the principle agents of economic globalisation, with its advantages, and also with its ominous consequences.

We will now review the subject of information technologies, not only because this is one of the most advanced and mature aspects of globalisation, but because it has the most important and immediate impact on urban design and city life. However, we will first briefly refer to the other axes of global technological change: biotechnologies and new materials.

BIOTECHNOLOGIES AND NEW MATERIALS

Biotechnologies and new materials are the two other main axes of the current technological revolution. Their impact on urban form and life in the Mexico City metropolitan area will be much more tenuous and indirect in the immediate future, although they will undoubtedly have a considerable impact.

The application of biotechnologies[40] will have their main impact on the amount of land area required for agriculture. So, on one hand, the application of biotechnology techniques will allow for greater productivity per hectare, and, on the other, stabilization of demographic growth rates worldwide will take place in the next few decades as the result of the last stage

[40] Mostly but not entirely trough the widespread use of genetically modified seeds and plants, or, in due, time to nitrogen fixation and other technologies.

of the demographic transition (a sharp drop in the birth rate). Thus, it is foreseeable that demand for food will stabilize and, very possibly, the actual land acreage used in food production will diminish somewhat; thus plenty of space will be freed for greening and wild habitats restoration. However, these changes will not take place in the short term. Thus, the spread of biotechnologies will have an impact on the availability of green areas per inhabitant and especially on the levels of sustainability of cities. It should be probably will only materialize beyond 2020.

It is evident that the world economy is changing from an era of intensive use of materials to one of intense digitalised information, or, as Nicolás Negroponte puts it, from an era of atoms to one of bytes of information.[41] The demand for materials such as minerals, metals, wood, etc. is significant, but is no longer the principle factor that activates the international economy. Services and computing now play an increasingly important role. In terms of the final product, basic materials are becoming less and less important compared to the high tech component. A perfect example of this is that of automobiles, which are increasingly lighter, more energy efficient and, above all, "digitalised." But the same can be said of the majority of home appliances, airplanes, machinery, etc. (see Section 5.1.1 above on "dematerialization"). This is thus a component of the new ecological paradigm of the global economy and civilization.

However, even with materials, rapid technological changes are taking place that affects and as the same time affected by, the two other components of the triad of technological change mentioned above. This is especially true of fibre optics, superconductor materials, ceramics and "composites" as well as new degradable plastics; fields in which the greatest number of connections between the three types of technologies can be found. The materials revolution is also made possible by expanding scientific knowledge of the atomic-molecular structure of different materials, which increasingly gives scientists the ability to influence the structure of, or even to design at the molecular level, new substances and materials. From this point, many new possibilities for the future are opened, including "intelligent materials" with all types of sensors and incorporated semiconductors capable of computing

[41]N. Negroponte, *Being Digital,* New York: Alfred A. Knopf, 1995, 243 p.

and modifying their characteristics, attaining flexibility, resistance, and so on. Also being studied is the possibility of materials that, being activated by a determinate degree of temperature, humidity, rework and modify their molecular structure. Yet another possibility –even more remote in terms of its time of practical applications—is that of intelligent microscopic machines which derive from "nanotechnology," and, by manipulating the level of individual atoms or molecules and applying quantum properties, build flexible, complex structures capable of self-replicating and carry out a number of functions. But this is something that goes beyond the scope of this work. Of course, as an example of this powerful synergy between one kind of technological innovation and another, this type of modelling and design is made increasingly more possible through the use of powerful computers.

As we already saw at the beginning of this chapter, it is always risky to attempt to predict the future of technology. Errors of omission, optimism (or even pessimism) are almost invariably made. If we look back to the 1970s, we find there was excessive optimism about certain technologies, while others were overlooked. For example, biotechnology has progressed at a much slower rate than expected; the same can be said of robotics and artificial intelligence. However, the development of microelectronics has been much greater than anticipated; telecommunications were similarly underestimated. No one foresaw the emergence of the Internet as a new medium of communication, nor did anyone predict the highly extensive applications of microelectronics and telecommunications.

There will always be unexpected events, synergies between two apparently unconnected discoveries, latent ideas, and unexpected applications of already known technologies (for example, fax, e-mail, etc.). Additionally, the economy places cost limitations on ideas and innovations that, at least in the laboratory, may seem very promising. The opposite may also occur: the market stimulates research, creation and implementation of new techniques and products. Thus, this mixture of invention, market and chance is what determines the path of technological advancement. Additionally –and this concerns us more—these factors have an influence on when technology will be truly and massively adopted, and when they will affect social practices, economies and cities. On the other hand, institutions –forms of

regulation, contracts, procedure, etc.—are undergoing changes in a complex network of causalities, along with technological change.

We are conscious of these risks but regardless, it will be necessary to take chances to determine some of the key technological trends now in place, in order to anticipate their impact, especially on Mexico City's urban economy [42]. On the other hand, 30 years in the future is not so far away as to warrant many mistakes (we could look back to 1970, for example). Choosing a planning horizon beyond 2030 would subject us to on an exponential curve that would multiply our ignorance and risk of fatal errors.

This is why we are concentrating of the topics we already know are significantly impacting societies and economies: microelectronics, telecommunications and, increasingly, knowledge of the environment and its problems. Also taken into consideration were already the materials and biotechnologies, although to a lesser degree, not because of they are less important, but because they have a less direct and obvious effect on urban form and city life.

MICROELECTRONICS, TELECOMMUNICATIONS AND THE DIGITAL REVOLUTION

A product of the happy marriage between optics and semiconductors, the current digital revolution will dramatically transform computing and telecommunications and will have a tremendous impact on cities, as seen above in section 5.1.2. This impact will be so vast that it will be comparable only to that of electricity and the automobile in the 20th century. We will look at the digital revolution from two perspectives: first in terms of its indissoluble ties with economic globalisation, of which it is a central, elemental part, and, second, through an analysis of the phenomenon itself, with a look at its components and the tendencies that will lead to massive changes in urban areas and the MZMC by 2030.

[42] C. Luiselli. *Assessments of Future Transport Models and Technologies with Impact on the MCMZ*, (Mimeo). Mexico. 2001.

5.2.2 The Future of the Automobile and Transport Modes and Systems

The means and methods of transport have always greatly influenced the life, urban form and economy of cities. Therefore it is indispensable to review the main transport trends if we wish to understand where Mexico City's urban form and way of life headed.

In the 20th century, the automobile broke onto both the urban and world scene as the dominant form of transport and transformed the world and the cities. It effects are obvious and numerous and its benefits have been obscured by the many problems it causes. Life and the urban landscape in the 20th century was radically transformed in order to make room for the automobile. North American cities (with Los Angeles at the fore) are the epitome of cities *for* the automobile. In the United States, the area used for streets parking lots and service stations is calculated to account for between 25% to 40% of urban space. The situation in the rest of the world and in Mexico City cannot be much different.

Of the many problems caused by the automobile, three should be emphasized: it pollutes, it contributes to the warming of cities and it creates traffic congestion. It is also a factor that deforms the urban form and landscape and it often contributes to the social segregation of the recreational and residential areas of cities. In Mexico City's closed basin, the negative impact of the automobile has seriously increased since the polluted atmosphere can neither evacuate nor dilute pollutants with ease, which leads to the multiplication of their negative effects.

Thus, anticipating and understanding the dynamics of the automobile (and buses) and traffic will be fundamental in understanding urban form, and in this case, Mexico City itself. We believe that in the future the individual mobility that the automobile provides will be combined much more effectively with other modes of mass transport such as buses, electric trolley trams and of course the metro. The automobile will not disappear, but instead will be transformed in such a way that the inefficient cars of the 20th century will be a vague memory. We will not for the moment delve into more details concerning the automobile, since it is important to look at the broader context of all means of transport

found in the urban setting. The analysis of the relationship between the use of the automobile and the Internet is closely analysed in section 5.2.3.

But the automobile also has a positive side above all it allows us a great freedom to move and because of this, without a doubt, it is here to stay: It simply broadened people's horizons, allowing for greater autonomy and independence. It gives a growing number of people flexibility and mobility. Of course, another positive factor is the huge number of jobs --relating to production, operation, maintenance and parking-- that the automobile generates. In developing countries, where the functional life of cars is prolonged for longer periods, such jobs tend to be more plentiful as repairs and maintenance are necessary. The automobile industry and that which supplies its fuel, oil, still make up the heart of the contemporary industrialized world.

These positive characteristics should be conserved. It is naïve to think that the automobile will disappear in the next century, much less in the time period under consideration in this thesis; specially considering the density (automobiles per inhabitant) of the use of the automobile observed internationally.

Mexico does not yet have the same density of automobiles per capita as the United States, Japan or Europe. In fact, given the clear positive correlation between per capita income and the number of cars, we can predict a process of "automobilisation" of the world. What is alarming is that if Mexico City comes to have a coefficient similar to that of the United States, the number of cars in its metropolitan area could reach 6 million by 2010 and more than 17 million by 2030. The hypothetical consequences of such a scenario will be analysed in the following section. In this chapter, our focus will be on analysing the technological tendencies and changes that affect the Mexico City metropolitan area.

The current technological revolution among other things will transform not only automobiles, but also all modes of transport, causing among these to interact in new ways since transport will be intertwined in many ways. Thus, we should look at not only what could happen to the automobile, but also at every form of transport that affects the

environment, as well as at communications between the metropolis and other spaces. Emphasis should necessarily be placed on people's mobility, not necessarily on their cars but on the means of transportation as well. The transformation of urban transport will be strongly influenced by the environmental (avoiding pollution) and economic (growing costs) imperatives that will greatly affect the patterns of demand for transport in cities.

In fact it is important to have in mind that the carrying capacity of the global environment could not stand a coefficient of automobilisation similar to that of the United States. Just think of the population of China or India, in the year 2030; if the number of cars in these places were to reach a density such as the one that currently exists in the developed world, there would be more than 2,000 millions of cars in these two countries (3,500 in the whole developing world.) The greenhouse effect and poisonous gasses, the increasing scarcity of fossil fuels and growing congestion would create a need for a radically different kind of automobile, something which we believe will occur around the third decade of this century. It will be necessary to bring about the euthanasia of the automobile that uses internal combustion motor fuelled by gasoline. It is apt in Mexico City to anticipate this gradual transformation, due to its magnitude and importance, and its many ecological-environmental advantages, which we will examine below.

This is why it is convenient at present time to establish, as rigorously as possible, what the automobile will be like by 2030, and to look at it in relation to and in the context of the totality of urban and interurban modes of transport. Thus, we should consider the future of trains, planes (in terms of their connecting of cities), the bicycle, of course, and even walking.

Indeed, the future of the automobile looks as a gradual metamorphosis: First of all, it should be pointed out that in the foreseeable future the, as we know it, will not be a single type of vehicle. There will be a variety of vehicles for different types of use. There have been signs of this tendency for the last two or three decades, when trucks and utilitarian cars emerged. There are currently a variety of such automobiles, with the addition of all terrain (or "4x4") vehicles; additionally, the small, light city car is already commercially

available. These small city cars can be less potent, are unable to reach high speeds and accelerate more slowly; yet these characteristics are not necessary in the heart of urban areas. Fleets of taxis might be a pioneering example of the introduction of such cars in large cities.

In fact, between the car and the bus, new options are continually emerging. Additionally, technological advances in manufacturing make for increasingly greater flexibility, which allows for a broader range of available cars based on the same chassis. Demand is expected to be strong enough to market increasingly differentiated vehicles for different types of uses, clients and environments. Of course, the most noteworthy of these are the environmentally friendly cars and those that are integrated with other modes of transport.

We can clearly make out three important paths of the future transformation of the automobile: engines and the types of fuel they use, the materials and parts used in construction and widespread use of navigation aids and smart highways. All these changes, in turn, are profoundly influenced by most of the pillars of the current technological revolution: microelectronics, computing and the emergence of new materials. Furthermore, the internet's increasing penetration, power and ubiquity are sure to have an effect on the use of the car. To speculate with some basis in fact, we will now look at each of these paths of transformation in some detail.

Improvements and incremental changes with regard to the internal combustion engines and the use of fossil fuels allow us to say that today's internal combustion engine has improved. Those using gasoline are cheap in terms of consumption and are energetically efficient. Their principal problem is the pollution they produce. The widespread use of this type of engine is expected to continue in the immediate future; they are also expected to improve notably in terms of performance and environmental "cleanliness." In fact, they have improved dramatically since the "Energy Crisis" of the 70s. They now emit up to 90% less pollutants into the atmosphere and their efficiency, measured in terms of distance per unit of fuel consumed, has at least doubled. There are still many possible ways to make engines better, such as through the use of new variable geometric valves, the improvement of

combustion processes and the axis, the reduction of friction and the weight of cars and the use of new materials such as ceramics, aluminium, polymers and even with much more advanced types of steel and alloys. Diesel motors are also being improved and they will foreseeable become more economic and less polluting.

Additionally, the use of catalytic converters sensibly reduces the emission of some pollutants, although not all of them. Their efficiency depends on how new they are and what kind of fuel they use (they require unleaded gasoline), and they work better when the engine is warm; (they do not work for the short distances of the typical interurban trip). Catalytic converters are effective for reducing emissions of carbon monoxide and other hydrocarbons (between 60 and 85%), although they do not eliminate carbon dioxide or sulphur dioxide.

Thus, despite the use of catalytic converters, this type of vehicle cannot completely eliminate pollution; eventually, the use of fossils fuels –due to their being a non-renewable resource-- will tend to become more expensive.

There are other types of fuel whose use can be considered in engine technology with minimal modifications such as natural gas (although much cleaner than gas, it is more expensive and, ultimately, non-renewable) and methanol gas which can be produced in variety of ways, but is mostly made from biomasses (such as sugar cane in Brazil or corn in the United States). But the two fuels present important problems for the urban environment: their combustion emits aldehydes into the atmosphere which, besides polluting, can also be carcinogenic, and they are energetically less efficient in terms of the energy released for each measured unit.

Thus, for these reasons, the automobile will inevitably have to change to another type of engine, which mostly likely will be electric, with a "hybrid" technology in the transition between gasoline and totally electric vehicles. The most likely scenario for around 2020 – 2030 will be the massive adoption of totally clean fuell cell electric cars using hydrogen.

The first automobiles were propelled by rudimentary electric engines, which were justifiably substituted by gasoline engines, due to their lower price and greater efficiency. Ironically, however, a return to the electric car is inevitable for the reasons outlined above. In our scenario of the foreseeable future, two types of technology seem probable: that of the battery or that of combustion cells.[43]

5.2.3 The Expansion of the Internet Space within the MCMZ

As we saw previously in section 5.1, it is necessary to establish a connection between the implications of information technology and economic globalisation. The central connection lies in the dramatic reduction of costs and processing and in the communication of information, which aid the globalisation of production, consumption, and especially the integration of financial markets. Globalisation of the economy and information technologies reduces the importance of time and distance.[44]

Some economists, dramatizing the implications of information technologies, talk about the "end" or "death" "of distance"[45] in the sense that its marginal cost in the formation of the price of communications will be virtually zero. This "death" of distance will perhaps be the most important economic variable in the ordering of the economy in the first thirty years of the 21st century. It is sure to transform economies, decisions about where to settle and work, ways of doing business, education, entertainment, etc. But before we analyse the dynamics of these changes, we will take a closer look at their connection with globalisation.

Just as the computing power of semiconductor materials –basically silicon—continues to grow exponentially (doubling almost every two years), the ability to transmit information by telephone, computer or television has increased more than a million times in the last couple decades, at the same time that meal costs have plummeted.

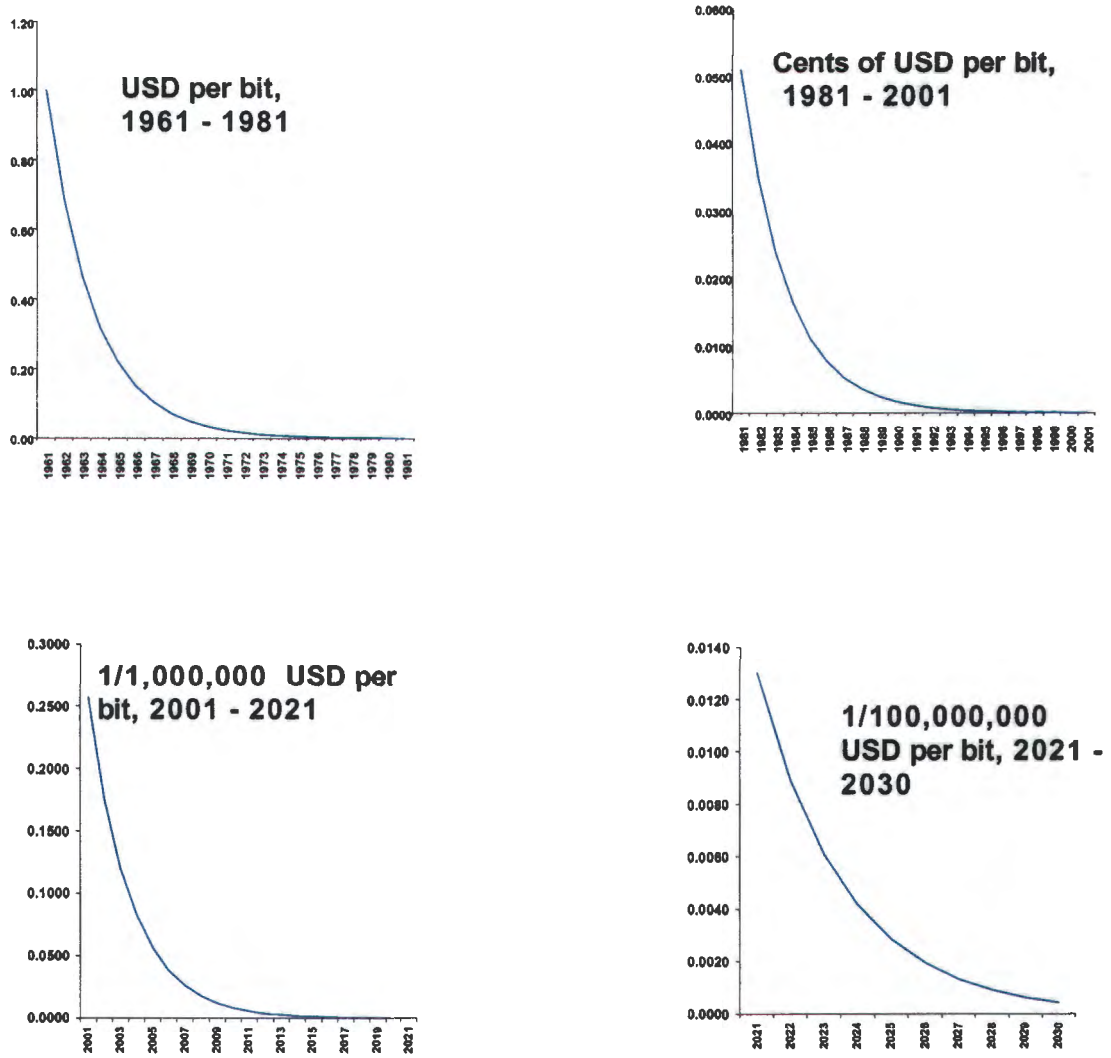
[43] C. Luiselli. Ibidem.
[44]The term "information technologies" is used to designate all those technologies, including the "internet," that, through the digitalisation of data, allow for its management, including computing, processing, storage and distribution, decentralisation of data, etc.
[45] Caincross, *Op.cit...*, pp. 280.

Likewise, there is a growing synergy between the different communications media. Today, the Internet is used by more than 150 million people; no other mode of communication has grown so quickly as the Internet, and it continues to expand exponentially. There were fewer than 50,000 computers thirty years ago, while today there are more than 150 million; and their numbers continue to grow at a similar rate. One of today's portable laptops, with a cost of 1,200 dollars, has the same computing power as a mainframe computer from the 70s which cost 10 million dollars. And prices continue to fall. Fibre optics and the digitalisation of information will soon make it possible to transmit virtually unlimited quantities of information to any part of the planet at an infinitely lower cost.

Although the limits of materials used for semiconduction (silicon, metals, integrated circuits, etc.) are close to being reached, the continuity of "Moore's Law" (see Figure 5.1) in time seems to be guaranteed, at least for the period under our consideration. Silicon still has an enormous potential for achieving up to a trillion transistors per chip. Thus, as is demonstrated in Figure 5.2, the tendency for the price of microprocessors to be reduced by half at the same time that they become twice as fast every 18 months is expected to continue from 2000 to 2010 at a pace of every 18 to 24 months, while from 2010 to 2020, the same will occur every 24 months. Later, Moore's Law may cease to be valid, making way for new technological platforms (ubiquitous computing, DNA, optical, quanta, etc.), which will imply unlimited possibilities for managing information.[46]

[46]J. D. Meindi, *et. al.*, Limits on Silicon Nanoelectronics for Terascale Integration, *Science*, Vol. 293, 14 September, 2001.

FIGURE 5.2
The Evolution of Cost per Byte[47] (Moore's Law)



SOURCE: By the author, based on information from N. Negroponte, *Being Digital*; For similar examples of the behaviour of the price of microprocessors and their memory capacity, see R. Miller, *et. al., The Promises and Perils of 21st Century Technology: An Overview of the Issues. 21st Century Technologies*, France: OECD, 1998, pp. 7 – 32.

[47]To determine the cost of a byte in 30 years, an exercise was carried out based on the fact that in 1961 one byte of memory cost one U.S. dollar, while currently 24 million bytes cost 60 U.S. dollars. This means that the annual average rate of reduction in the cost of a byte is slightly over 31%. See N. Negroponte, *Being Digital.* Assuming that this rate will remain constant over the next 30 years, a corresponding projection was calculated and its results are shown in the figure. Additionally, taking into account other data, such as the fact that a megabyte cost $550,000 U.S. dollars twenty years ago and today it costs four U.S. dollars, an annual rate of 37% would be reached. *Miller, et. al., The Promises and Perils of 21st Century Technology: An Overview of the Issues. 21st Century Technologies*, France: OECD, 1998, pp. 7 – 32.

As during the previous century (the 20th), the road towards the integration of markets has come about due to the reduction of the cost of transporting merchandise. In the present century, globalisation will be brought on by the dramatic falling communications (and computing) costs. This informatisation permits efficient, cheap communications networks and allows businesses to decentralise their production and distribution sites.

As we discussed earlier, in economic terms, globalisation numbers are even more revealing. In the last decade, not only has international trade grown twice as fast as the global product, but direct external investment has grown three time as fast as the latter. Almost all the economies of the world are now more open than ever, and, partly thanks to information technologies, an extremely vast global financial market has been created, which exchanges 1.3 trillion dollars a day. This sum can be moved instantaneously through the principle, interconnected financial markets, which not only draws in isolated economies, but makes them more vulnerable and quickly erodes their macroeconomic autonomy.

Of course, the world economy is far from being entirely "global"; despite everything we have seen, the main national economies are still far from trading close to 50% of their product. Many markets are not only not integrated, but they encounter growing (perhaps futile) obstacles to their integration, such as those related to labour. Protectionism and neo-mercantilism are still practiced in innumerable industrial segments and countries. The dollar, despite its importance, is not the "global" currency; it has even lost ground to the Yen and the strong Euro. Undoubtedly, however, if the tendencies that we have observed over the last 30 years continue, within a few more years we will have gotten much closer to a clearly globalised economy, where national economic units will have become less relevant than the way we still conceive of them today.

This is why information technologies will be the vehicle of a new wave of economic expansion and globalization that, like those that came before, will bring a mixture of costs and benefits. Many jobs will be eliminated, while others are sure to be created, although at an uneven pace and with different characteristics. Thus, it is necessary to outline what the intrinsic characteristics of information technologies are, and what is different about them.

First of all, it should be pointed out that the impact of information technologies will be more widespread and generalized than any other central component of past industrial revolutions: it will be applied not only to all sectors of the economy, but to all the different functions of businesses and economic agents in general, from design, production, marketing, control, administration, the buying process, etc. We will be witnesses to a generation of economies of scale in the presentation of products, employee training, marketing efforts and the providing of technical support, with lower costs and faster execution.

It is important, however, to differentiate between the two types of economic relations that, as a consequence of this vertiginous growth, will be affected differently. The first of these are "business to business" transactions and the second are "business to consumer" transactions. As of the moment, the use of digital technologies have had the greatest impact on the first type of relations and this tendency is expected to continue in the short and medium term. There are three basic reasons for this: the possibility of reducing the cost of transactions and improving the quality of final products by having greater control over the production process and all the providers involved, and due to the defensive reaction to greater competition from other businesses and the "coercive" power that many large businesses wield in order to force small and medium-sized providers to connect their productive processes through digital media.

In any event, it is foreseeable that the increased use of information technologies in "business to business" relations sooner or later leads to greater rates of penetration of these technologies in the population. This, in turn, also brings generalised usage within "business to consumer" relations.

On the other hand, unlike steam or electric energy, information technologies can be a reinvestment or final product. They will not only transform all sectors of the economy, but they will also create many other new sectors and products. It is foreseeable, for example, that the tertiary sector of the economy will be significantly transformed by the use of the Internet. Trade will be increasing affected by the economy and by its capacity to manage large amounts of information at a very low cost, which will create a closer relationship between buyers and sellers and strengthen consumer-oriented policies. Those merchants whose only strength is sales, not customer service, will tend to go out of business.

In the second place, the reduction of costs is much greater than at any other time in history, especially, as of the moment, of the information processing and computing power of chips or semiconductors. In real terms, their price has gone down by an estimated 30% per year since the 70s and its still falling rapidly. According to *The Economist*,[48] the processing power of a byte of information today costs 1% of one one-hundredth of what it cost in the 70s. A way of putting it is by using the now classic example: if automobiles had been developed at the same speed as semiconductors, they would now cost five dollars and would get 250,000 miles to the gallon of gasoline. An important fact is that never before has a significant industrial good gone down in price more quickly and more dramatically. This was not the case with steam, or electricity, or gasoline in their respective moments. This vertiginous drop in price has allowed for an enormous expansion in the market of products tied to information technologies, which reinforces the adoption of such technologies and makes innumerable new businesses viable.

Thirdly, the production of information technologies is much lighter and less polluting and their use of natural resources is much less intense than other technologies. In fact, one of its foundations, the byte of information, is only a computerized electrical impulse. Many of its goods are intangible and the fact that huge amounts of information are produced and made available to millions of users will allow for a reduction in congestion and the transport costs associated with the need to transport people (and bulky materials) to a single employment centre during the same hours.

[48] *The Economist*, September 28, 1996.

In the fourth place, it is a fact that information technologies, unlike steam and electricity, not only transmit data, but knowledge and technology as well, along other manifestations of the human spirit such as the visual arts, music, science, etc. More and more human knowledge can be codified –or digitalised—stored in computers or transmitted (and visually retrieved) in milliseconds at increasingly lower costs to any part of the planet: It seems as the construction of Jorge Luis Borges "*Aleph*".

Thus, information technologies will undoubtedly transform the economy and social organisation of the entire world. Their implications go beyond that which is immediately relevant from an economic point of view, that is, the dramatic reduction of transaction and communications costs which allows markets to operate more effectively. This reduction of costs will continue at least for the next thirty years which concern us. Prices will surely drop at an even faster rate as a result of three overlapping factors: the persistence of technological changes, the huge increase in the ability to transmit data due to the digitalisation of information and the use of fibre optics, and, most importantly, the increased competition to achieve the deregulation and liberalisation of telecommunications markets.

As we said above, some experts predict that the marginal cost of telecommunications will reach close to zero, making the distance an irrelevant cost-price factor. It will be equally "expensive" to talk on the telephone or send some type of data within the same city as to a city on the opposite side of the globe,[49] literally globalising the impact of the effects of this peculiar revolution of information technologies. The implications of this are only beginning to become evident.

Nevertheless, we should mitigate this optimism taking into account the particular conditions of a relatively less developed country such as Mexico, and especially to consider the threat represented by a growing "digital divide," defined as the imbalances or inequalities that stunt developing countries in terms of their access to the benefits of this great wave of technological applications. In other words, we should review what has

[49]Cambridge Strategic Management Group, *The Economist.*

already been said to determine whether Mexico meets the conditions that should be achieved in developing countries for the Internet and digital systems in general to become popular in such a way that they generate the changes previously mentioned and, above all, in the important ways and to the same degree as already described.

In the first place, two factors that limit the growth of the Internet in developing economies such Mexico's are income levels and the cost of the different requirements for hooking up to the web.[50] However, as was already mentioned, this factor will become less and less important over the next thirty years, since the cost of a byte, which can be used to manage data in the form of images, sounds and text, among other things, will continue to drop in the next few decades to such an extent that their accessibility will be less an economic problem than a generational one.

Secondly, the digital market will be vastly greater if the interface between people and their computers improves to the point that talking to the computer becomes as easy as talking to another person.[51] Although the development of the interface between man and computer stagnated for some time, there is at the moment a tendency to make this interaction more and more easy, through the convergence of a number of channels of communication, that is, with multimodal capability. This means that computers will become increasingly user-friendly, in such a way that even the generational barriers that currently block more generalised internet access will be gradually overcome over time.

In this respect, it is worth mentioning that the evolution of the demographic variables in Mexico City during the next thirty years will constitute an additional factor that will favour the popularisation of the use of the web and digital technologies in general. At the same time that the average age of the population will rise, it is also true that the large number of

[50]In its more simple form, these requirements include the cost of local telephone service, telecommunications taxes, the cost of accessing the web per minute and necessary hardware and software. In the case of productive companies, the installation and maintenance of a web site are also necessary, and in some cases, specialized assistance for the installation of an internal network which gives internet access to all members of the company.

[51]See N. Negroponte, *Being Digital*; R. Miller, *et. al., The Promises and Perils of 21st Century Technology: An Overview of the Issues. 21st Century Technologies.*

children who are currently perfectly familiar with the Internet will be joining the city's labour force over the next two decades.

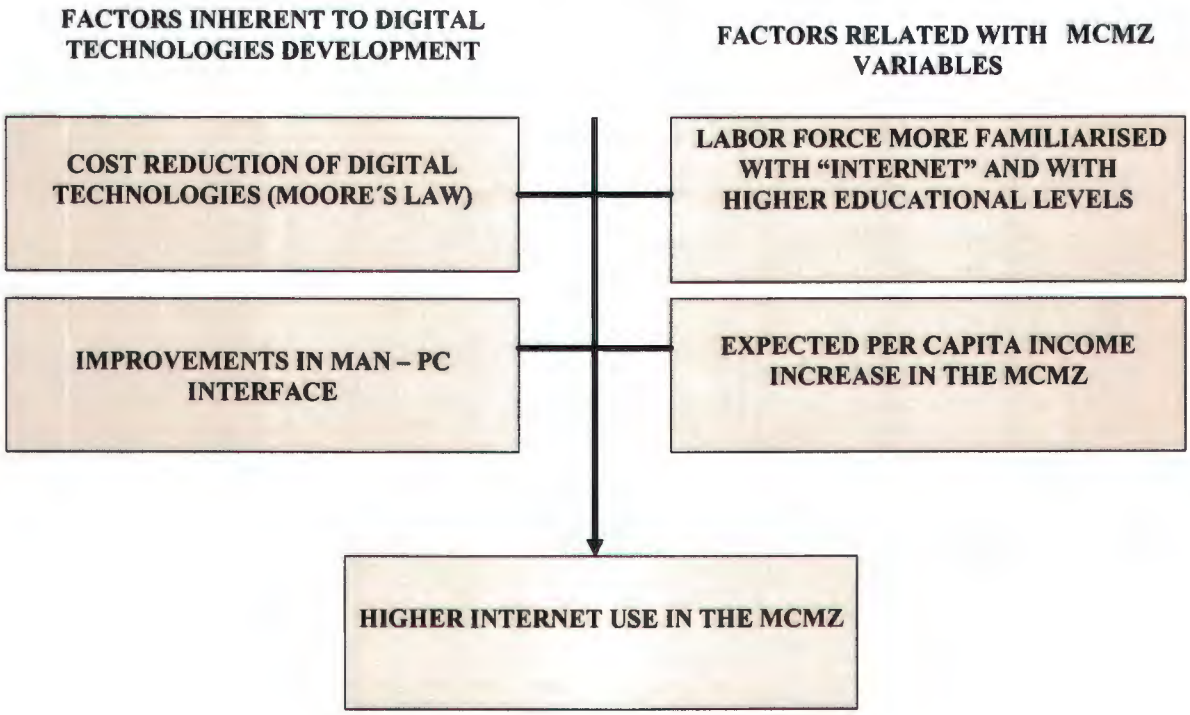
It is also important to mention that the average number of years of schooling is expected to increase amongst the metropolitan population, which will favour the more generalised use of digital technologies even more.

In economic terms, Mexico City is expected to continue to play a central role in the country's economy, although, unlike in past decades, it will now do so through economic activities with higher added-value such as specialized technical, financial and educational services, among others. This will imply an increase in Mexico City's per-capita income -- which is already much higher than in rest of the country—leading, in turn, to the greater economic resources necessary for the widespread use of digital technologies.

Thus, as is shown in Figure 5.3, during the next thirty years, there will be in play factors inherent in the technological progress in the area of digitalisation and factors related to the underlying dynamics of Mexico City itself which will favour intensive use of the Internet to carry out different economic activities. Other factors, which limit the growth of the Internet and whose elimination will depend on public intervention through adequate policies, have to do with confidence in terms of the relations between consumers, sellers, providers and manufacturers.

FIGURE 5.3

Factors that will Favour the Widespread Use of the Internet in the City



SOURCE: By the author.

5.2.4 Energy Transition

We now turn briefly to the future of energy –its sources, processing and distribution— because is also of major importance to the future of cities and urban form, since it is a central part of their "metabolism." As we mentioned previously in Chapter 4, it is not only a matter of the cost and thermal efficiency of energy sources, but the pollution and the risks that their residuals tend to have. Thus, the future of technologies and forms of energy will also be relevant to the MCMZ, which has excessively used fossil carbon energy (gasoline, combustible oil, mainly) which has been highly subsidised and has, without a doubt, contributed to the increase of automobile use and to the generation of grave amounts of

atmospheric pollution. On the other hand, the advantage of mild, relatively constant weather in the city, makes for few concerns about costly (and polluting) heating systems, which are virtually non existent.

With the direct implications for Mexico City in mind, we will now briefly review the future of different energy sources: fossil hydrocarbons, solar, biomass, nuclear and fusion-generated energy. Later on (6.1.7) we will undertake the task of measuring how sustainable Mexico City is and could eventually be, in terms of energy, through the construction of an indicator that takes into account issues to be analysed below.

First of all, the different energy sources should be understood as a continuum, where replacement of one source for another, with much possible overlapping, will happen gradually over time, depending on the relative prices of these sources[52]. Of course, with the prices of energy sources, not only should perceived eventual scarcity be taken into account (fossil hydrocarbons), but also their negative impact on the environment. We therefore adopt the vision that we are in the midst of a long "Energy Transition" from hydrocarbons towards new forms of renewable energy. Solar energy is one such form; the eventual use of nuclear fusion to cheaply produce huge quantities of non-polluting energy will be a revolutionary occurrence. As we will see later on, there is every indication that, in commercial and applied fields, this latter energy source will not come about for at least another 50 years or more. Fusion is the next technological threshold in energetics: it will probably not affect city life until as far away as the last couple of decades of the 21st century and it is not part of our analysis. In any event, it is relevant for us to anticipate and prepare for the transition in energetics, and not to express our "bet" on one type of energy or another.

Energy permeates all of human life and culture. Economic growth and human well-being depend to a large extent on the energy supply. By the year 2030, the demand for fuels will have grown by at least another 30%, while demand for electricity will expand by 270%. Thus, despite the increasingly efficient use of these resources, new forms of energy will

[52]A. Concheiro, *Alternativas Energéticas,* México, 1985.

continue to be necessary, especially when taking into account the problems related to pollution and climatic change, or rather, warming (the greenhouse effect and the growing and the thinning hole of the ozone layer).

Secondly, it is very important to distinguish between at least two alternate uses of energy: for electricity and non-moving artefacts, and for transport.

FOSSIL HYDROCARBONS (PETROLEUM) AND NON-RENEWABLE SOURCES

Fossil hydrocarbons are used for generating energy, as fuel for transport and for petrochemical materials (plastics, fibres). In Mexico's particular case, their availability is assured for at least the next 50 years. We will now look at how to encourage a transition in energetics that is orderly and privileges growing sustainability and clean air. We should be careful with relative costs and hidden subsidies for pollution and technological obsolescence.

SOLAR ENERGY

After many years of development, it seems that solar energy is about to take off, with more practical, more impacting applications. Its advantage is that it is a clean, non-polluting and virtually inexhaustible type of energy. Obviously, the primary source of this energy source, the sun, is virtually unlimited (when it runs out, life on earth will irremissibly end). According to Hoagland, "Every year, the earth receives more energy than the sum of all known reserves of carbon, petroleum, gas and uranium," that is, 15,000 times more than the world's annual need.

Solar energy is not just what we are able to trap and transform; it is also stored in biomass, wind and hydraulics (and, in fact, in hydrocarbons as well). Only nuclear and geothermic energy come from another source. For many years, the economic advantages of energy stored in carbon or petroleum made the development of solar energy unnecessary. Development was taken up in the 70s, with the so-called "Energy Crisis," only to be

abandoned with a renewed, prolonged drop in the price of petroleum. There is, however, renewed interest in solar energy --since petroleum will have to run out sooner or later—and there are currently very promising lines of investigation. These are, biomass; through the combustion of vegetal waste or materials, which produce combustible ethanol or methanol, the construction of wind-powered turbines and the use solar or photovoltaic cells to trap, store and finally distribute solar energy and solar heat motors. Surely no single energy source will predominate; a number of them have niches of applicability and usefulness. Together, they could be connected into a general energy grid network. The transition toward cleaner energy will be gradual in terms of the degree to which these types of energy are used in the context of all sources.

With the exception of biomass, the most promising uses of solar energy are those related to directly producing electricity for principally stationary use. The slow but sure reduction in the unitary cost of energy produced by photovoltaic cells indicate that those uses will eventually be profitable and competitive; for urban uses this is expected to happen by the early part of this century. Thus, for domestic uses such as heating water, exterior lighting and heating, the solar energy of photovoltaic cells will become competitive and its usage will increase in the near future. As we saw previously, solar energy could also be used in future in the application of energy cells so that –by using hydrogen to carry out photoelectrolysis —electrical energy will be produced for automobiles. In any event, Mexico City future energy policies (see 6.1.7 below) will be in tune with this broad scenario of energy gradual transition. This will have a direct bearing on its eventual overall sustainability.

5.3 The Challenge of Urban Environmental Sustainability

In his classic work *The City in History*,[53] the celebrated American urbanist, historian and philosopher Lewis Mumford reminds of how cities were created to protect their inhabitants from nature's threats. He also indicates, however, that by the end of the Renaissance, with technological progress and the excessive growth of cities, they become the main threat to

[53] Lewis Mumford, 1961.

nature instead. In our times, nature is very much at risk by the proliferation growth and voracity of cities.

In any event, a concern for the ecology and sustainability of cities is something very recent. It was perhaps in the 50s, when people were faced with London's lethal "smog," that the environmental conditions of cities began to be taken seriously into account. However, for almost two decades after that, the discourse on urban environmental conditions was dominated by a few conservationists, talking about fighting only the most egregious pollution. It was only until the 80s that the subject of sustainability began to come up in debates about urban ecology.

5.3.1 "The Urban Ecosystem" as a Metaphor for City's Environment

To consider cities to be ecosystems is an error in strict scientific terms, since they do not contain trophic chains (or the consumption pyramid of the biomass), nor is life organised around autotrophic beings (primary producers, responsible for photosynthesis), or heterotrophs (consumers and decomposers). In the best light, the concept of an "urban ecosystem" serves as good metaphor for city's environment, because it allows for a analogy between the "metabolism" of a city, in terms of input and residuals, and the operation of an ecosystem, and because it allows us to analyse a city from an entropic perspective, as we will see below.

On the other hand, to consider an ecosystem sustainable, four basic principles have to be observed.[54] First, all elements have to be recycled. Second, sunlight should be the basic source of energy. Third, the size of consumer populations should remain stable to avoid depredation of the ecosystem. Finally, the fourth principle dictates that for an ecosystem to be sustainable, its biodiversity should be kept intact. As is easy to observe, no city, however "sustainable" it may be, can become a "sustainable ecosystem."

[54] B. J. Nebel & R. T. Wright, Environmental Science, *The Way the World Woks*. Sixth Edition. New Jersey: Prentice Hall, 1998.

We will now look briefly at the evolution of the concept of an "urban ecosystem" and examine its analytic and predictive capacity, as well why the construction of quantitative indicators of urban environmental sustainability allows us to approach and resolve the problem of the sustainability of cities.

It is evident that urban ecology is not what was proposed by the University of Chicago's influential school of urbanism, which used the term for other reasons, more to refer to "human ecology." Its theory of urban economy (income) and urban dynamics based on concentric rings is still very useful, although it is too schematic to capture all the complexity of urban dynamics, especially when it comes to the environment. Similarly, it has nothing to do with the subjects of environmental hygiene and urban health, although these are useful and are, in fact, related to the Chicago theory.

Of greater relevance is the pioneering study on Hong Kong published in 1981 for the "Man and the Biosphere" (MAB) program. Australian researchers analysed the city's complex interrelations, both biotic and non-biotic, as well as social and cultural.[55]

Eugene P. Odum[56] defines a city as a partially heterotrophic ecosystem that depends on areas for obtaining external supply of the energy and materials needed to sustain urban life. The city, furthermore, requires much larger input of energy per unit of area (currently, this is especially true of fossil fuels). But this analogy goes only so far, since the biological processes of natural heterotrophic communities differ greatly from exchanges between cities and nature. However, his calculations on the energetic requirements of a "type" city are useful for estimating the enormous need cities have for external input and energy. Perhaps by only including the total occupation of territories that should "nourish" the city, we could talk about "urban ecosystems." But as we have said this is not possible since today's cities require input not only from surrounding areas, but from far-away places as well. Other authors who think the city can be considered an ecosystem are Abel Wolman[57]

[55] Boyden, 1981.
[56] Eugene P. Odum, 1983.
[57] Wolman 1965.

and Ian Douglas.[58] Wolman describes the principle forms of input and output of the urban "metabolic" system –water, energy and food and their respective residuals. But Douglas goes farther, describing elegant geomorphic, biogeographic, climate and energy models from which he generates a metabolic analogy (inputs and outputs).

But perhaps the most finished model of a city as an "ecosystem" is the one we owe to James Trefil.[59] He argues that cities are natural systems, and are therefore subject to the same cycles as natural ecosystems. The author establishes for the city the concept of energy flows (a concept that is now common in current models of urban ecology) and the cycles of materials; he also talks about "environmental niches" and the succession of these in the city. From there, he makes his most interesting contribution: the centre of the urban ecosystem is the entirely-constructed city, with its huge consumption of energy and materials. But as we move away from the centre, the urban ecosystem begins to respond more to the natural environment that surrounds it than to the metropolis.

All these authors expand knowledge about the city as an open system, with a great deal of interaction with the environment. However, in our opinion, their models are still metaphors for the "applied ecosystem" concept that only describes conceptually the urban reality; they do not explain much and have a low predictive and normative capacity.[60] They are models of artificial ecosystems where, unlike natural ecosystems, they are not autarkic and they do not recycle, since they expel pollutants and residuals to their exterior.

The vision of the city as an entropic phenomenon, which is favoured by a number of authors,[61] furthers the understanding of the dynamics of the city. It requires that cities be understood as "open" and "dissipative systems," capable of importing a great deal of material and energy, with negative entropy. That is, they import much more energy than they export. In fact, cities are true "islands of heat." The city as a system should be subject

[58] Douglas 1983.
[59] J. Trefil,A Scientist in the City. New York: Anchor Books, 1994.
[60] E. Ezcurra, El Ecosistema Urbano, *La Ciudad de México en el fin del segundo milenio,* G. Garza, coord.., México: Gobierno del Distrito Federal, El Colegio de México, 2001 pp. 447-453.
[61] V.Bettini, *Elementos de Ecología Urbana.* Madrid: Editorial Trotta, Colección Estructuras y Procesos, Serie Medio Ambiente, 1998.

to dynamic feedback processes (positive and negative) between its dynamic vectors in order to be able to regulate itself. This entropic vision does not contradict the essential aspects of the urban metabolism vision.

But we can conclude that the city is not a closed system and that the parameters of its sustainability are still unresolved. To the contrary, the city is by definition a highly complex open system that exchanges energy, materials and information with the external system. We might be able to understand and know about the city and its more general conditions, but not each and every one of its interactions with each of its components. Perhaps cities will never be understood with models of linear behaviour.

Based on the futility of wanting to extrapolate the metaphor of "urban ecosystems" from the normative field (since these are neither self-regulated nor autarkic), an interesting concept comes to light that in some way serves as a bridge between the concepts of "urban ecosystem" and "urban sustainability." We are referring to the "ecological foot print" that derives from accepting the fact that cities are incapable of producing what they need for urban life. Cities import huge amounts of energy, water and raw materials; this is transformed (economic added-value is affixed) and partially restored in the form of residuals and emissions. The area or "ecological footprint" needed by a large city has been calculated to be about 100 times the area of the city itself.[62] This would seem to vary little from the old models of "urban metabolism," but the basic difference is the capacity to measure many more variables with much greater precision and to have them refer them to specific areas. The measurement of the environmental footprint is the productive area that is needed to withstand a city with certain levels of consumption. In this sense, it is the inversely symmetric concept to "carrying capacity," which measures the maximum number of individuals of a species that a certain area can withstand. Rees proposes five categories: eating and other types of consumption, housing, transport and services in general. At the same time, this is related to different types of soil –the conversion allows for visualization of a certain productive area necessary for sustaining a determinate use or consumption of resources.

[62] Rees, 1992.

So, if we want to sustain a certain level of consumption in a determinate city, we can quantify its ecological footprint: thus, with a smaller ecological footprint, there would be a better the utilisation of space, which indicates greater sustainability in time. As can be seen, the theoretic-empiric progress with respect to concepts of urban ecosystems still leaves much to be desired, although there have been interesting advances in the last two decades.[63] The metaphor of the urban ecosystem still has a series of restrictions; nonetheless, it helps to understand the complex ecological dynamics of cities, and, increasingly, to measure the dimensions of and impact on its territory and nature. This is why indicators of "environmental sustainability" are important --they bring us closer to the possibility of measuring and understanding whether or not a city is beginning to minimize its external consumption of materials and energy: its level of negative entropy[64].

We will now look at the concept of urban sustainability in more detail in order to justify and explain the quantitative indicators of environmental sustainability in the Mexico City metropolitan zone which we designed.

5.3.2 The Concept of Environmental Sustainability in the Urban Context

The problem of "environmental sustainability" in general is that it is still too vague and general a concept, one which lacks a precise meaning and is difficult to validate empirically. It is often misused as a rhetoric phrase, or it serves as a catch-all term, meaning everything and nothing at once. There are some who talk about social, political, economic and even cultural sustainability, and thus the term loses all its real meaning.

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[63] Lynch, 1981.

[64] The universe is made up of matter and energy; while the first is defined by having mass and occupying space (as much as it has weight in the presence of gravity), energy is the capacity of the movement of matter and not the occupation of space, nor does it have a specific mass. Two powerful laws of physics explain the behaviour of energy: they are the laws of Thermodynamics: the first law states that energy does create or destroy only transforms itself into another form; the second law states that during the process of transformation from one form into another, energy losses energy in the form of heat and this heat can only become colder. This second law is known as "Entropy" and states that there is growing disorder of whatever "system" (including a city) that has spontaneity toward greater entropy. This, in whatever finite system can be counteracted with external energy input. But in the universe, as it is everything, entropy cannot be counteracted.

We assume a closer, more pragmatic position, basing our argument on the almost universally adopted definition of sustainability in the "Brundtland Report,"[65] which deals with the conservation of natural capital for future generations; we will look at this report forthwith. We can therefore define, with as little ambiguity as possible, the seven indicators of sustainability that we have designed for the Mexico City metropolitan zone, which we believe will be relevant not only from a theoretical point of view, but also for their practicality, inclusiveness and empirical manipulability, which will make the indicators powerful enough to truly allow us to observe whether the metropolitan area is able to transition towards true measurable environmental improvement (sustainability).

The indicators of sustainability that we designed are accompanied by a diagnostic of the biggest environmental problems facing Mexico City's metropolitan zone and each one of theme is complemented by suggestions for urban public policy measures. This precisely will determine the difficult road of reform that should be taken in order to improve levels of sustainability on key environmental matters such as water supply, green areas, air pollution, housing, transport and traffic control, and energy consumption patterns.

THE CONCEPT OF "SUSTAINABLE DEVELOPMENT" AND ITS EMPIRICAL PROBLEMS

As we stated above, the concept of "sustainable development" is as appealing as it is elusive. This is why it is important to strip it of unnecessary adjectives. We think that the concept of sustainability should be linked to the categories of natural or environmental capital (the stock of natural resources and biodiversity) in a determinate biome and its maintenance over the long-term; in our case, this would be Mexico City's metropolitan zone, or, more broadly considered, the Mexico Basin as we described it in sections 2.1 and 2.2 of this thesis. The "natural capital" to which we refer is not necessarily something static, but instead can be replenished and even increased. It is intimately embedded in ecosystems and the "urban metabolism" process, as we described it previously. Thus, a necessary condition for rigorously defining environmental sustainability will be for it refer

[65] *Brundtland Report,* 1987.

to the stability or increase over time of our stock of environmental capital; that is, this stock should not be depleted beyond its regenerative capacity. At the same time, this is based on two important principles of intergenerational or inter-temporal justice. The first is basic: to maintain for future generations at least the same stock of natural or environmental capital for its use and enjoyment. The second often has to do with making certain public goods or environmental services available to a broader group of people. To the economic concept of substitutability of capital, it can be added that natural environments should continue working as a single entity, so as not to jeopardize on the margin the entire habitat, biome or ecosystem in question. It is clear that all this, despite its conceptual value, presents serious empirical challenges and difficulties for measurement. However, we are only establishing general principles at this point.

As indicated, we will adopt the definition of sustainable development that is most accepted worldwide, since, despite its elegant simplicity, it observes the stated principles upon which we will comment the following:

"Sustainable development is that which satisfies present needs, without endangering the capacity of future generations to satisfy their own needs."[66]

In terms of environmental capital, this imposes limits on the types of "consumption" of such capital and speaks of the need to take steps to bring about its replenishment. It is clear that this definition, the most precise and elegant amongst dozens of others, has led to a great deal of debate between environmentalists and economists on how to make their precepts operative and measurable. On one hand, the term "need" is overly vague, considering that needs change over time and no one knows what real needs will exist in the future in light of the profound social and technological changes we are currently experiencing. Another problem is how to translate needs into real demands to which a price or opportunity cost can be assigned. With this concept, however, there is clearly an interest in intergenerational justice over time. In terms of environmental matters, it is basically

[66] *Brundtland Report...*, p. 8.

clear: correct or slow down the grave deterioration of natural resources, the degradation of the landscape, pollution and the generalised waste of energy and other goods.

This is why we should be cautious with indicators of environmental sustainability in the urban context, which we will discuss later on. All the indicators are, *lato sensu*, based on the definition of sustainability adopted in this paper. The idea behind it is to maintain and increase the environmental capital of cities, as we described previously and as we will define in more detail later on. We can state here that the concept of reducing or minimising the "ecological footprint" of Mexico City's (MCMZ) is evidently in harmony with the definition of sustainability that we have adopted.

The matter of environmental sustainability in cities is becoming fashionable, although in reality it is a very new concept that still lacks rigorous study; the literature on the subject is already quite robust, although very reiterative. The pioneering studies of M. J. Breheny, Peter Nijkamp and Cedric Pugh,[67] who establish an interesting connection between the sustainability of cities and common access goods, have been followed by a number of other works on the subject, such as those by K. Williams, A. Blowers, D. Satterthwaite, G. Haughton and C. Hunter.[68] However, despite all this, it continues to be a new paradigm in search of content. We saw previously that the concept of an urban ecosystem in all its varieties still does not constitute a mature theory capable of valid empirical predictions. It deals with, for example, incorporating into its analysis the conventional theory of environmental economy (externalities, pigouvian taxes, etc.), as well as the basic principles of the dynamics of ecosystems, as we saw above. Furthermore, the crucial interface between energy and the environment has yet to be thoroughly considered.

Based on this vision of sustainability, indicators can be constructed that are empirical representations of reality (not reality itself), which link or translate the abstract

[67] M .J. Breheny, *Sustainable Development and Urban Form 2*, European research in regional science, London: Series editor P. W. J. Batey, 1992, 292 p.; Peter Nijkamp, 1994 y Cedric Pugh, 1996.
[68] K. Williams, Burton, E. & Jenks, M. 2000. *Achieving Sustainable Urban Form*. Oxford, U.K.: Oxford Brookes University; A. Blowers (ed). *Planning for a sustainable environment. A report by the Town and Country Planning Association*. Reprinted. London: Earthscan Publications, 1995; G. Haughton & C. Hunter, *Sustainable Cities*, London and Bristol, Pennsylvania: Regional Studies Association, London, Regional Policy and Development Series 7, 1996, 357 p.

conceptualisations that we have been undertaking into concrete empirical categories that reflect the present situation and the rate and direction of change. To build the indicators of environmental sustainability that we have developed, many other indicators have been examined, such as those used in the pioneering work of "Sustainable Seattle", as well as other examples for cities in advanced countries. The idea was to have indicators that could recover the principle attributes of the urban "metabolism" or the concept of "urban ecosystem," but that would be applicable and could be measured, and, above all, compared with other indicators. This is why we have based our work on the indicators developed by the OCDE,[69] which are powerful, but at the same time are simple and relatively easy to quantify. They include indicators of energy, which have important implications for the urban environment. Of course, the OCDE's model of indicators was adapted to our conceptual concerns as outlined and above all, to the reality of the Mexico City metropolitan area. Particular care was taken to assure that the indicators were consistently "translated" into a certain model of urban form that was also applicable to the realities of the Mexico City megalopolis.

[69] *OCDE*, 1997.

CHAPTER 6

ENVIRONMENTAL SUSTAINABILITY: INDICATORS FOR THE MCMZ

6.1 Environmental Sustainability: Indicators and Policy Measures

Although in a developing stage that makes for many limitations, the use of indicators represents an opportunity to complement the theoretic-analytic framework provided by the concept of an urban ecosystem, principally because this conjunction expedites the monitoring of the key variables in matters of sustainability, as well as the objective analysis of corresponding policies.

Among its limitations, it is worth mentioning that the proposed focus is of "weak sustainability," since it does not consider inherent financial restrictions on the proposed political measures.[1] In this sense, a more detailed economic and social evaluation needs to be carried out, something beyond the reach of this work.
On the other hand, in order to gain a long-term vision of the problems of sustainability that Mexico City could face and of their possible solutions, different variables are analysed during a thirty-year time frame. It is important to recognise the possibility that the best time frame for carrying out corresponding analysis may differ from variable to variable. For example, the relevant time frame for analysing problems related to the "water" variable might be much shorter than that of the "green areas" variable, and so on.

When discussing a term as broad as "sustainability," the objectivity of analysis and proposed solutions is a function of the time frame and starting point or base year which are

[1]Regarding the difference between "weak sustainability" and "strong sustainability," see Bell, *Sustainability Indicators*, 2000.

chosen. Depending on the period of time which is used, almost anything can be demonstrated. Thus, although there is no differentiation between variables, it makes sense from a historic point of view to use 1990 as the starting point for the present paper since the late 80s marks the change in the role Mexico City played with respect to national development, a redirection with direct implications in terms of environmental and urban sustainability.

Another subject related to the use of indicators of sustainability is the definition of the "quality of a system." Although the term "sustainability" is limited to the use of natural resources and the environment, the matter of "people's quality of life" is always implicit. Thus, the order of importance assigned to the different variables depends on such highly subjective things as the perception the people and policy makers who deal with the different problems of sustainability.[2]

At the same time, one should not lose sight of Daly's analytic scheme,[3] which proposes that "the three most basic aggregate measures of sustainable development are the sufficiency with which ultimate ends are realized for all people, the efficiency with which ultimate means are translated into ultimate ends, and the sustainability of use of ultimate means".[4] Implicit in this idea is not only the term natural capital, but human capital and social capital as well.

This is why a "global indicator of sustainability" has been constructed that is a direct function of the existing gap between the analysed situation and the threshold of sustainability defined for each of the seven variables being considered must be considered as an analytical tool, rather than a prescriptive policy recommendation. Thus the indicator offers the possibility of assigning different weights, and thus allows for the evaluation of the results in terms of sustainability, under different orders of importance, as a function, of course, of human capital, social capital and access to financial resources.

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[2]S. Bell & S. Morse *Sustainability Indicators. Measuring the Immeasurable*, Reprinted. London: Earthscan Publications, 2000, 175 p.
[3] D. Meadows, Indicators and Information Systems for Sustainable Development, *in* D. Sattethwaite, *Sustainable Cities,* 1999, pp. 366 – 368.
[4]D. Meadows, *Sustainable Cities...*, pp. 364 – 385.

On the other hand, among the advantages of these indicators, it is worth mentioning that they make it easier to introduce market mechanisms in the tendencies of behaviour and the responses to different relative price policies. At the same time, like other premises of sustainability, with the indicators that are presented the imbalances between supply and demand become vital for understanding a resource's degree of sustainability. The basic principles are to determine the supply of the resource in question, to ascertain whether it is renewable or non-renewable, and then to establish the demand that allows for the utilisation of the resource without jeopardizing its use by future generations and without making technological capabilities necessary for repairing damages.

Using these basic principles, sustainability thresholds have been established which allow for the clear definition of the boundary beyond which a series of policies or conjunctural situations have led to sustainability with respect to a certain resource in Mexico City's metropolitan area. These thresholds are simply defined and in most cases refer to the existence of imbalances between supply and demand. However, according to Quadri:[5]

> "From a perspective of sustainability, it is necessary that these resources are managed in such a way that they do not systematically go beyond certain critical thresholds, after which excessive social/environmental costs are generated. In this sense, the thresholds do not necessarily represent absolute limits of social/environmental costs, but instead represent significant jumps or inflection points, given a certain level in the existing technology. The idea of thresholds can be based on empirical observations, scientific or technological data, daily experience or even subjective preferences, which reveal the existence of physical, functional, ecological or social limitations on the expansion of certain urban processes under the existing conditions. Taking on thresholds means facing limits and scarcity, which implies interpreting common environmental resources as economic goods (...).

[5]G. Quadri, Políticas ambientales para una ciudad sustentable, *Comercio Exterior,* Vol. 45 Num. 10 1995, pp. 756 - 765.

In any event, the use of this focus permits the linking of variables of sustainability with market dynamics, since it is in perfect harmony with the Daly's "three basic rules of sustainability":[6]

- Renewable resources should not be used more quickly than the rate at which they are regenerated.
- Non-renewable resources should not be used faster than the pace at which renewable substitutes can take their place.
- Pollution and residuals should not be produced more quickly than they can be absorbed by natural systems, or, than they can be recycled or managed without damages.

Finally, although there is a great number of possible indicators that could be constructed to describe the processes of environmental sustainability, our focus consists of the use of "fundamental variables" that have an indicative character and a sort of Pareto point of view, which permits the understanding of 80% of the phenomenon with 20% of the variables.

As it was obvious from the above section 4.7, there are seven key variables being proposed for the sustainability indicators, in the order in which they are presented and analysed, are the following:

1. Water Resources (Lakes and the Overall Hydraulic Model)
2. Green Areas and Urban Land Use
3. Roads and Transport
4. Atmospheric Pollution
5. Management of Solid Wastes
6. Housing Supply
7. Energy Transition

As it can be clearly seen, they consider the main ingredients of the Basin Ecosystem on the environmental set up of MCMZ. Let us now see each one with greater detail.

[6]D. Meadows, *Sustainable Cities...*, pp. 364 – 385.

6.1.1 Water Resources (Lakes and Overall Hydraulic Model)

In contrast with the traditional approach of attending to the "grey agenda" for water, which only focuses on the increase of drinking water and drainage supply, the concept of "natural capital" previously discussed, must be incorporated. And finally, from a long-term perspective, it is important to live from the "flow" generated by that capital, not from the capital.

The basic elements that shape the flows generated by that natural capital in the case of water are: make use of rain water, groundwater extraction and finally, water reuse through discharge treatment. At this point it is important to bear in mind the basic lacustrine origin of the closed or endohreic basin of Mexico, described in the 2nd Chapter above. In this sense, according to Daly's principles [7] an "educated" hydraulic model in terms of environmental sustainability must obey the following principles:

- Use of surface water to diminish groundwater exploitation.
- Groundwater extraction that does not exceed the recharge rate (aquifer recharge or injection)[8]
- Water imports from outside sources must not substitute reuse possibilities within a basin.

DEFINITION OF WATER SUSTAINABILITY INDEX[9]

Based on the described principles, "water balance" is the key variable to determine just how sustainable is the use of this resource in Mexico City. Thus, the corresponding rate must base itself on the measure of existent unbalances between supply and demand for water.[10]

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[7]D. Meadows, *Sustainable Cities*.
[8]It is important to point out the difference between concepts. "Recharge" is a natural process directly related to soil permeability, on the other hand, "injection" is a high cost process induced by men through artificial jeans.
[9]Througout this section (6.1.1) the terms "index" and "rate" is used as "indicator"

Water supply was determined, based on the total availability that may be generated in that same zone (springs, dams, treatment and reuse, aquifers' recharge and subterranean extraction) plus the volume imported from external sources such as the Lerma's basin and the Cutzmala River.

On the other hand, water demand was determined by taking in consideration the cubic meters per second, or the litres per inhabitant that will be demanded due to population dynamics, industry, trade and Mexico City's growth of services.

With these considerations the following rate was constructed:

Water Sustainability Rate = 100 *(WSt)/(WDt)

Whereas

WS_t = Total water supply in year "t". It is conformed by the possibilities of water reuse in the city, the extraction of aquifers (including importation from external sources: Cutzmala's basin and the Lerma river, among others), dams and springs in year "t".

WD_t = Total water demand in year "t". It is derived from the domestic, service and trade, and industry sectors in year "t". With regards to the agricultural sector's consumption, as mentioned in the past chapter it is important to point out that most of it is attended with residual water, in the watering districts of the states of Mexico and Hidalgo, in the outskirts of Mexico City so that it is reflected in the existing trade off due to a less amount of water that can be reused in the interior of The Mexico basin.

About the devised rate it is important to point out the following aspects.

[10]This focus allows analysing the water problem through a long – term horizon, taking into account several economic, social, politic and environmental factors that affect the demand and supply of the resource. These considerations have been made in other cities of the world in which sustainability indicators development have been applied, as the case of Toronto. See, for example *Urban Sustainability*, www.geocities.com/RainForest

- From a "water balance" (supply = demand) scenario, that is from a rate value of 100, less availability of water from external sources makes the rate fall under a value of 100 and therefore leads to a "non-sustainable" scenario. For example, if a great quantity of residual water is assigned to water district irrigation in Hidalgo, this represents an additional obstacle for a sustainability scenario for the City and vice versa if a greater quantity of reused water is assigned to Mexico City.

- From a "water balance" (supply = demand) scenario, that is from a rate value of 100, the increase in per capita water consumption, makes the rate to take on a lower value than 100, leading to a "non sustainable" situation. The best example is the trend from previous years; greater *per* capita consumption has diminished the capacity to supply Mexico City making it a difficult task and obliging authorities to consider unsustainable measures, such as the importation of water from external sources (Cutzamala second phase).

- From a "water balance" (supply = demand) scenario, that is from a rate value of 100, an increase in the possibilities of water reuse or aquifers recharge, allows the rate to rise above 100, thus, leading to a more sustainable situation. The increase of green areas, soil restoration or the use of permeable pavement in urban zones, are measures that could increase the index value, but this idea will be thoroughly explained in the next sections.

Presently, the consumption in Mexico City is 360 lts. a day per inhabitant.[11] Nevertheless, this number includes domestic, industrial and trade and services intake; the distribution among these rubrics is 67%, 17%, and 16% respectively. Thus, to obtain the intake per inhabitant which corresponds to the domestic rubric only, the intake per industrial unity and the intake per commercial and/or services establishments it is necessary to:

1) Obtain the total of water intake: 360 multiplied by the total population of Mexico City.

[11] *Estadística del Medio Ambiente del Distrito Federal y Zona Metropolitana 1999*, México: Secretaría del Medio Ambiente. INEGI.

2) Deduce the total volume of each consumption type, according to the proportions mentioned above.

3) Divide each of the total volumes obtained by the number of inhabitants, the number of industrial establishments, or the number of service establishments, depending on the case.

TABLE 6.1
Water Demand in Mexico City, 1999

		WATER CONSUMPTION (millions of liters)				ECONOMIC UNITS		UNITARY CONSUMPTION (Mill. of liters)			
POPULATION	Per Capita consumption (daily liters)	TOTAL	Domiciliary	INDUSTRIAL	SERVICES AND TRADE	INDUSTRY	SERVICES AND TRADE	PER CAPITA (DOMICILIARY)	UD. INDUSTRIAL	UD. SERV AND TRADE	Total Water Demand (millions of cubic meters)
17,992,314	360	2,364,190	1,584,007	401,912	378,270	48,394	290,868	0.088	8	1	2,364

SOURCE: Own elaboration, based on *Estadística del Medio Ambiente del Distrito Federal y Zona Metropolitana 1999*

To fulfil the water demand projections, the hypothesis described in the previous chapter concerning population growth and the number of economic units in the industrial and services sectors was utilized.

On the other hand, consumption units were maintained constant in the year 2030 projections; nevertheless it is necessary to point out that this would imply not taking any measures whatsoever to control water demand consumption of 360 litres per person which is reduced to 350 in the year 2030. This is mainly due to the assumption that the growth in the number of economic units (industrial and services) it similar to that of the population.

TREND SCENARIO: WATER SUPPLY

[12]*Estadística del Medio Ambiente del Distrito Federal y Zona Metropolitana 1999*, México: Secretaría del Medio Ambiente, Instituto Nacional de Estadística Geografía e Informática, 231 p.

Supply is defined by water availability and its growth capacity toward the year 2030. It was assumed that average precipitation in the conservation zones that conform the principal recharge area of the Basin of Mexico's aquifer, remains at an average of 1200 annual mm., equal to 773 million cubic meters, and that the recharge rate in relation to this number continues being too low, so that changes in infiltration capacity are marginal.[13] In geographical terms, this would be directly linked to an unmeasured and anarchical increase of the urban trend, with no measure addressed to the ordered consolidation of urban sub-centres, especially in zones with the most important recharge areas, located at the south, southeast and east of the City.

According to these assumptions, the exploitation of aquifers at the present rate would imply a deficit close to 1000 million cubic meters per year, which is considered physically impossible and implies that in the next 10 years the extraction shall have to be reduced to no more than what is annually recharged (based on one of the principles stated by Daly)[14] that is, no more than 170 million cubic meters a year, by the year 2030. As a consequence, if soil restoration works are not made on the high parts of the basin and no green areas are restored to increase the water recharge in the following decades, a supply/demand unbalance, and therefore the sustainability level in water use in Mexico shall be drastically reduced.

With regard to the water importation from the Lerma River and the Cutzmala basin, it is assumed that in the next three decades, water extraction in the first case cannot increase beyond its present levels, of 150 million cubic meters,[15] and in the second case it is assumed that the old and overall erroneous overall hydraulic model keeps on going, therefore the next phases of the Cutzmala are constructed, thus 20 million cubic meters are obtained, in addition to the 305 million cubic meters that are presently extracted.[16]

[13] One of the most pessimist scenarios of the National Water Commission (CNA) considers the possibility of increasing such recharge, trough soil restoration works, in 1 m^3/ second. *Estadística del Medio Ambiente del Distrito Federal y Zona Metropolitana 1999...* 231 p.
[14]D. Meadows, *Sustainable Cities.*
[15]D. Meadows, *Sustainable Cities.*
[16]SEMARNAT, México, 2000.

Unfortunately, if previous hydraulic programmes from the National Water Commission (CNA) are closely studied, the trend still points toward that same direction.

On the other hand, it is assumed that Lake Texcoco's restoration project continues to be incipient in this scenario, that is, with a limited capacity to contribute to the recharge of aquifers and water reuse in Mexico City that restrains itself to the approximate number of 35 million m3. Thus it is considered overall, water reuse in the city rises to 194 million m3 and remains constant in a 30 year horizon.

It is important to point out that there is an initiative on behalf of diverse organisms in charge of regulating water supply to implement a series of measures set out to improve the institutional framework, achieve integral restoration of the Mexico Basin and to finalize several hydraulic infrastructure projects[17]. Nevertheless, these initiatives were not taken into account at this point of the work, because they are still outside the hydraulic program of the National Water Commission, so that it can be considered as part of a possible policy scenario for the future.

TREND SCENARIO: WATER BALANCE

Beginning from the previously described assumptions, the result from a comparison between water supply and toward observing the year 2030, is a drastic and growing unbalance that progressively reduces the value of the sustainability rate, constructed for this variable. (Graph 6.2)

SUSTAINABILITY THRESHOLD

It is considered that the sustainability threshold presents itself when supply (conformed by all the previously described sources) equals demand, considering the three principles

[17] Martínez Baca, Atlas, 1987, pp. 262-263.

presented by Daly.[18] This means that Mexico City will be sustainable in terms of water use, as long as supply is not lesser than demand (rate > =100) and will not be sustainable in the contrary (rate < =100).

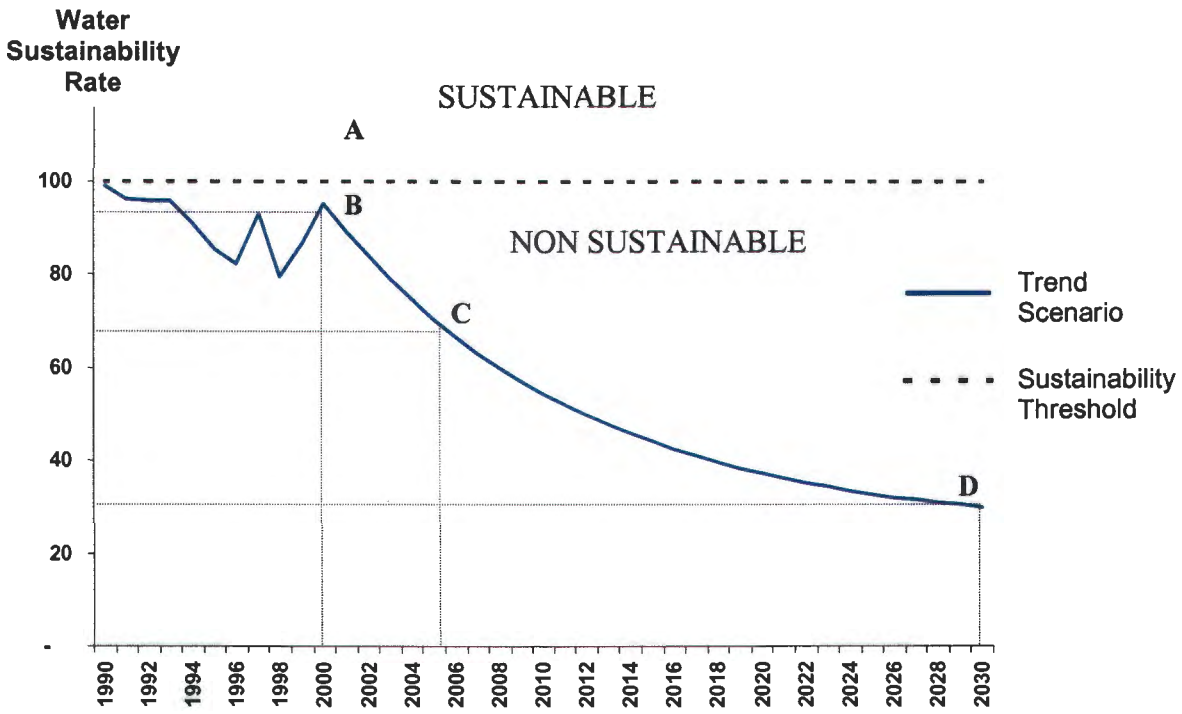
Graph 6.1 illustrates the different concepts developed for the analysis of water. At point "A" water supply exceeds demand, which implies a sustainable situation (or apparent sustainability, if the principles of Daly are not respected). In contrast, point "B" is representative of the present problem, derived from a water supply deficit. The change between "B" and "C" and "C" and "D", are a direct consequence of the mentioned deficit trend that will continue on the 30-year horizon.

Whereas it is true that in 1990, departed from a point that might be categorized as "sustainable", this is only so in appearance, for the development of the rate in the following years suggests the matter as qualitative which would involve the nature of water supply sources at a given point of time, in this case the aquifers shoot down, results crucial to the rate's future evolution. That is, the fact that the city presents a sustainable scenario at a given period in time does not mean it is maintainable in the long run.

[18] D. Meadows, *Sustainable Cities.*

GRAPH 6.1

Water in Mexico City:
Sustainability Threshold Vs Trend Scenario



SOURCE: Own elaboration, based on the sustainability indicator constructed for the "water balance" variable.

Table 6.2 displays the different categories necessary to calculate water sustainability rates for several time periods. The pronounced reduction in the rate's value, illustrated in Graph 6.1, is due to the stagnant water supply, in comparison to demand growth in a 30 year period. Whereas supply reaches up to 1.130 million cubic meters, demand reaches to 2.980 million cubic meters, toward the year 2030.

TABLE 6.2
Trend Scenario: Water Sustainability Indicator
(Millions of m^3)

	Total Acuquifer Extraction (Mexico Valley + Lerma + Cutzamala + Flowings	Recycle or Water Treatment	Supply (Total Extraction + Reuse)	House Cons.	Industrial Cons.	Trade and Services Cons.	TOTAL DEMAND	TREND INDEX (SUPPLY/ DEMAND)
2000	2,136	195	2,331	1,541,605	419,076	394,424	2,455,105	95
2005	1,676	195	1,871	1,741,749	425,409	400,385	2,567,543	73
2010	1,369	195	1,564	1,849,002	431,844	406,441	2,635,288	58
2015	1,169	195	1,364	1,923,841	437,356	411,629	2,772,325	49
2020	1,043	195	1,238	2,002,793	442,942	416,887	2,852,521	43
2025	971	195	1,165	2,053,620	447,762	421,423	2,932,304	40
2030	935	195	1,130	2,100,998	452,637	426,011	2,976,645	38

SOURCE: Own elaboration based on constructed sustainability indicator.

NEW HYDRAULIC MODEL: POLICY SCENARIOS

The challenge consists in implementing policies that encourage a balance between supply and demand, without applying non-sustainable measures, such as aquifer exploitation beyond its recharge capacity and without projects that imply a high social and financial cost such as obtaining hydraulic resources through external sources.

Policies measures that will contribute toward this new vision can be divided in two large categories: supply improvement and demand administration. In the first case it is of vital importance to increase the water reuse and aquifer recharge rates. In the second case, through orthodox market mechanisms (but including some social protection schemes) and heterodox programs such as installation of eco - technologies, the improvement of the measurement system and a decline in per capita consumption in Mexico City should be favoured.

It is important to stress that the elements that make-up the new hydraulic model, are in line with policies that have been applied at an international level to induce a more efficient and sustainable water use. For example in Waterloo, Ontario Canada a 10% consumption reduction per capita was achieved through a higher price policy, citizen's education campaigns and the use of saving – water devices to economize the use of this resource. In 1986, in San Jose, California, a similar policy was implemented and with the support from

90% of the households, a consumption reduction of between 10% and 17% was achieved. Also, water saving in industry has allowed economizing up to 5.5 million cubic meters annually.[19]

On the other hand, since 1987, the metropolitan area of Boston, U.S when demand growth began to surpass the system's natural recharge, an energetic water conservation campaign was taken on, saving water devices were installed in 100 thousand homes, leaks in old pipelines were corrected and an extensive informational campaign was carried out in schools and industries. As a result to this effort, annual demand fell from 462 million cubic meters in 1987 to 386 million in 1991, a 16% reduction. Presently, water use in this urban area is beneath the natural recharge level.[20]

Installation of Water Saving Devices in Existent Dwellings.- An important lesson can be drawn from the analysis of different international experiences, this is, the effectiveness of installing water- saving devices in city housings. Thus, the reason for analyzing this policy measure in first instance, through the water balance indicator.

According to a SEMARNAP Survey, (1999) domestic water use in the city is divided as: toilet evacuation, 40%; shower, 30%; dish washing, 6%.

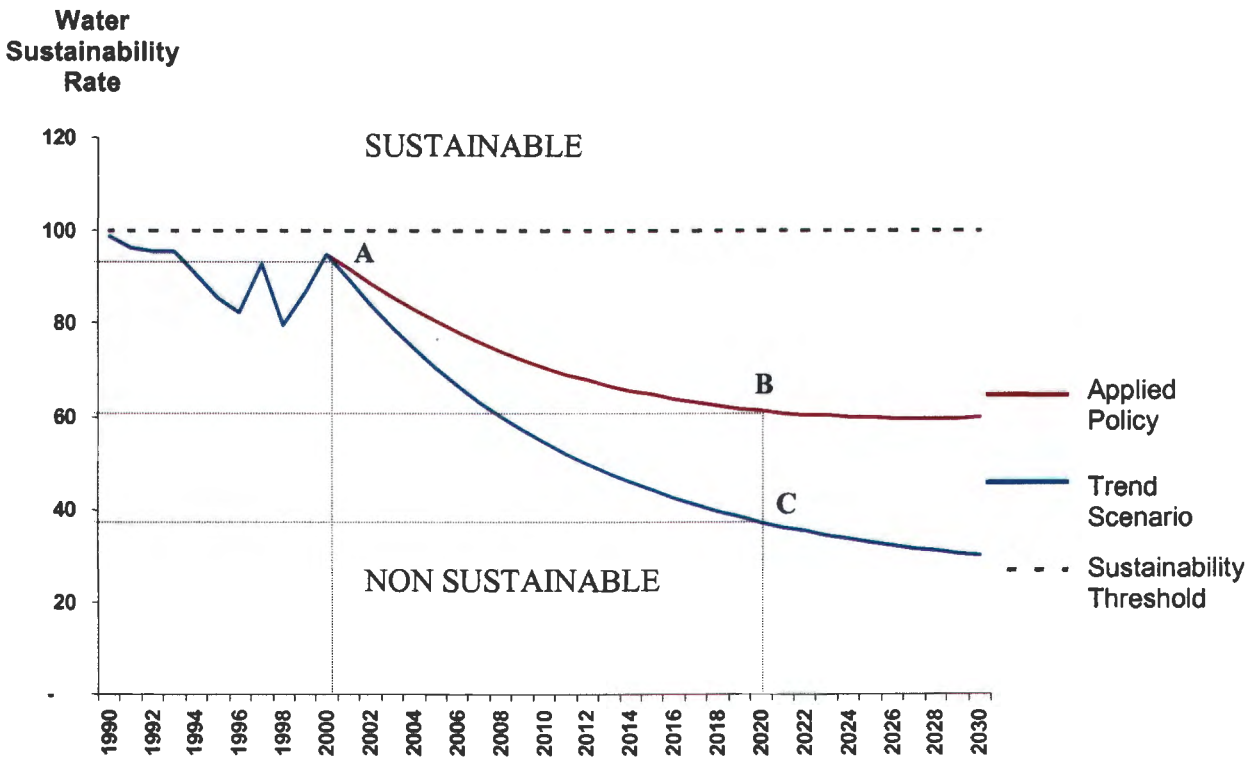
As it may be appreciated, the categories of toilet use and shower use represent together 70% of domestic consumption. Thus, assuming the compulsory use of water saving devices,[21] such as 6 litre toilets, so that a reduction in the water use in toilet evacuations and showers by a 50% can be reached in at least 50% of houses within the city,[22] then

[19] *Entering the 21st. Century, World Development Report 1999/2000,* U.S.A: Oxford University press, Published for the World Bank, 2000, 300 p.
[20] *Entering the 21st. Century, World Development Report 1999/2000...,* 300 p.
[21] The importance of a policy of this nature is stated in the Program for Development in the Federal District, 1995-2000 and the details can be seen in A. Deffis, *Vivienda Social. Conjuntos Habitacionales Autosuficientes*, México: 2000.
[22] This percentage is rather conservative if it is observed that some authors such as A. Deffis, Armando, *Vivienda Social. Conjuntos Habitacionales Autosuficientes*, point out the possibility of reaching up to 60% or 74%, depending on the device that is used.

consumption per dwelling unity would be reduced from 85,000 annual litres to just 74,250 in only six years.

Graph 6.2 displays changes in sustainability rates, as a consequence of the installation water saving accessories in toilets. Point "A" represents the situation in the starting year. Point "C" is the point where, following this trend, we would arrive in the year 2020, and the difference in respect to point "B", the effect of the proposed policy. In this case, a 65% reduction in the gap would be achieved.

GRAPH 6.2
Use of Water Saving Devices in Existing Dwellings: Effect on the Water Sustainability Rate



SOURCE: Own elaboration, based on constructed sustainability rates.

Table 6.3 shows the quantification of the different concepts used to construct the sustainability rate that was illustrated in Graph 6.2. The 62% reduction in the gap is due exclusively to a lower level of domestic water consumption in "C" compared to "B". The total savings are 1,500 million cubic meters in the year 2030.

TABLE 6.3
Water Sustainability Indicator:
Installing Water Saving Devices in Existing Dwellings

	Total Aquifer Extraction (Mexico Valley + Lerma + Cutzamala + Flowings)	Recycle or Water Treatment	Supply (Total Extraction + Reuse)	House Cons.	Industrial Cons.	Trade and Services Cons.	TOTAL DEMAND	TREND INDEX (SUPPLY/ DEMAND)
2000	2,136	195	2,331	1,596,629	419,076	394,424	2,410,126	97
2005	1,676	195	1,871	1,381,263	425,409	400,385	2,207,056	85
2010	1,369	195	1,564	1,194,949	431,844	406,441	2,033,234	77
2015	1,169	195	1,364	1,014,313	437,356	411,629	1,863,298	73
2020	1,043	195	1,238	860,984	442,942	416,887	1,720,813	72
2025	971	195	1,165	723,344	447,762	421,423	1,592,528	73
2030	935	195	1,130	600,478	452,637	426,011	1,479,126	76

SOURCE: Own elaboration based on constructed sustainability rates.

Impact of Housing Provision that Integrate "eco - technologies".- It is important to point out that the previously proposed policy focuses on the installation of water saving devices in existing homes. Nevertheless, housing availability with eco - technologies,[23] could mean an important change in the water sustainability rate. In Mexico City, this is of vital importance, especially when taking into account that one of the institutional priorities for the up coming years -from the Federal Government and the Federal District Government- is an aggressive program for the construction of social interest housing.

This is how we confront the juncture between the option of incorporating environmental criteria in several housing projects and the alternative of developing such projects without any environmental considerations, not only for water management, but for other issues that will be discussed later -such as green areas, soil and energy use- that could represent a real urban disaster for Mexico City.

[23]See A. Deffis, Armando, *Vivienda Social. Conjuntos Habitacionales Autosuficientes.*

Among the projects that can be included as part of the construction of multifamily dwelling groups, it is relevant to emphasize the following: waste-water treatment plants, fluvial re - infiltration system, reuse of grey water, among others.

Other "eco - technologies" that are not considered in the installation of water-saving devices and that could have a significant impact on housing availability, are the so-called "dry tank toilets", that make use of a soapy washbasin water for discharges. A mechanism of this nature could mean saving of up to 50% of the total water consumption in households.[24]

Globally, the addition of all these "eco - technologies" to newly constructed housing in the city in the upcoming years, could mean savings of up to 60% of water that the new housing groups would normally consume.

Tariff System Adaptations.- With the tariff structure displayed in the previous chapter, the following income with regard to water in 1996 and 1997 was obtained:

TABLE 6.4
Water Tariff Collection, 1996 and 1997

	1996	1997
Thousand of current pesos	5,729,296	6,584,297
Total water consumption	2,376,827	2,486,162

SOURCE: Estadísticas del Medio Ambiente del Distrito Federal y Zona Metropolitana, México, 1999. Own estimates about total water consumption.

[24]See A. Deffis, Armando, *Vivienda Social. Conjuntos Habitacionales Autosuficientes.*

Based on this data, it is possible to obtain an approximation of the price - elasticity of water demand- with the purpose of being able to subsequently evaluate the effects of a policy set out to increase the tariffs corresponding to Mexico City.

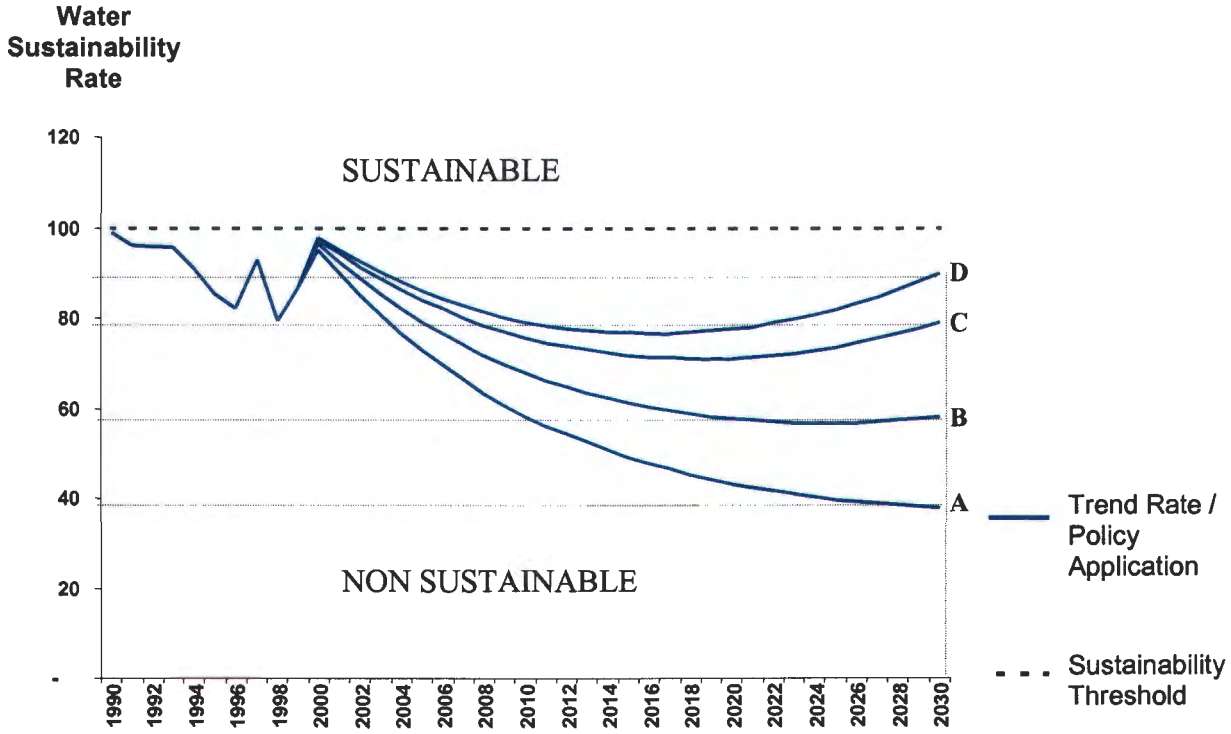
Tariff data for 1996 and 1997 were obtained. In 1997, these were changed to real pesos when adjusted by an inflation of 20%. With this adjustment, it turns out that tariffs decreased in real terms between 1996 and 1997, and in a similar way, water consumption per inhabitant (includes domestic, industrial and services composing elements) was increased by a 4.6%. As a result, it was estimated that the elasticity -price for water demand- is approximately -0.548, that is, that for every percentage point prices are raised, consumption decrease 0.548%

Finally, with the displayed results in terms of price - elasticity of water consumption and with the purpose of analyzing the effect on the sustainability indicator, a policy exercise was made, in which water prices raised in various percentages.[25]

Graph 6.4 displays the effects of raising water tariffs in different magnitudes. Point "A" represents the situation in the year 2030. Point "B" could be possible with a real increase of 50% in prices (1.36% annually). Point "C" with 100% (2.34% annually) and final point "D" with 125% (2.74%).

[25]About the need of a more intensive use of marketing mechanisms, see Seralgedin, *Water Supply, Sanitation, and Environmental Sustainability. The Financing Challenge*, Washington, D.C.: World Bank, August, 1995; WMO, Water. Assessing a precious resource, No. 801, Ginebra, Suiza: 1994, pp. ; El *Programa para el Desarrollo del Distrito Federal, 1995 - 2000....*, 80 p.

GRAPH 6.3
Water Consumption and Increase in Mexico City: Effect on the Water Sustainability Indicator



SOURCE: Own elaboration base on constructed sustainability rates.

Table 6.5 displays the quantification of different rubrics used for obtaining the results illustrated in Graph 6.3 with greater detail. As it may be appreciated, this is a policy designed to inhibit water demand in its various uses: domestic, industrial and in commerce and services. In comparison to the trend scenario (point "A") a real 50% increase in prices (point "B"), signifies an annual reduction of 1.796 million cube meters in water demand, a 100% increase (point "C") would bring a reduction of 1.955 million cube meters, and finally, a 125% increase would imply a 2,008 million cube meters decrease (point "D").

TABLE 6.5
Water Sustainability Rate Indicator: Price Scenarios

50% Real Increase in Prices

	Total Aquifer Extraction (Mexico Valley + Lerma + Cutzamala + Flowings)	Recycle or Water Treatment	Supply (Total Extraction + Reuse)	House Cons.	Industrial Cons.	Trade and Services Cons.	TOTAL DEMAND	TREND INDEX (SUPPLY/ DEMAND)
2000	2,136	195	2,331	1,619,268	413,373	398,057	2,421,698	96
2005	1,676	195	1,871	1,604,297	391,837	368,788	2,364,923	79
2010	1,369	195	1,564	1,589,466	371,429	349,580	2,310,474	68
2015	1,169	195	1,364	1,545,138	351,263	330,601	2,227,002	61
2020	1,043	195	1,238	1,502,046	332,196	312,655	2,146,897	58
2025	971	195	1,165	1.445,195	313,576	295,131	2,053,902	57
2030	935	195	1,130	1,373,952	296,003	278,591	1,948,546	58

Source: Own elaboration, based on constructed sustainability rates.

A 100% Real Increase in Prices

	Total Aquifer Extraction (Mexico Valley + Lerma + Cutzamala + Flowings)	Recycle or Water Treatment	Supply (Total Extraction + Reuse)	House Cons.	Industrial Cons.	Trade and Services Cons.	TOTAL DEMAND	TREND INDEX (SUPPLY/ DEMAND)
2000	2,136	195	2,331	1,603	409	385	2,398	97
2005	1,611	195	1,806	1,387	369	347	2,104	86
2010	1,261	195	1,456	1,200	333	313	1,846	79
2015	1,028	195	1,222	1,019	300	282	1,600	76
2020	872	195	1,067	865	270	254	1,388	77
2025	768	195	963	726	242	228	1,196	80
2030	698	195	893	603	217	205	1,025	87

A 125% Real Increase in Prices

	Total Aquifer Extraction (Mexico Valley + Lemma + Catamaran + Flowing)	Recycle or Water Treatment	Supply (Total Extraction + Reuse)	House Cons.	Industrial Cons.	Trade and Services Cons.	TOTAL DEMAND	TREND INDEX (SUPPLY/ DEMAND)
2000	2,136	195	2,331	1,597	408	384	2,388	98
2005	1,611	195	1,806	1,381	360	339	2,080	87
2010	1,261	195	1,456	1,195	318	299	1,812	80
2015	1,028	195	1,222	1,014	280	264	1,559	78
2020	872	195	1,067	861	247	233	1,341	80
2025	768	195	963	723	217	205	1,145	84
2030	698	195	893	600	191	180	972	92

SOURCE: Own elaboration based on constructed sustainability indicators.

It shall not be forgotten that these types of measures are very unpopular, especially in middle – income countries, such as Mexico. It is not possible to ignore the drastic inequities associated with income distribution, therefore, it must be stressed that the success of this strategy depends, in great measure, of three fundamental components:

- Social protection schemes
- To be implemented in progressive form, that is, through a scheme of increases distributed in the long run
- An integral strategy aimed at diminishing water leaks, since this problem makes it hard to implement adequate water fees

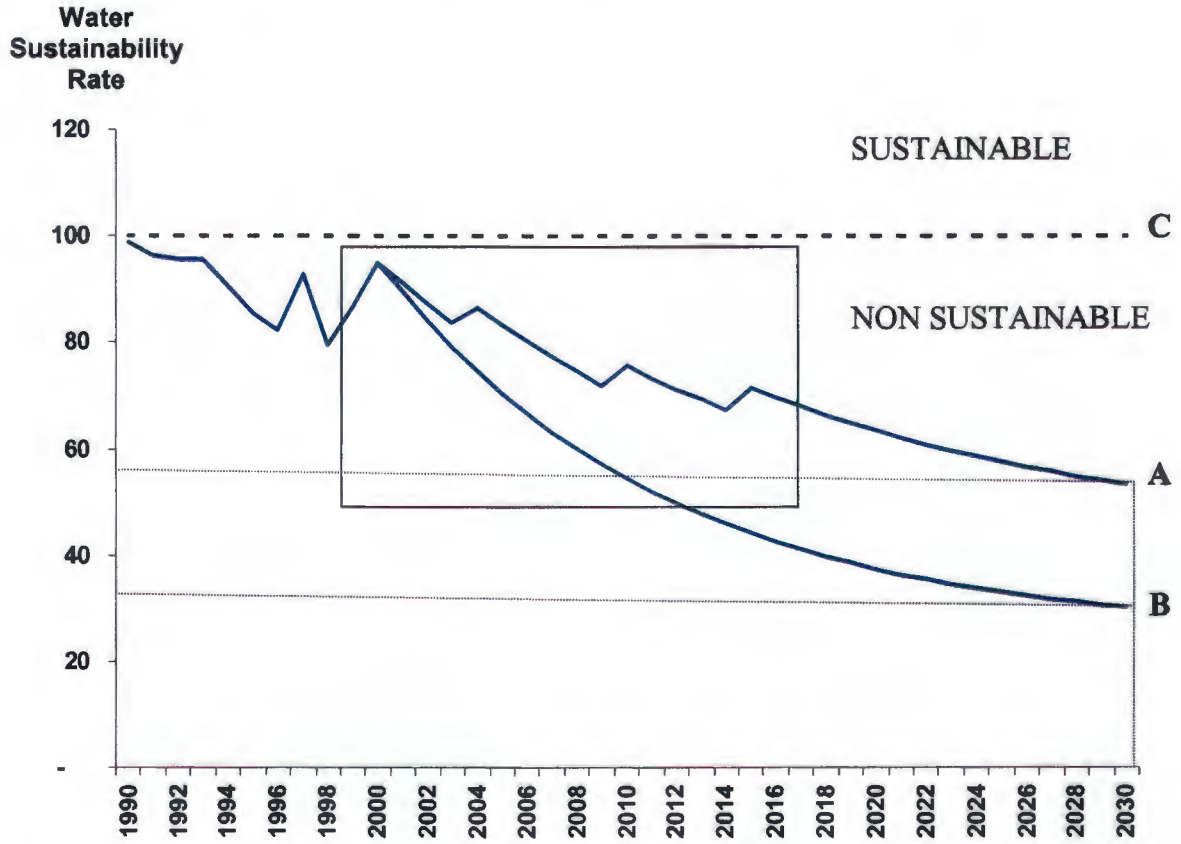
TEXCOCO LAKE ECOLOGICAL RESTORATION

The environmental restoration of the Texcoco Lake and its nearby zone is fundamental for the new urban model and the objective we want to reach by 2030 and which will be further explained in Chapter 7. The relevance of this project lies in its contribution to hydraulic regulations, water supply, ecological ordainment and environmental regeneration needs. Such as restoring the original flora and fauna of the lacustrine basin of Mexico as discussed in section 2.3.3 and 2.3.3 above.

On the other hand, if in the following 30 years Texcoco Lake Restoration,[26] is completed, so that the project reaches its maximum contribution in terms of water reuse and recharge in the Mexico Valley aquifer, the trend scenario would be importantly modified. It is estimated that Lake Texcoco could contribute 200 million cube meters in terms of water reuse. Altogether, these increases in water supply equal a displacement of the water sustainability indicator, from B to C.

[26] About the importance of the lake, see statemts by Luiselli and Perla en Lara (2000).

GRAPH 6.4
Derived Effect from the Texcoco Lake Full Restoration

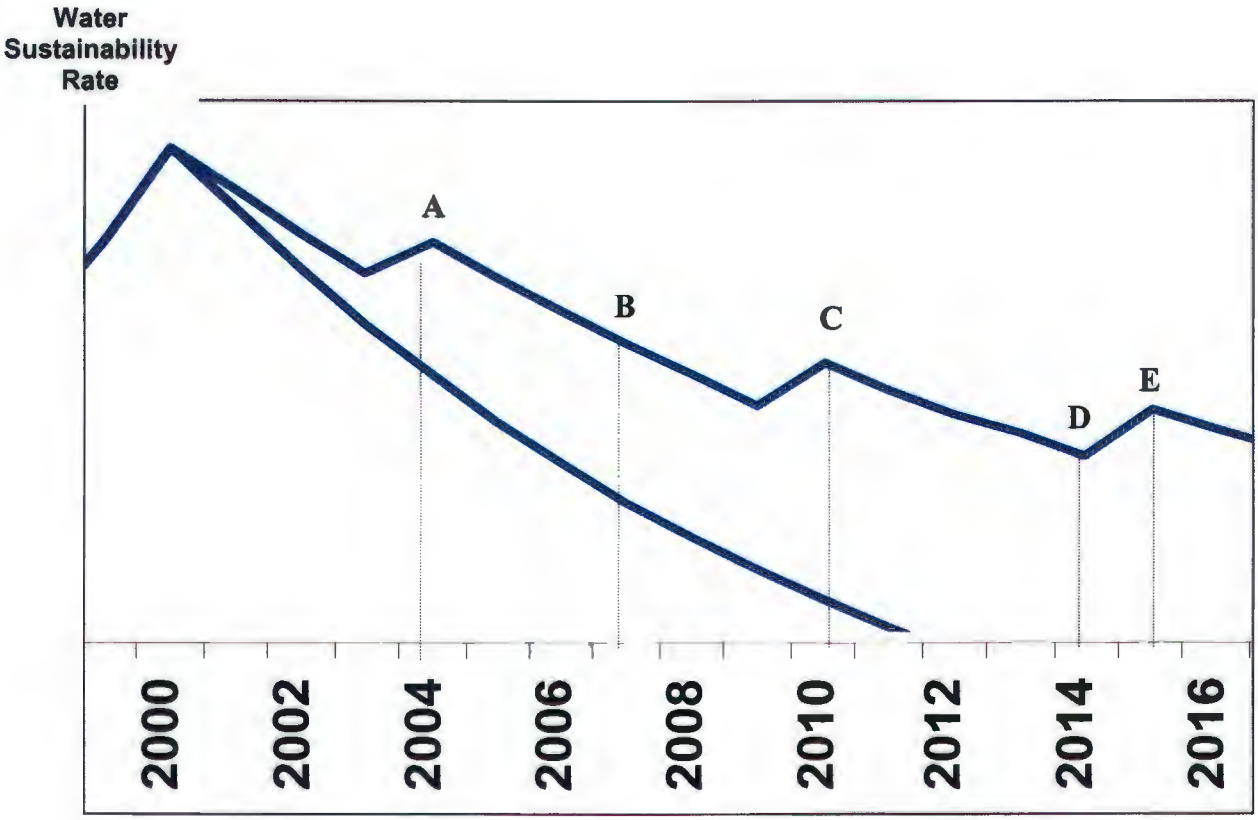


SOURCE: Own elaboration based on constructed sustainability indicators.

Upon the execution time of Lake Texcoco's project,[27] as can be seen on Table 6.6, it is important to point out the following assumptions: the increase in capacity of water reuse is given in three stages, in 2001 (163 million cubic meters, point A), 2010 (327 million cubic meters, point C) and 2015 (491 million cubic meters, point E) Also, reforestation, of which increase in the aquifers level depends, is given in three stages, in 2007 (point B), in 2014 (point D) and in 2021.

[27]C. Luiselli, & J. C. Domínguez, *Aspectos Económicos del Rescate del Lago de Texcoco*, México: Mimeo. Futura, 2000.

GRAPH 6.5
Details on Texcoco Lake Restoration Stages



SOURCE: Own elaboration based on constructed sustainability indicators.

Table 6.6 displays the data related to the water sustainability indicator in detail. As it can be appreciated, Texcoco Lake recovery's effect in comparison to the trend scenario is an increase in water supply. As a consequence of more water reuse, in 2005 there exists an additional 200 million cube meters a year, and this number increase to 491 in 2030. On the other hand, an increase of the recharge aquifers, would allow an increase in annual extraction of up to 898 million cubic meters in comparison to 698 in the trend scenario.

TABLE 6.6
Water Sustainability Indicator:
Lake Texcoco's Recovery

	Total Aquifer Extraction (Mexico Valley + Lerma + Cutzamala + Flowings	Recycle or Water Treatment	Supply (Total Extraction + Reuse)	House Cons.	Industrial Cons.	Trade and Services Cons.	TOTAL DEMAND	TREND INDEX (SUPPLY/ DEMAND)
2000	2,136	195	2,331	1,642	419	394	2,455	95
2005	1,780	359	2,138	1,742	425	400	2,568	83
2010	1,504	522	2,026	1,848	432	406	2,686	75
2015	1,291	686	1,997	1,934	437	412	2,773	71
2020	1,125	686	1,812	2,003	443	417	2,863	63
2025	997	686	1,684	2,064	448	421	2,933	57
2030	898	686	1,585	2,101	453	426	2,980	53

SOURCE: Own elaboration based on constructed sustainability indicators.

The New Airport and the Rescue of Green and Water Zones in the Texcoco Area.- Finally, it is worth mentioning that the decision to locate the New Mexico City International Airport (NAICM) in Texcoco, far from appearances and unfounded assumptions, is convenient for the zone's environmental development.

- It is true that any airport installation has inherent and inevitable environmental impacts (as will further be seen in chapter 6) however, in the case of Texcoco, the airport represents outnumbered advantages that compensate all possible environmental impacts:

- With the potential to become the biggest airport in Latin America and in a "hub" that could possibly compete with American airports like Los Angeles, Miami or Houston as we will see on Chapter 7, it represents an important factor for investment attraction, many of which can be allocated to the consolidation of hydraulic works and environmental rescue

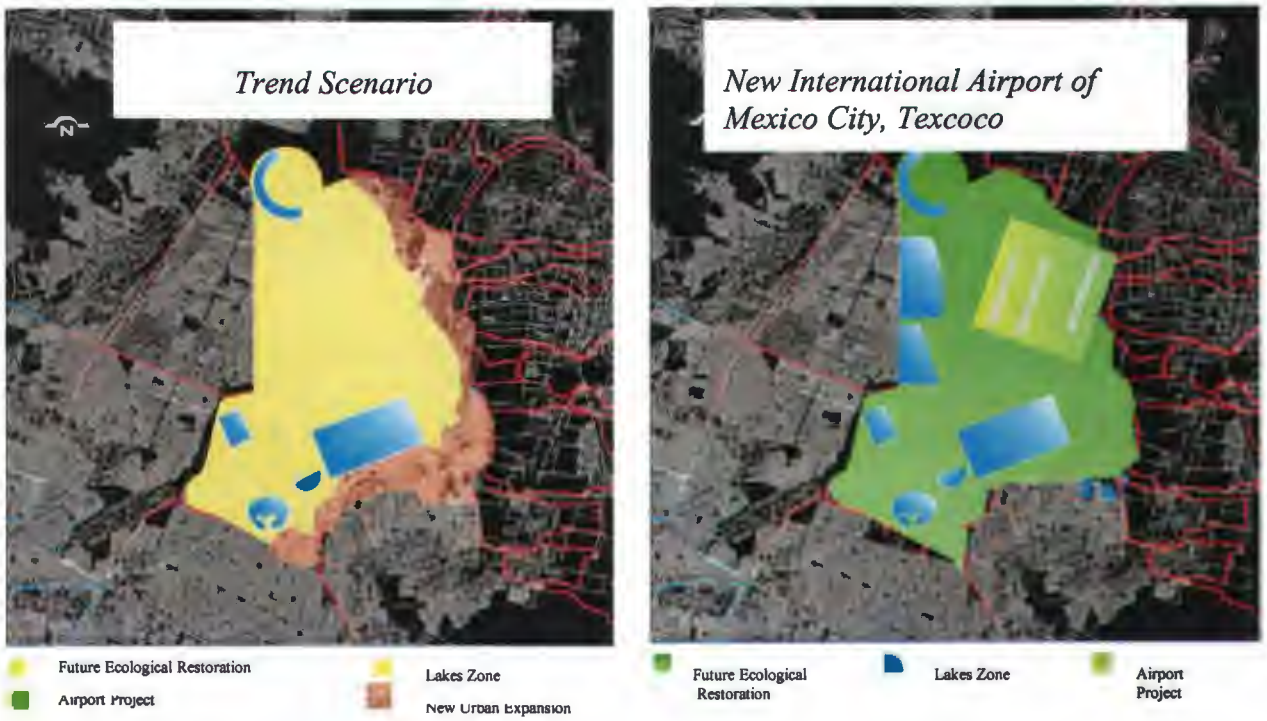
- Its hydraulic infrastructure is not only perfectly compatible, but complements the needed infrastructure to regulate the flows of eleven eastern rivers, in such a way that the basic elements of this infrastructure can be linked to treatment plants, soil restoration projects, etc.

- It represents a barrier for the proliferation of irregular housing (squatting), in a zone characterised by its larger demographic growth compared to the remaining areas of the City.

- The compensation scheme plans the creation of a green belt surrounding the airport, this includes soil restoration, bird management and reforestation activities, among others.

FIGURE 6.1

Urban Growth Scenarios of the Eastern Part of the Mexico Basin



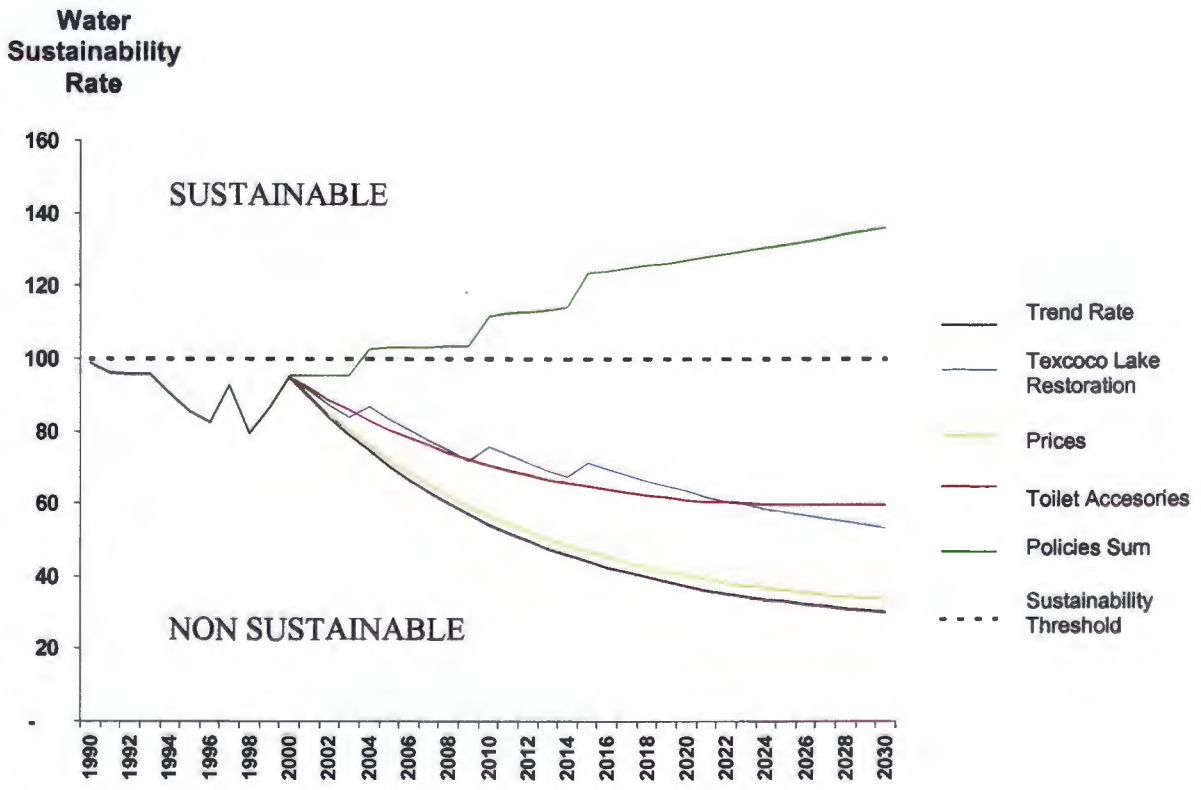
SOURCE: Own elaboration.

- Since it substitutes the existing International Airport (AICM), the territorial reserve which it now occupies will be reused for environmental and urban purposes. This reserve embraces an area near 800 hectares, therefore, it will be the most ambitious project ever designed for urban renovation for Mexico City. An adequate management of this enormous area implies the inclusion of two basic principles: high value added activities and the lowest environmental impact. Some examples include universities and research centres, green areas and recreation spaces, marshes, bird reserves, etc. It is important to stress that it will be built in the poorer area of the city. It also will be linked to the "green corridors".

THE SUM OF WATER BALANCE RELATED POLICIES

Thus, if it so that the increase in water price is politically unpopular, the combination of different measures set on to achieve a sustainability scenario, such as the obligatory introduction of devices that reduce water waste in toilets and Lake Texcoco's restoration, allow the need of increase in prices to reduce substantially. Thus, the implementation of a group of policies related to different topics on the subject of water and in different stages, allows the drastic achievement and surpassing the defined sustainability threshold.

GRAPH 6.6
Policy Proposals Combined:
Effect on the Water Sustainability Indicator



SOURCE: Own elaboration based on constructed sustainability indicators.

TABLE 6.7
Water Sustainability Rate, in Different Policy Scenarios

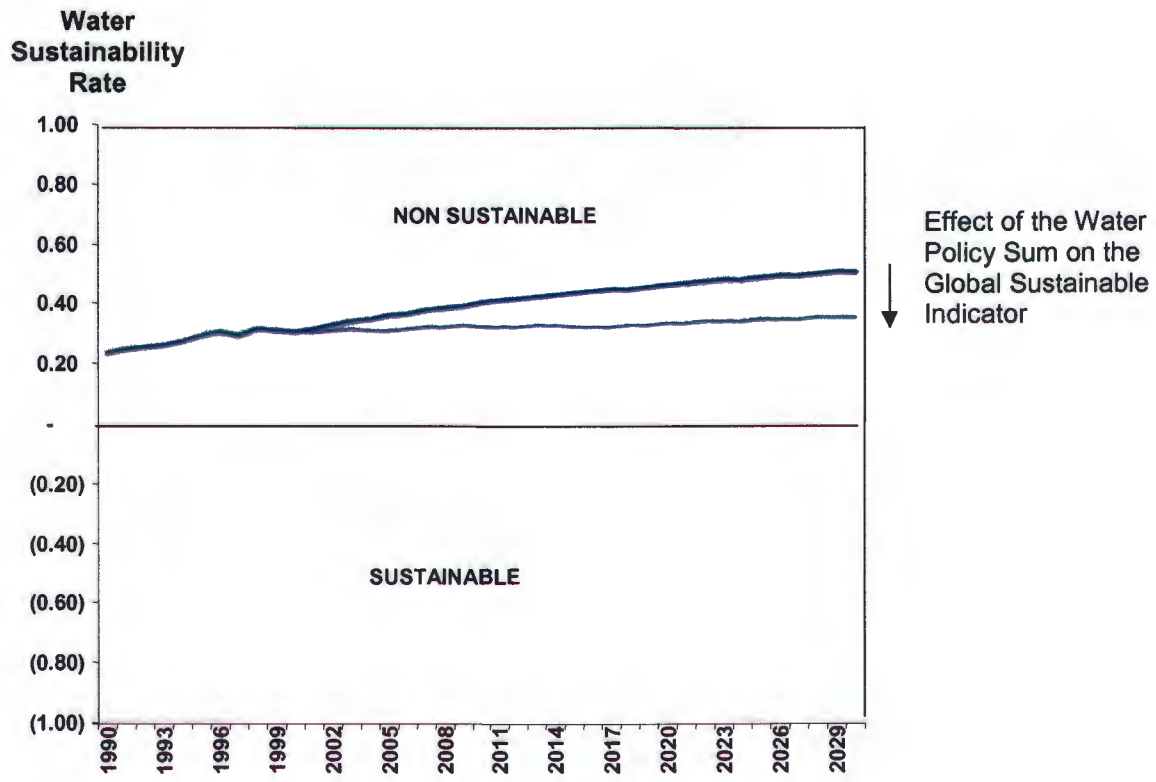
	Trend	Toillets	Lake Texcoco Recupeartion	Prices	Sum of Policies
1999	86.70	86.70	86.70	86.70	86.70
2000	94.94	94.94	94.94	95.24	95.24
2001	89.15	91.60	90.92	89.72	95.27
2002	83.83	88.50	87.11	84.64	95.30
2003	78.95	85.60	83.52	79.96	95.33
2004	74.46	82.91	86.56	75.66	102.58
2005	70.34	80.42	83.29	71.70	102.74
2006	66.56	78.10	80.19	68.06	102.90
2007	63.07	75.95	77.25	64.70	103.07
2008	59.87	73.97	74.47	61.61	103.23
2009	56.92	72.13	71.83	58.76	103.39
2010	54.20	70.45	75.44	56.14	111.61
2011	51.84	69.06	73.22	53.86	112.19
2012	49.66	67.79	71.11	51.77	112.76
2013	47.66	66.63	69.10	49.83	113.34
2014	45.80	65.57	67.20	48.04	113.91
2015	44.09	64.61	71.29	46.39	123.35
2016	42.50	63.75	69.53	44.87	124.08
2017	41.04	62.97	67.85	43.46	124.80
2018	39.68	62.28	66.26	42.16	125.53
2019	38.42	61.66	64.74	40.95	126.25
2020	37.26	61.12	63.28	39.84	126.97
2021	36.20	60.68	61.94	38.83	127.75
2022	35.24	60.32	60.69	37.92	128.58
2023	34.36	60.04	59.52	37.09	129.45
2024	33.56	59.83	58.43	36.34	130.34
2025	32.82	59.68	57.41	35.66	131.26
2026	32.15	59.59	56.45	35.04	132.20
2027	31.53	59.55	55.56	34.48	133.16
2028	30.97	59.56	54.72	33.97	134.13
2029	30.45	59.61	53.93	33.51	135.11
2030	29.98	59.70	53.18	33.09	136.09

SOURCE: Own elaboration based on the sensibility analysis of the constructed sustainability rate.

WATER BALANCE POLICY EFFECT ON THE GLOBAL SUSTAINABILITY INDICATOR

Supposing that a relative weight equal to all the considered variables including water is assigned to the interior of the global sustainability indicator, the effect of the sum of the mentioned policies would be the following:

GRAPH 6.7
Water Balance Policy:
Effect on the Global Sustainability Indicator



SOURCE: Own elaboration based on constructed sustainability indicators.

As it may be appreciated in Table 6.8 the sum of water balance in the MCMZ headed policies applicability, implies and improvement in the global sustainability indicator, that goes from 0% in the year 2000, to a bit more than 27.83% in the year 2030, a remarkable achievement but not yet sufficient.

TABLE 6.8
Percentage Annual Effect of Water Balance Policies on the Global Sustainability Indicator, 2000 - 2030

	Trend	Policy Scenario	% Improvement
2000	0.231316625	0.2313	0.00%
2001	0.243487369	0.2435	0.00%
2002	0.252064933	0.2521	0.00%
2003	0.257469513	0.2575	0.00%
2004	0.270863507	0.2709	0.00%
2005	0.289315745	0.2893	0.00%
2006	0.298947922	0.2989	0.00%
2007	0.288726091	0.2887	0.00%
2008	0.315873299	0.3159	0.00%
2009	0.311231778	0.3112	0.00%
2010	0.300972826	0.3005	0.14%
2011	0.312784447	0.3040	2.80%
2012	0.327471019	0.3111	5.00%
2013	0.337989409	0.3146	6.92%
2014	0.347998293	0.3078	11.54%
2015	0.355898954	0.3096	13.00%
2016	0.365604386	0.3137	14.20%
2017	0.374794156	0.3177	15.24%
2018	0.383640665	0.3217	16.15%
2019	0.392177793	0.3258	16.93%
2020	0.40043658	0.3184	20.48%
2021	0.407036404	0.3208	21.18%
2022	0.413469208	0.3233	21.80%
2023	0.41971724	0.3259	22.36%
2024	0.425800755	0.3285	22.85%
2025	0.431738402	0.3185	26.23%
2026	0.437707839	0.3212	26.62%
2027	0.44354442	0.3239	26.98%
2028	0.449282699	0.3266	27.30%
2029	0.454936195	0.3295	27.58%
2030	0.460517419	0.3324	27.83%

SOURCE: Own elaboration based on constructed sustainability indicators.

6.1.2 Public Green Areas and Urban Land Use

It's important to study this variable through an urban ecosystem focus, complemented with the concept of environmental indicators for sustainability, given the value of landscape and the role, perfectly measurable, it plays in the relationship of aquifer recharge, temperature regulation and particle matter control. Furthermore, our overall proposed project for sustainable urban for the MCMZ requires extensive reforestation with the native species of trees of the original basin ecosystem as indicated in the section 2.3.1 and 2.3.2.

As explained in Chapter 4, we can state that any living being that forms part of an urban ecosystem requires a minimum amount of green areas to carry out his vital functions. Therefore, when we talk about an index or a sustainability threshold, it's inevitable to include "minimum requirements per capita"

GREEN AREAS RATE DEFINITION

Based on the "minimum requirements" concept, the international benchmarking indicates that there should be $9m^2$ of green areas per inhabitant. Nevertheless in Mexico City's case, green areas do not reach even $3m^2$ per person. Considering this information, a sustainability rate dependant on the total population and the green area square meters per inhabitant our indicator was constructed.[28]

It is important to point out that the desirability of certain continuum in green areas is another vital factor in terms of environmental sustainability, and it was taken in consideration for the constructed indicator's rate. This follows from the fact that such continuum (Vs. "Patchwork" green spots) favours green area contributions to the mentioned processes: aquifer recharge, wildlife recovery, temperature regulation and particle matters control. In this way, the index was designed as follows:

[28] *Estadística del Medio Ambiente del Distrito Federal y Zona Metropolitana 1999...* 231 p.

Green Areas Sustainability Rate=

$$((CP)_t * (m^2 \text{ per inhabitant})_t * (\text{total population})_t / ((CP)_b * (m^2 \text{ per inhabitant})_b * (\text{total population})_b)$$

where "t" corresponds to variables in the period of time, and "b" to the value of variables in base year (1990).

CP = Green areas continuum consideration.

PC = Consideration by continuum of green areas.

Trend Scenario.- In order to achieve the trend scenario construction, the elasticity that relates the percentage change in total population with the percentage change in total green areas was calculated. Such elasticity was estimated under the assumption that the requirement of $9m^3$ of green areas per inhabitant was achieved in 1940, when population climbed to barely 1,645,000 people. With this data and the present numbers (17 million people and 51 million m^2 of green areas) it was calculated that for a 1% increase in population, corresponds a decrease of 0.48% in green areas.[29]

Additionally, it was supposed that presently there exists 80% degree of continuity in green areas, a measure that is presumed in the proposed scenario for the next thirty years. Even though the international norm upon which we based the index construction uses a strict definition for "public green areas", we must recall there are other definitions, maybe too broad but not less important, especially when considering the environmental processes with which the variable relates (recharge, temperature, regulation of suspended particles, etc.)

[29] The result of these calculations is an average decrease of 1.88% similar to public green areas estimations for 1950-1980, based on aerial photographs that result in 1.5%. Regard to this, see M. Lavin, in E. Ezcurra, et. al, The Basin of Mexico. Critical Environmental Issues and Sustainability, United Nations.

"Green area" quantification based on these definitions has been addressed in the previous chapter, "trend scenarios", when we spoke about "soils for conservation", "natural protected areas", "rural areas", among other concepts. However, given the difficulty of taking these into account to make an international comparison and for designing the "minimum requirements", it begs to limit the concept to "public green areas" to analyse trend and the policy scenarios.

However, this does not mean we shall not consider them when defining the goal of the urban "proposed image" that will be discussed in greater detail in the next chapter. As we will see, in the case of the Mexico Basin it is impossible not to talk about a considerable perimeter of low environmental impact with the objective of fostering aquifer recharge, as well as green corridors[30], which do not necessarily belong to the "public green area" category, but are a fundamental aspect to reach greater environmental sustainability levels.

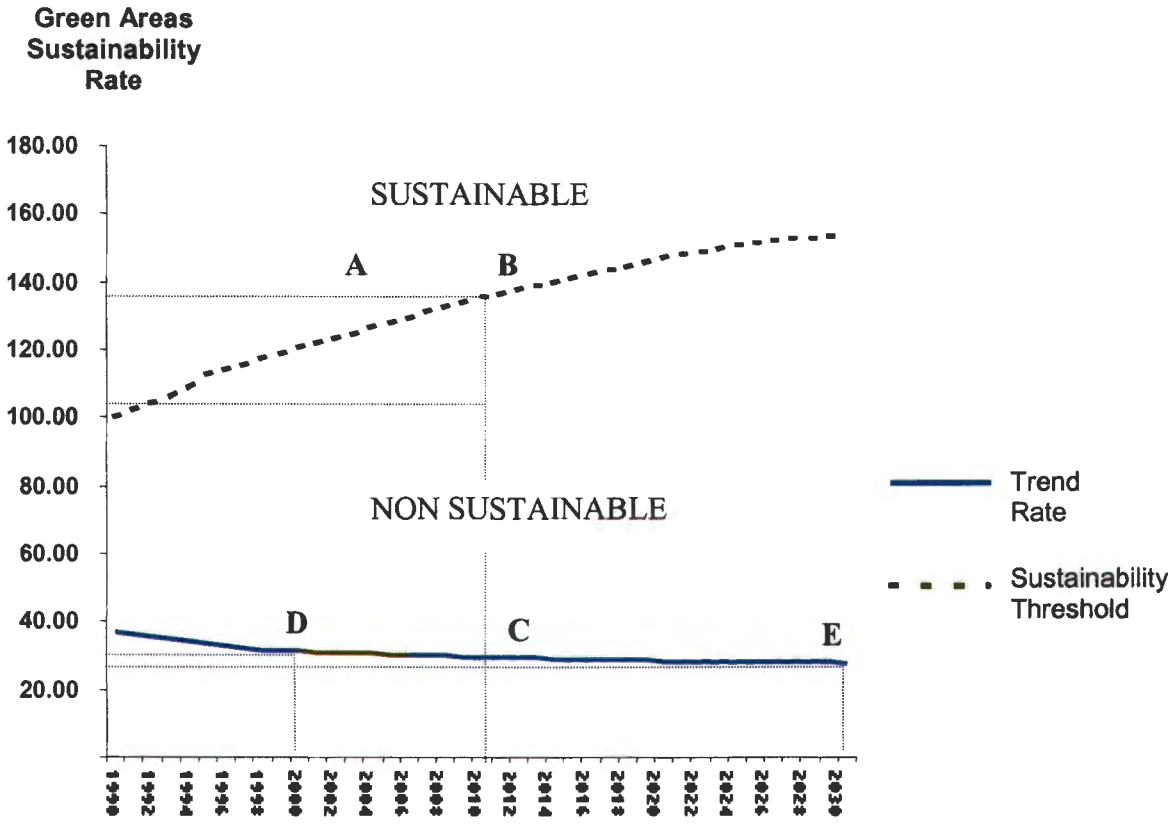
SUSTAINABILITY THRESHOLD

The sustainability threshold is but a multiplication of the number of expected inhabitants between year 2000 to 2030 (according to the hypothesis displayed in the present situation diagnosis) and the international benchmark requirement of 9 m^2 of green areas per capita, considering 1990 as base year with a 100% continuity consideration.

Point A, in Graph 6.8, displays a situation where public green areas surpass the $9m^2$ per person needs established by the international benchmark. In contrast with point C, point B represents a sustainability case for the year 2010. The difference between one and another is around 170,000 thousands of public green areas square meters (see Table 6.7). On the other hand, as shown in Graph 6.10, under the previously described supposition and the constructed indicator, an increase in the trend scenery gap with regards to the sustainability threshold of about 11.15% in a 30 year horizon is expected (the difference between point D and point E).

[30] C. Luiselli, [*et. al.*]. *El corredor Verde "Chapultepec"*. México: Futura Desarrollo Urbano. 2000.

GRAPH 6.8
MCMZ Green Areas Sustainability Threshold Vs Trend Scenario (1990 =100)



SOURCE: Own elaboration based on built sustainability indicators.

In Table 6.9, numbers used to construct the Sustainability Threshold and the Green Areas Trend Scenario are displayed in detail.

TABLE 6.9
Green Areas Sustainability Indicator[31]

	POPULATION	Green Areas: Sustainability Threshold (9 square meters per inhabitant)	Rate (Sustainability Threshold; 1990 = 100)	Green Areas: Tendency Scenario*	Rate (Tendency Scenario)	Green Areas per Inhabitant (Tendency Scenario)
2000	18,240,060	164,160,540	120	42,900,307	31	2.94
2005	19,352,771	174,174,937	128	41,705,096	31	2.69
2010	20,533,361	184,800,249	136	40,543,183	30	2.47
2015	21,376,015	192,384,139	141	39,774,681	29	2.33
2020	22,253,251	200,279,259	147	39,020,746	29	2.19
2025	22,929,112	206,362,011	151	38,469,950	28	2.10
2030	23,344,420	210,099,778	154	38,143,816	28	2.04

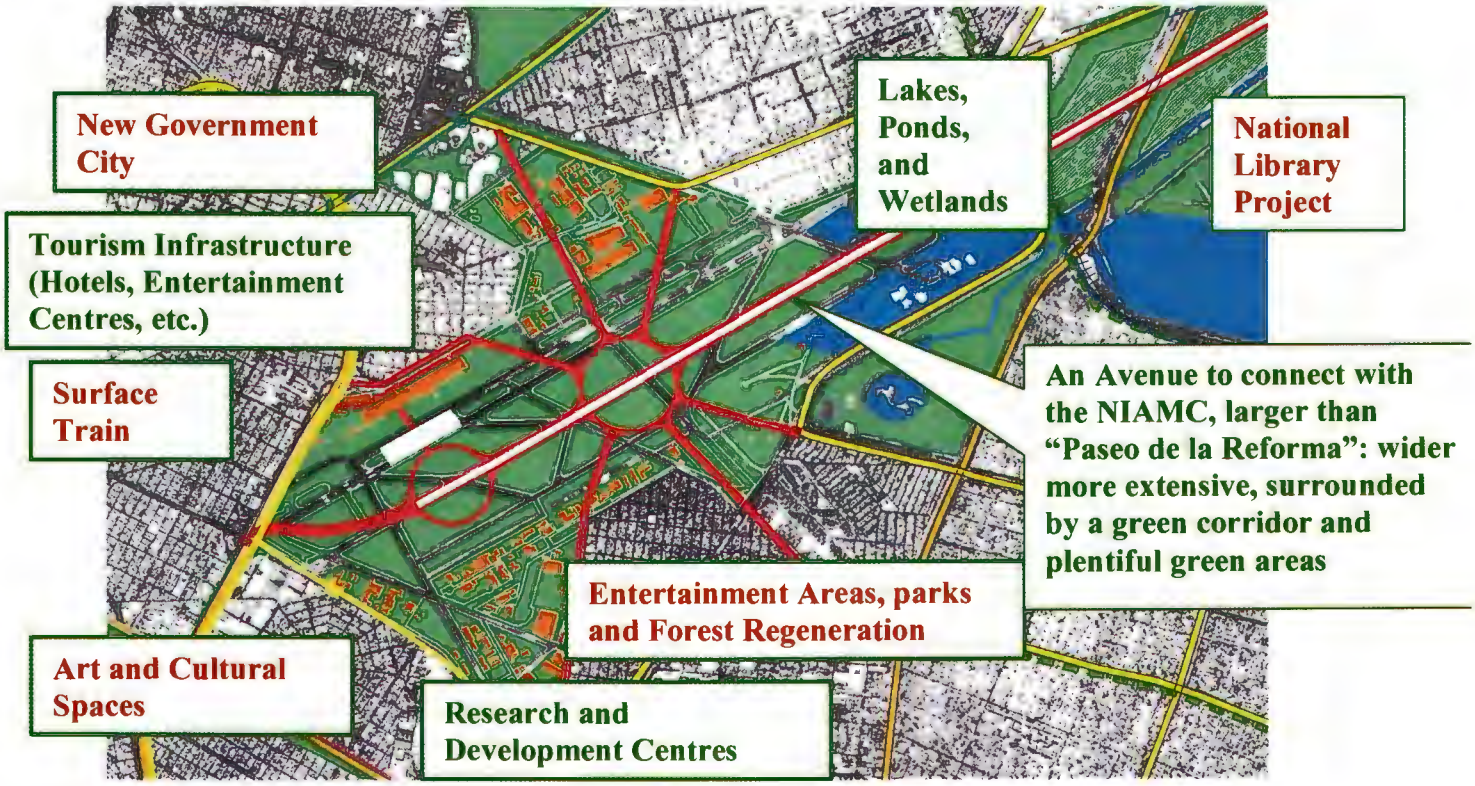
SOURCE: Own elaboration based on built sustainability indicators.

GREEN AREAS: POLICY SCENARIOS

Texcoco Lake Ecological Restoration and reconfiguration of the area of the present airport (AICM). - In terms of the green areas rate, the Texcoco Lake ecological restoration and airport project plays a vital role (see Map 6.1). As it may be appreciated in Graph 6.9, a slow, yet constant recovery of 30,000 hectares of green areas as part of the Texcoco project and 800 in the centre of the city implies a substantial improvement in the green area sustainability rate in relation to the Trend Scenario.

[31]Green areas in the Trend Scenario were calculated by applying the rate of population growth multiplied by -0.47 elasticity. Thus, green areas tend to decrease through time.
Source: own elaboration based on sustainability rates.

MAP 6.1
Urban and Environmental Reconfiguration Potential of the Actual IAMC[32]

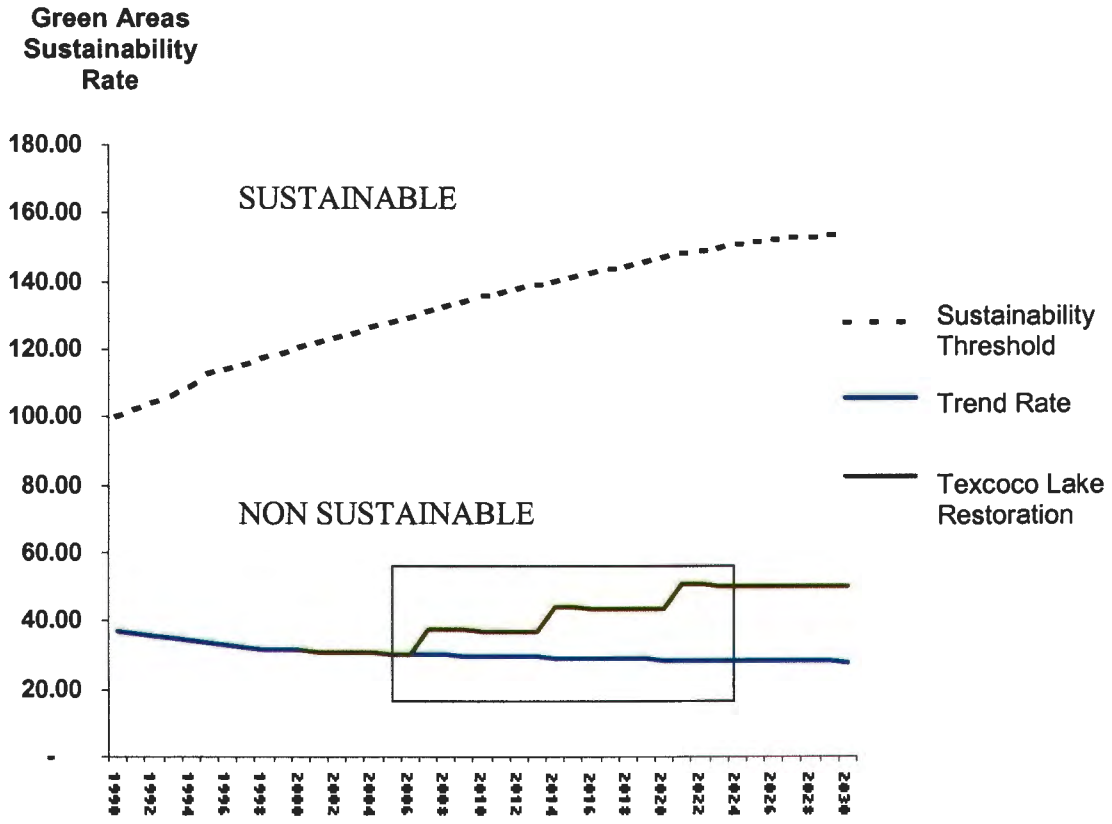


SOURCE: Own elaboration.

[32] NIAMC stands for "Internacional Airport of Mexico City"

GRAPH 6.9

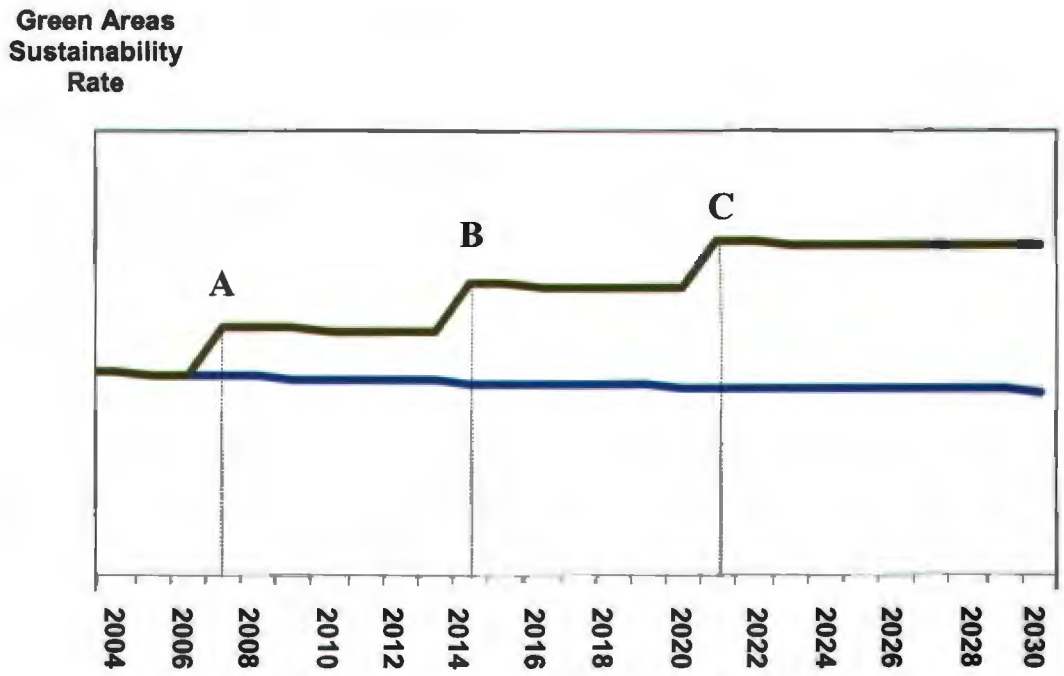
Effect of the Texcoco Lake on the Green Areas Indicator



SOURCE: Own elaboration based on built sustainability index.

Graph 6.10 displays in detail the way in which Lake Texcoco associated reforestation, improves the green areas sustainability rate. The implicit supposition is the existence of three seven -year stages, with achieving the proposed reforestation of 30,000 Hectares. Point A represents the first, point B the second and point C the third.

GRAPH 6.10
Detail on the Texcoco Lake Restoration Stages:
Effect on the Sustainability Indicator



SOURCE: Own elaboration based on built indicators.

Table 6.10 displays the extent associated with the change in the green areas sustainability rate, as a consequence of the execution of the proposed three reforestation stages. The final effect is to avoid a further decrease in the square meters of public green areas.

TABLE 6.10
Construction of the Green Area Sustainability Indicator: Texcoco Lake Recovery

	POPULATION	Green Areas: Sustainability Threshold (9 square meters per inhabitant)	Rate (Sustainability Threshold; 1990 = 100)	Green Areas: Tendency Scenario*	Rate (Tendency Scenario)	Green Areas per Inhabitant (Tendency Scenario)
2000	18,240,060	164,160,540	120	42,900,307	31	2.35
2005	19,352,771	174,174,937	128	41,705,096	31	2.15
2010	20,533,361	184,800,249	136	50,543,183	37	2.46
2015	21,376,015	192,384,139	141	59,774,681	44	2.80
2020	22,253,251	200,279,259	147	59,020,746	43	2.65
2025	22,929,112	206,362,011	151	68,469,950	50	2.99
2030	23,344,420	210,099,778	154	68,143,816	50	2.92

SOURCE: Own elaboration based on built indicators.

Urban Reconfiguration of the present International Airport of Mexico City.- It's important to talk about the potential benefits derived from the new localization of Mexico City's International Airport in Texcoco. As it was mentioned in the previous sections, the project implies the closure of the present airport, hence, the opportunity to reconfigure the zone in benefit of the environment and the urban form is simply formidable. This shapes, as will be seen in Chapter 7, the new urban project.

Precisely, one of the main indicators that shows considerable improvements is the one for green areas; if the posed premises to define new activities' localization and development (low environmental impact and added value) are respected, it is possible to convert around 70 to 80% of the 800 occupied hectares into green area amenities for the poor located at the east of the City.

Green Corridors.- To a world wide level, one of the most important urban policies to reach high levels of environmental sustainability consists in the generation of green corridors of

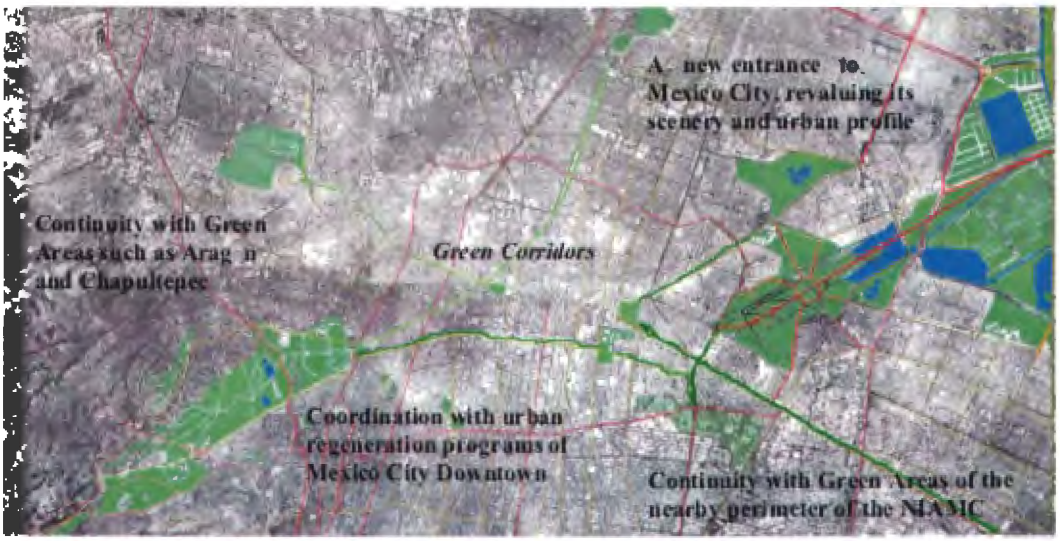
which function is to connect and communicate the main green areas of a given urban area, in Mexico City's concrete case, Chapultepec and Aragon (see Section 7.2.2)

To an international level, a clear example of the appliance of this type of measures is the metropolitan area of Rhine- Main, which "green circle" measures about 80 km^2. In general, it's about green areas that conserve local species where there are also organic agriculture and horticultural developments, under a "city coexistence" focus."[33]

Particularly, in the case of Mexico City, it is worth mentioning the possibility of a corridor from Chapultepec to Aragon, which would be perfectly linked to the IAMC zone (see Map 6.2). This green area creation strategy could also be linked to other policies and programmes for urban regeneration. In Chapter 6 we will talk about another corridor, the south-north from Chalco to Chimalhuacán, where we propose the new lake will be created (Chalco).

[33] *An Urbanizing World, Global Report on Human Settlements, 1996*, Oxford: Oxford University Press, United Nations Centre for Human Settlements, Habitat, 559 p.

MAP 6.2
Green Corridors and Urban Reconfiguration of the IAMC

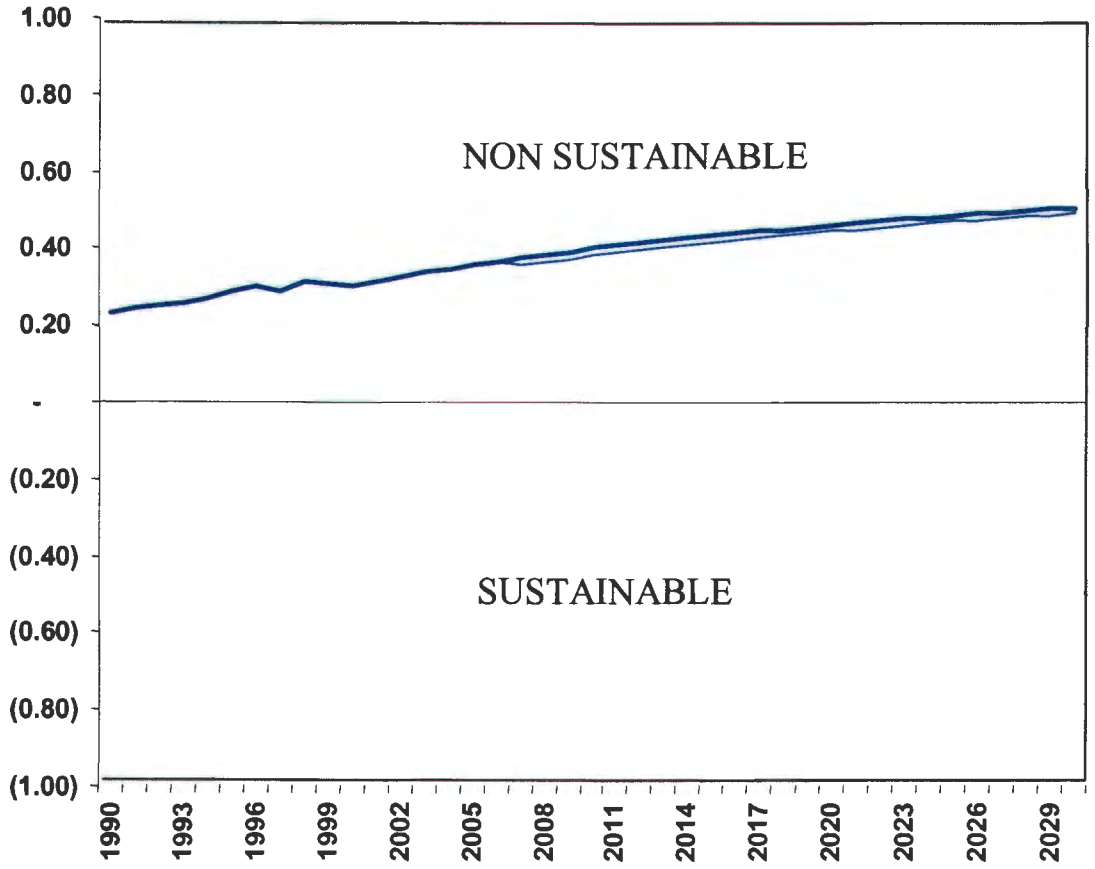


SOURCE: Own elaboration.

EFFECT OF GREEN AREA POLICIES ON THE GLOBAL SUSTAINABILITY RATE

Assuming that a relative weight is equally assigned for all the considered variables that compose the global sustainability index, the effect of the sum of green area recovery policies would be the following:

GRAPH 6.11
Effect of Green Areas Policies on the Global Sustainability Indicator, 1990 – 2030



SOURCE: Own elaboration based on constructed sustainability index.

As it may be appreciated in Table 6.11, the combined application green area recovery policies implies an improvement in the global sustainability indicator that goes from 0% in the year 2000 to a bit more than 1.58% by the year 2030.

TABLE 6.11
Percentage Effect of Green Area Policies on the Global Sustainability Indicator, 2000 to 2030

	TREND	GREEN AREAS POLICIES	% IMPROVEMENT
2000	0.300972826	0.3010	0.00%
2001	0.312784447	0.3128	0.00%
2002	0.327471019	0.3275	0.00%
2003	0.337989409	0.3380	0.00%
2004	0.347998293	0.3480	0.00%
2005	0.355898954	0.3559	0.00%
2006	0.365604386	0.3656	0.00%
2007	0.374794156	0.3556	1.92%
2008	0.383640665	0.3647	1.89%
2009	0.392177793	0.3735	1.86%
2010	0.40043658	0.3821	1.84%
2011	0.407036404	0.3889	1.82%
2012	0.413469208	0.3955	1.80%
2013	0.41971724	0.4019	1.78%
2014	0.425800755	0.4082	1.76%
2015	0.431738402	0.4143	1.75%
2016	0.437707839	0.4204	1.73%
2017	0.44354442	0.4264	1.71%
2018	0.449282699	0.4323	1.70%
2019	0.454936195	0.4381	1.68%
2020	0.460517419	0.4439	1.66%
2021	0.465789003	0.4493	1.65%
2022	0.470803645	0.4544	1.64%
2023	0.475647832	0.4594	1.63%
2024	0.480344085	0.4642	1.62%
2025	0.484912659	0.4688	1.61%
2026	0.489128632	0.4731	1.60%
2027	0.493341584	0.4774	1.60%
2028	0.497451088	0.4816	1.59%
2029	0.501470495	0.4856	1.59%
2030	0.505457283	0.4896	1.58%

SOURCE: Own elaboration, based on built sustainable index.

6.1.3 Road Infrastructure and Transport

Trend scenario analysis and policy proposals concerning transport and road systems are probably one of the most important topics for environmental sustainability. Since they determine population mobility patterns, and help define the location and housing as they are closely linked to urban form and growth patterns.

International experience shows that as travel time decreases, the opportunity costs for private car owners diminish, thus, creating an additional incentive to increase participation in this mixed transport mode.[34] In other words, it has been proved that reduction in travel time encourages car owners to increase the number of travelled kilometres. Moreover, the reduction in travel time, along with the increase in travelled distance, encourages the population be at greater distances from the so called business centres, creating a vicious cycle with three basic components, linked through the following sequence:

1) Road Infrastructure Supply
2) Reductions on Travel Time
3) Urban Expansion
4) Traffic Congestions
5) Supply of New Road Infrastructure

Another variable that also plays a role in this process is the mixed of modes of transport. For example, if every time a new road infrastructure supply privileges the use of private cars, then the vicious cycle not only determines an immeasurable and anarchic urban expansion, but also increases the negative externalities or "hidden costs" derived from transport which are socially undesirable –emissions, lost time, accidents, among others.

Thus, the way towards a sustainable city requires a perfect binomial between infrastructure and mixed mode of transport to encourage the use of means of transport greater unit capacity (subway, suburban train, etc.). In both cases, the relationships with land use and

[34] Word (1990) & *Surface Transportation Policy Proyect,* 1998.

urban development policies need to be taken into account, since the principle must be to "avoid trip demand" instead of "catering to trip demand". In colloquial terms, a city is more "lively" when less time is required to travel from one place to another, less time is spent in automobiles or any other means of transport, compared to a city in which available time for productive or recreational activities is limited by distances and traffic.

URBAN TRANSPORT DEMAND IN MEXICO CITY

There are various focuses and variables that can be used with the objective of measuring and determining the transport and road system of a given metropolitan area. With an integral vision, such varied aspects include the road infrastructure situation, public transport mode, quality and localizing trip-generating centres, among others, must be considered.

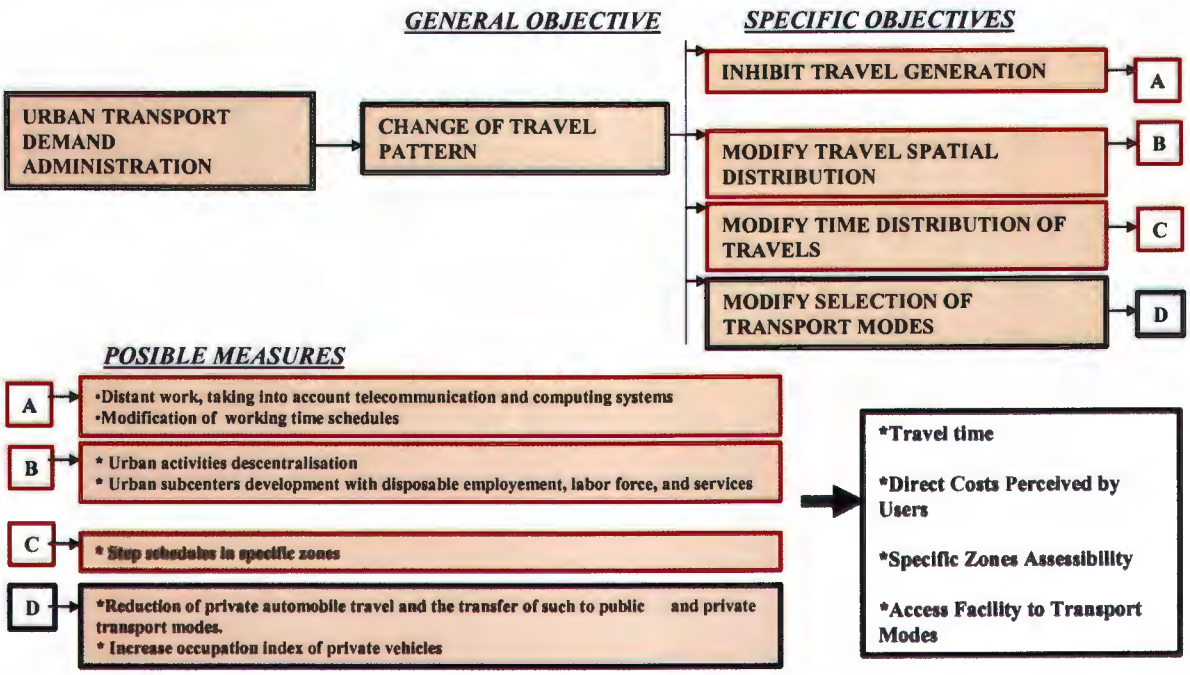
Nevertheless, we must not forget one of the indicator's characteristics is to point out situations without exhaustive detail, so that the objective of this section is to display a simple approximation of the transportation and road system in the City. For this reason, the modal distribution of travel portions that are generated on a daily basis in the metropolitan area, has been chosen as the key variable, so as the trend scenario and sustainability threshold area are defined in conjunction with the travel demand administration. The other factors that should be normally considered for such an analysis will be handled as suppositions that in a way, also cover the travel demand administration in the City.

For example, instead of internalizing in the index the situation of physical infrastructure, it is suggested to make assumption about the effect of a change in this variable in the total amount of daily travel (and therefore, of sections of travel) to be undertaken everyday in the City or about the degree in which a certain travel demand administration situation translates to a determined trip speed.

Even inside the demand administration focus itself, it is suggested to manage through the adequate supposition, in themes related to special distribution and travel temporality in the City.

All these factors remain implicit if each mode of transport is graded by desirability in terms of its function within the necessities of infrastructure, quantity of total urban trips on its overall urban impact relationships.

FIGURE 6.2
Travel Demand Administration
(as a Focus to Analyze the Situation and Problem of the Road and Transportation System in Mexico City)



SOURCE: *Estudio Integral de Transporte y Calidad del Aire en la Zona Metropolitana del Valle de México*, COMETRAVI, 1999.

TRANSPORTATION AND ROAD SYSTEM RATE DEFINITION

The last step was to consider each mode of transport according to it "desirability" taking 1990 as base year. The concept of "desirability" was defined based on the unitary capacity of each mode of transport media. In this way, transport modes with a larger unitary capacity are considered more desirable, because of the implied lower level of congestion problems in the City.

Transportation and Road System Rate=

$$\frac{100*(DSubway_t*(Psubway) + Dbus_t *(Pbus) + Dtrolley\text{-}bus_t *(Ptrolley\text{-}bus) + Dsuburban_t * (Psuburban) + Dtaxi_t *(Ptaxi) + Dprivate_t *(Pprivate) + Dcolective_t *(Pcolective) + Dothers_t * (Dothers)) / TOTAL_{1990})}{((Dsubway_{1990} *(Psubway) + Dbustr_{1990} *(Pbus_t) + Dtrolley\text{-}bus_{1990} (Ptrolley\text{-}bus) + Dsuburban_{1990} *(Psuburban) + Dtaxi_{1990} *(Ptaxi) + Dprivate_{1990} *(Pprivate) + Dcolective_{1990} *(Pcolective) + Dothers_{1990} *(Pothers)) / TOTAL_{1990})}$$

Where

Dsubway = subway travel sections[35] demand
Dbus = bus travel sections demand
Dtroleybus = trolley-bus travel sections demand
Dsuburban = suburban transport travel sections demand
Dtaxi = taxicab travel sections demand
Dprivate = private automobile travel sections demand
Dcolectivo = collective transport travel sections demand
Dothers = other transport modest of travel sections demand

And, at the same time:

Psubway = desirability ponderation of subway travel sections
Pbus = desirability ponderation of bus travel sections
Ptrolebus = desirability ponderation of trolley-bus travel sections
Psuburban = desirability ponderation of suburban transport travel sections
Ptaxi = desirability ponderation of taxicab travel sections
Pprivate = desirability ponderation of private automobile travel sections
Pcolective = desirability ponderation of collective transport travel sections

[35] "Travek Sectuibs" *Stands as discrete portions of a given journey on final trip.*

Pothers = desirability ponderation of other transport media travel sections

These desirability ponderations are in function with the following variables:

(1-sw) = subway use desirability indicator
(1-b) = bus use desirability indicator
(1-t) = trolley-bus use desirability indicator
(1-s) = suburban transport use desirability indicator
(1-t) = taxicab use desirability indicator
(1-p) = private automobile use desirability indicator
(1-c) = collective transport use desirability indicator
(1-o) = other transport media use desirability indicator

sw = 1/subway's unitary capacity
b = 1/bus unitary capacity
t = 1/trolley-bus unitary capacity
s = 1/suburban transport unitary capacity
t = 1/taxicab unitary capacity
p = 1/particular automobile unitary capacity
c = 1/collective transport unitary capacity
o = 1/other transport media unitary capacity

Finally:

$Total_{1990}$ = sum of travel section estimated demand in 1990
"t" = refers to the year in matter (that is always analyzed in relation to base year: 1990)

TRANSPORTATION AND ROAD SYSTEM: TREND SCENARIO

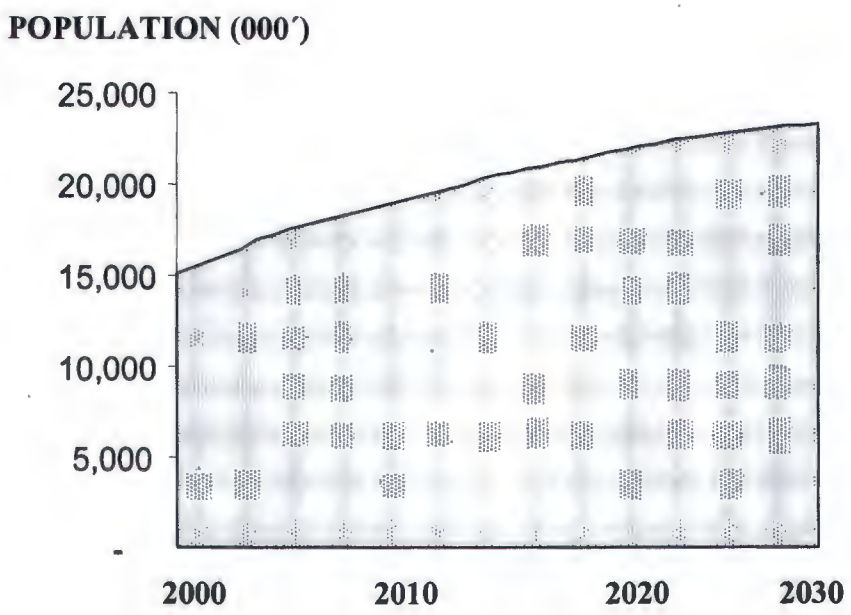
For the construction of the Trend Scenario for the defined in the previous chapter, it is necessary to project the day-to-day travel demand (and travel area) in the MCMZ from year 2000 to year 2030. This scenario is characterized principally by the absence of consideration with regard to the "internet" popularization impact and in general digital technology.

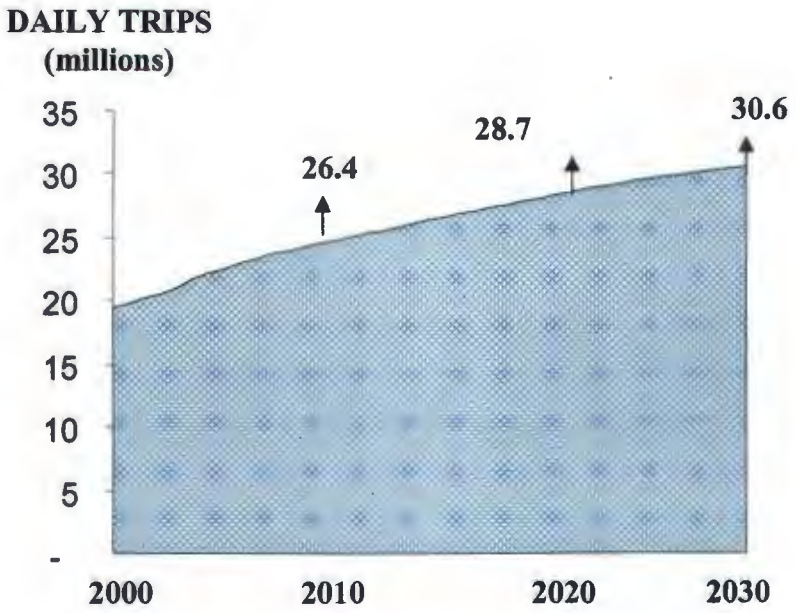
For this purpose, suppositions about trips per person rate development were made for the Federal District and nearby municipalities in the State of Mexico [36] (with a progressive evolution of up to 1.01 in year 2030[37]) and additionally, CONAPO population projections were considered with a result of a total of 30.5 million trips everyday in the year 2030, as shown in Graph 6.12.[38]

On the other hand, suppositions about the growth in the number of MCMZ's economical units displayed in Chapter 4 were used.[39] The direct result of those suppositions is the growth in travel amounts from 46 in year 2000 to almost 47 in the year 2030 in Mexico City and 51 to 63 in the nearby municipalities of the State of Mexico.

[36]Indicator obtained according to *Encuesta Origen - Destino* realizada por INEGI en 1994.
[37]This was constructed so that the relation between the number of economic units in the Federal District and in the conurbados municipalities would continue being equal to the relation of daily trips per person..
[38]If this appears to be a rather conservative scenery, results coincide in order of magnitude with other projections, like the ones made by COMETRAVI in 1999, according to which estimate 28.3 million trips the year 2020 are expected according to the shown results, projections of this study oscillate in a number close to the 28.7 million trips for the same year..
[39]The introduction of a relative journey p/economic unit measure is important to compare the "internet" generalization effect.

GRAPH 6.12
Projection of the Daily Travel Demand in MCMZ, 2030
(Trend Scenario)





SOURCE: Own elaboration based on CONAPO; *Estudio Integral de Transporte y Calidad del Aire en la Zona Metropolitana del Valle de México*, COMETRAVI, 1999.

TABLE 6.12

Trend Scenario: Results Summary

	Daily Trips	Population	Daily Trips per Person	ECONOMIC UNITS*	TRAVEL/ EC. UT
1994	29,124,242	16,441,163	1.77	443,588.00	65.66
1995	29,939,212	17,034,527	1.76	452,903.06	66.11
1996	30,460,616	17,269,085	1.76	459,810.96	66.25
1997	30,990,817	17,506,872	1.77	466,838.49	66.38
1998	31,529,954	17,747,933	1.78	473,987.83	66.52
1999	32,078,171	17,992,314	1.78	481,261.16	66.65
2000	32,635,612	18,240,060	1.79	488,660.74	66.79
2001	32,969,939	18,457,362	1.79	492,493.27	66.94
2002	33,309,299	18,677,254	1.78	496,366.46	67.11
2003	33,653,774	18,899,765	1.78	500,280.79	67.27
2004	34,003,444	19,124,926	1.78	504,236.73	67.44
2005	34,358,394	19,352,771	1.78	508,234.75	67.60
2006	34,718,707	19,583,329	1.77	512,275.35	67.77
2007	35,084,470	19,816,635	1.77	516,359.01	67.95
2008	35,455,770	20,052,720	1.77	520,486.24	68.12
2009	35,832,696	20,291,617	1.77	524,657.53	68.30
2010	36,215,338	20,533,361	1.76	528,873.39	68.48
2011	36,500,292	20,699,192	1.76	531,860.00	68.63
2012	36,788,466	20,866,362	1.76	534,868.06	68.78
2013	37,079,898	21,034,882	1.76	537,897.71	68.93
2014	37,374,629	21,204,762	1.76	540,949.14	69.09
2015	37,672,697	21,376,015	1.76	544,022.50	69.25
2016	37,974,145	21,548,651	1.76	547,117.97	69.41
2017	38,279,012	21,722,682	1.76	550,235.73	69.57
2018	38,587,341	21,898,117	1.76	553,375.93	69.73
2019	38,899,173	22,074,970	1.76	556,538.76	69.89
2020	39,214,552	22,253,251	1.76	559,724.39	70.06
2021	39,506,702	22,415,476	1.76	562,594.60	70.22
2022	39,781,351	22,562,976	1.76	565,244.93	70.38
2023	40,039,911	22,696,992	1.76	567,694.02	70.53
2024	40,283,704	22,818,681	1.77	569,959.20	70.68
2025	40,513,961	22,929,112	1.77	572,056.53	70.82
2026	40,731,827	23,029,275	1.77	574,000.85	70.96
2027	40,938,363	23,120,083	1.77	575,805.85	71.10
2028	41,134,548	23,202,373	1.77	577,484.12	71.23
2029	41,321,287	23,276,917	1.78	579,047.20	71.36
2030	41,499,411	23,344,420	1.78	580,505.70	71.49

SOURCE: Own elaboration based on CONAPO projections and assumptions about the development of economical units and daily trips per person for the MCMZ and nearby municipalities in the State of Mexico.
*An economic unit is equivalent to a business unit.

Additionally, an index was obtained of trips per private car in stock. Thus, 5 million trip sections corresponding to private transport and 2.6 million privately owned cars in 1994 are equivalent to 1.93 trips per day per private car in the Mexico City metropolitan area.

The next step was to use the projections for private cars presented in previous sections to estimate the participation of private transport in the daily demand for the total number of trip sections. Maintaining the assumption of 1.93 trip sections per private car, the corresponding participation would shoot up to 90%, which would be impossible considering that Mexico City's street network has a limited ability to absorb vehicle traffic.

An additional factor that should be considered is that greater saturation of the street network as a result of increased use of private vehicles causes the average driving time per trip to increase, and this, in turn, implies an increase in the opportunity cost derived from the time lost for the trip. This acts as a force against the use of the automobile in such a way that, although greater per capita income can lead to more private cars, the opportunity cost derived from the loss of time while driving simultaneously inhibits their use. Thus, the daily trip sections per private car should tend to decline somewhat. This assumption is critical, as we saw with more depth in section 5.2.2, when we talked about the future of the automobile and its possible competition with the Internet: in the future it is expected a higher number of cars per person, but at the same time, less used.

Supposing that the average driving time per trip in the metropolitan area increases in direct proportion to the participation of private vehicles in the modal distribution of transport, and supposing an elasticity of 0.8[40] to measure the percentage of change in the number of trip sections per private car with respect to an increase in opportunity cost associated with a trip, private transport's participation in the mix of modal transport was recalculated through a series of iterations. This procedure was necessary since the recalculated number of trip sections per private car implies a change in private transport's participation in the modal

[40]Estimated value based on the data from the *Estudio Integral de Transporte y Calidad del Aire en la Zona Metropolitana del Valle de México*, COMETRAVI, 1999. This study presents data which demonstrates a reduction in the participation of private cars from 25% to 17% (32%) in the modal mix of trip sections from 1986 to 1995. At the same time, between 1988 and 1995, the cost per trip section, derived from the existing modal mix, was estimated to increase by 40%.

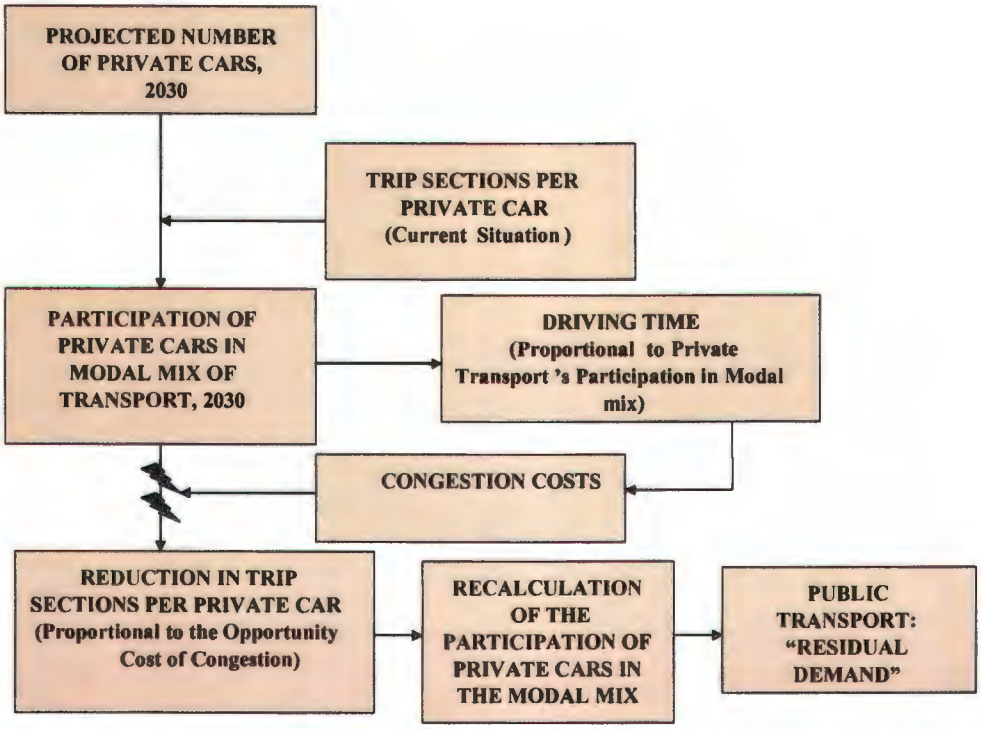
mix and, therefore, a change in the cost of congestion and so on. Once the corresponding iterations were carried out, the results in terms of private transport's participation in the modal mix is much more congruent: instead of increasing, this percentage tends to decrease, even dropping to a figure close to 20% by the year 2030.

Later, the participation of public transport in the modal mix of transport was calculated as if it were a "residual demand," resulting from the determination of the demand for private transport. The mix within public transport of buses, trolleybuses, the metro, collective transport, taxis and suburban varieties, among others, remained constant toward the year 2030.

This assumption does not seem to be entirely realistic; nevertheless, for a change in the public transport modal distribution, it is required political goodwill and cooperation between two entities that have been in conflict in the last years, especially in rewards to environmental topics: the Federal District and the State of Mexico. Without such cooperation, it is not possible to talk about a change in the public transport modal distribution for the trend scenario. This consideration could maybe be made for one of the policy scenarios that we will analyse later.

FIGURE 6.3

Interaction Between Critical Variables Related to Roads and Traffic



SOURCE: Own elaboration.

ROAD AND TRAFFIC: CONSIDERATIONS ON "INFORMATION TECHNOLOGY" IMPACT

In contrast with the Trend Scenario, if the possible effects of the "digital age" are taken into account, the projection for the demand for daily trips in the metropolitan area will change significantly.

Employing the same assumptions used in the Trend Scenario about growth and the number of economic units in the Federal District and the nearby municipalities, but taking into account certain considerations about the impact of the internet on the evolution of the number of daily trips associated with certain economic activities, it is possible to outline an alternative transport and road system scenario for Mexico City.

In the first place, it is necessary to estimate the rate of penetration of the use of computers in homes in the metropolitan area. Recent studies by the OECD,[41] based on data from the United States, Canada, Japan and Australia from 1989 to 1996, have led to the estimation that, for at least these economies, an increase of 10,000 U.S. dollars in a home implies a six percent increase in the number of homes with a computer.

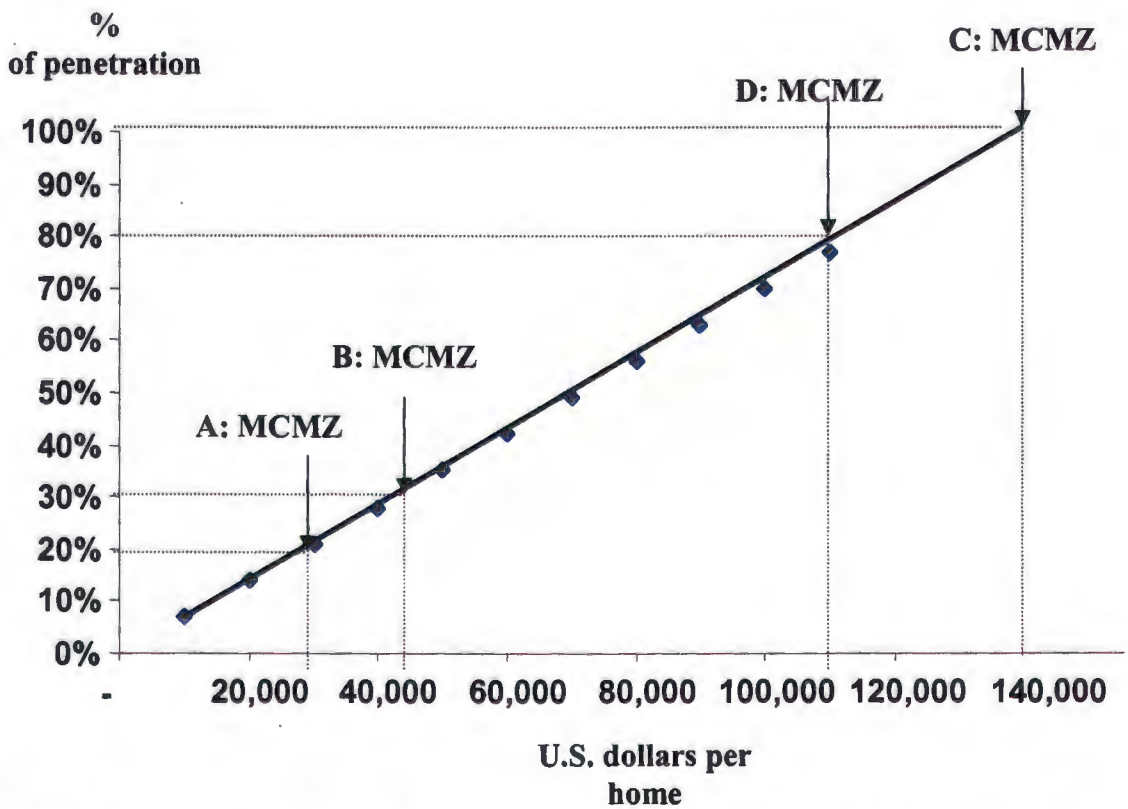
Supposing that this relationship is applicable or at least similar to Mexico City's case, and using as a basis the existence of a total of 4.2 million of housing units (as an approximation to the number of houses), the penetration of computers in Mexico City should currently be around 22% (point A in Graph 6.13).

This means that in a thirty-year time frame, with a median growth rate of 4% for the entire metropolitan area, a progressive reduction in the number of inhabitants per housing unit that will reach 2.5, that is, a total of 9.4 million houses, and without taking into account the exponential reduction in the cost of digital technologies, the rate of penetration will reach at least 32% (see point B in Graph 6.13).

[41]OECD, *The Economic and Social Impact of Electronic Commerce: Preliminary Findings and Research Agenda,* (2):1999, p. 19.

On the other hand, figuring in the possibility of an exponential reduction in the price of the basic goods and services needed to connect to the internet, the corresponding penetration could reach up to 100% (see point C in Graph 5.13). However, for the purposes of this study, and considering that despite the existence of empirical evidence such as Moore's Law, there is still uncertainty about the effect of other factors of cultural and social character and having to do with unequal distribution of wealth, an intermediate scenario between B and C will be adopted, and described by point D, that is, with a penetration of 66%.

GRAPH 6.13
Computer Penetration Scenario According to Income Level

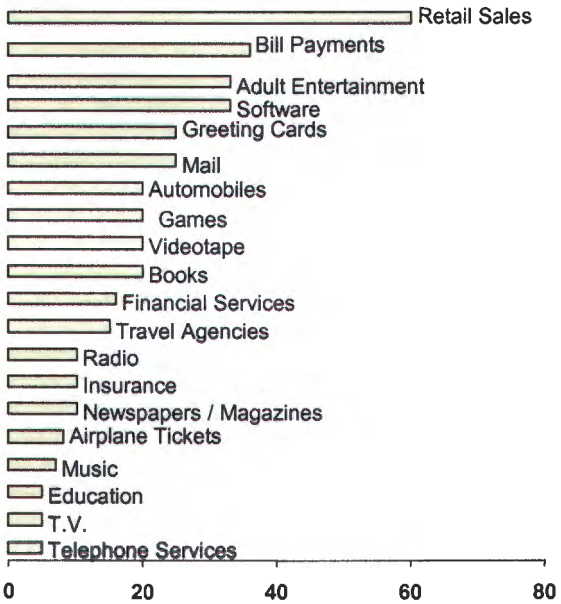


SOURCE: The graph is by author, and is based on data from *The Economic and Social Impact of Electronic Commerce: Preliminary Findings and Research Agenda*. The estimates are based on information from the United States, Canada, Australia and Japan from 1989 to 1996.

Starting with this assumption and considering that it is very likely to be the rate of penetration reached by developed economies such as the United States in the middle term (three to five years), it is possible to take OECD estimates of the participation of electronic business in the different branches of the U.S. economy in a time frame of five years and use them as a reference, with certain qualitative considerations, for the Mexico City metropolitan zone in the year 2030. Graph 6.14 shows the percentages estimated by this international organisation for said types of participation.

GRAPH 6.14

Importance of Business via the Internet in the United States for Some Economic Activities



SOURCE: Graph is by author, and is based on data from *The Economic and Social Impact of Electronic Commerce: Preliminary Findings and Research Agenda.*

Thus, assuming that the participation of business via the Internet for a certain activity translates into a directly proportional reduction in the trips associated with that activity, the following considerations were made for the Mexico City metropolitan zone with respect to trips per economic unit:

- In *direct retail sales* they will go down by 60% between 2000 and 2030. This figure is in agreement with OECD estimates (1999) for the United States, which predict that 60% of retail sales transactions will be carried out via the internet by the year 2005.

- In the *manufacturing industry* they will drop by 20%. Although the OECD (1999) does not take into consideration the large sector that is manufacturing, the automobile industry is a good example of the tendency that could also prevail in other branches of manufacturing in the long term.

- In *financial services and specialised technical services* they will go down by 60% between 2000 and 2030. In the case of the United States, this number is expected to reach 16% by 2005, which, with the continuation of this tendency, would imply a little more than 60% by 2030. In this case, the trend figure was used instead of the one for 2005, since the financial sector in Mexico is increasingly characterised by mergers and associations with foreign banks, which will accelerate the process of technological modernisation, even in a developing country like Mexico.

- In entertainment services and hotels and restaurants, there will be a reduction of 5%.

- In *education and research services* they will drop by 20%. In the United States, this number is expected to reach 5% by 2005. Again, a figure greater than the one estimated for 2005 in the United States was used since in Mexico there are already important "distance learning" projects in place, which –without completely replacing the physical links of educational services-- will gain an increasingly important degree of participation.

- Government services will go down by 80%.

It should be pointed out that these assumptions are not intended to be determinant in any way since the lack of a clear definition of what it concretely means to do business via the

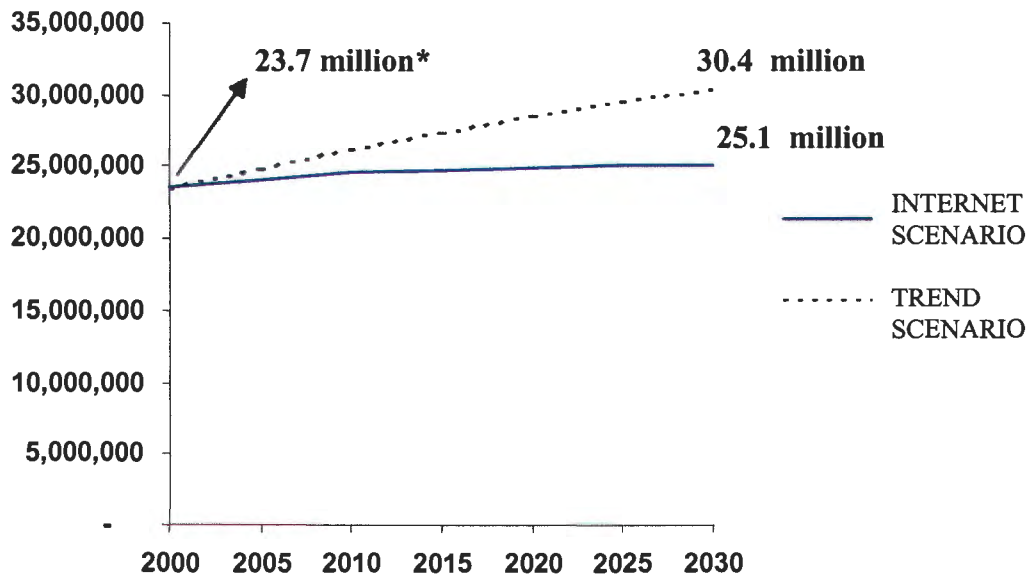
Internet and the absence of measurement and historic statistical techniques for this matter prevents the formulation of more educated, better founded hypotheses.

Thus, it is necessary to take into account that the majority of information available refers to the United States, since currently 80% of all business via the Internet is carried out in said OECD country (1999).

EFFECTS ON TRANSPORT

The result is a reduction of around five million daily trips in the year 2030 with respect to the Trend Scenario, as is shown in Graph 6.15

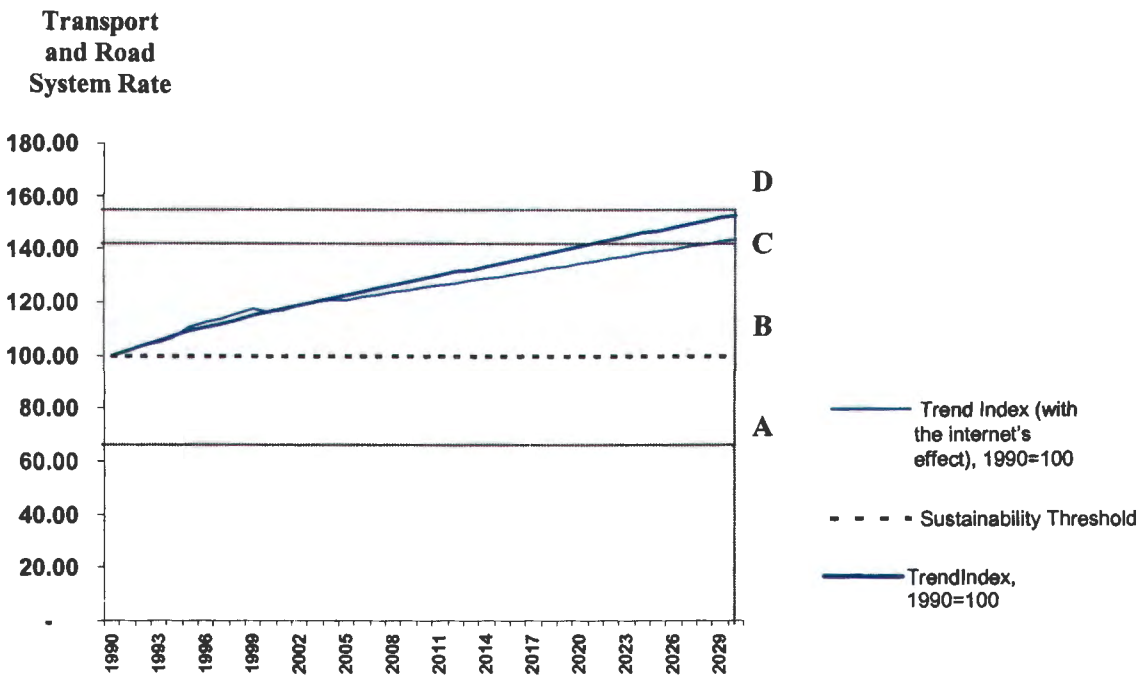
GRAPH 6.15
IMPACT OF GENERALISED INTERNET USE ON TRIPS IN MCMZ



SOURCE: Own elaboration.

Sustainability Threshold: The Sustainability Threshold was defined simply as if the situation which prevailed in 1990 was desired as a minimum. Graph 6.16 illustrates the concepts described above. In terms of Roads and Traffic, point A represents a sustainable situation, B is barely sustainable and D is the Trend value that does not take into account the impact of the internet. Finally, the reduction of D to C is due to the impact of the internet.

GRAPH 6.16
Roads and Traffic in MCMZ:
Threshold of Sustainability Vs. Trend Scenario (1990 =100)



SOURCE: Own elaboration based on constructed rate.

Table 6.13 shows the quantification of the main concepts necessary to obtain the values of the sustainability index of Roads and Traffic.

TABLE 6.13
Sustainability Index of Transport and Road Systems

Without considering the impact of the Internet

	Expected Demand of Segments of Daily Trips	Segments of Trips in Private Transport	Segments of Trips in Public Transport	Tendential Weighted Average Demand	Trend Index
2000	32,848,833	5,584,606	27,264,228	0.131	116
2005	34,668,106	6,010,933	28,657,173	0.138	122
2010	36,642,634	6,469,806	30,172,828	0.145	129
2015	38,224,531	6,963,709	31,260,823	0.151	135
2020	39,909,205	7,495,316	32,413,889	0.158	141
2025	41,358,003	8,067,507	33,290,496	0.165	147
2030	42,489,492	8,683,378	33,806,114	0.171	152

Considering the Impact of the Internet

	Expected Demand of Segments of Daily Trips	Segments of Trips in Private Transport	Segments of Trips in Public Transport	Tendential Weighted Average Demand	Trend Index
2000	32,667,275	5,584,606	27,082,669	0.130	116
2005	33,342,490	6,010,933	27,331,557	0.136	121
2010	34,144,293	6,469,806	27,674,487	0.141	126
2015	34,298,450	6,963,709	27,334,741	0.146	130
2020	34,647,528	7,495,316	27,152,211	0.151	134
2025	34,902,652	8,067,507	26,835,145	0.156	139
2030	34,861,454	8,683,378	26,178,076	0.161	143

SOURCE: Own elaboration, based on constructed sustainability indexes.

ROADS AND TRAFFIC: POLICY SCENARIOS

When defining some policy scenarios we should pay attention to some certain international experiences. These go, from isolated measures, such as the promotion of pool travelling or parking restrictions, to the implementation of integrated transport programs. The later, the more desirable to take into account the most important points, mentioned in pass sections: the binomial relation between infrastructure – modal distribution in one side, and the relations between land use and urban development, in the other.

The encouragement of pool trips in shared cars and group trips has been used in Seattle, Washington, Los Angeles and Vancouver with satisfactory results. These kinds of programs are based on advantages offered to people who travel in said manner (exclusive lanes, preferred parking, fiscal incentives, special parking rates, etc.). The results have been satisfactory. Obligatory measures have been the most successful, reducing car trips between 14% and 36%, while voluntary measures have resulted in a decrease of from 5% to 12%.[42]

Another possible measure is the administration of parking lots, which has been established in North America (San Francisco in 1977, for example) and the European Community. In Vancouver's case, the increase in parking rates in business areas by 50% to 75% achieved a reduction in single-driver car trips of between 28% and 35%.[43]

In the other side, the use of exclusive lanes for buses has been set up in Bangkok and Puerto Alegre. The results have been encouraging since a reduction of driving time of 25% to 30% has been achieved. Other similar measures include giving the right-of-way in rows, prohibiting turns to all vehicles but buses and counter-flow lanes and physically separated lanes, as well as traffic laws that give the right-of-way to public transport. In San Francisco it has been found that passengers switch to public transport more frequently when the savings of time is greater than 15 minutes, but almost never do so when the savings is less

[42] *Estudio Integral de Transporte y Calidad del Aire en la Zona Metropolitana del Valle de México*, COMETRAVI, 1999...
[43] *Ibidem.*

than five minutes.[44] It is important to indicate that if demand grows to be more than what the bus system can accommodate, the exclusive lane can be converted to allow for the introduction of light-rail trains.[45]

Other possible measure is the implementation of restricted access areas. They have been created in many cases because of the attractiveness of creating pleasant spaces for pedestrians and bicyclists, which leads to a consequent reduction in polluting emissions. Examples of these projects are to be found in the historic downtowns of Tuscany, Strasbourg, Gothenburg, Cologne and Bologna. In Milan, rush-hour traffic has been reduced by up to 25%. However, in the cases of Kuala Lumpur and some cities in the United States, these restrictions have not had the same kind of success. In Vancouver's case, increasing tolls by 28% to 55% has led to a 1.2% to 2.1% reduction of trips.

One of the most novel policies is the so called "road pricing". For example, in Singapore access tolls have been implemented in certain areas via smart technology systems that allow tolls to vary according to the driving time and location of the route taken[46] (Pendakur, 1975). Additionally, and in contrast with the recommended measures based on World Bank studies, in 1972 the government of Singapore decided on the following strategy (Pendakur, 1975):

- Zoning strategies that minimise the need to travel
- Design and construction of roads in function of public transport instead of private transport
- Adoption of traffic administration measures
- Improvement of bus service (integration of private companies)
- Use of school buses during heavy-traffic hours
- Application of different taxes to reduce the acquisition of private cars (in contrast to the prediction of 267 cars per person in 1984, there were 86)

[44] *Estudio Integral de Transporte y Calidad del Aire en la Zona Metropolitana del Valle de México*, COMETRAVI, 1999...
[45] The Urban Edge, Issues and Innovations, 1991.
[46] Pendakur, Toll Road Strategy Assesment. Singapore. 1975

These measures achieved a composition of 69% of people transporting themselves in bus, 8% as passengers in cars, 6% on motorcycles, 2% on other forms and 15% driving cars.

Another common policy has been the application of gasoline taxes, which is an option for inducing a reduction in the use of private cars.[47] Stone (1994) evaluates the objectives and measures implemented in Denmark, France, Germany, Japan, Spain, Great Britain and the United States for reducing polluting emissions. Only Denmark and Great Britain got favourable grades and both plan to use taxes on certain fuels.

Although all these measures are useful in one way or another, it is more desirable to design and apply integral programs. Such kind of programs have been implemented in several countries, where the application of one-way traffic systems and integrated traffic lights, traffic administration schemes intended to improve pedestrian and bus mobility, lanes reserved for buses in central areas, bus networks with express service and the construction of needed lanes, among other things, cut traffic in the central area in half during the period of highest demand.

One part of an integral approach that should be kept in mind is the ease with which transfers can be made between different modes of transport, in such a way that the use of public transport is made accessible. To this end, there are simple measures that can be carried out: the installation of racks to transport bicycles on buses and light-rail trains, and other tactics with high unitary capacity.[48]

Other measures can be included within an integral program such as the introduction of fiscal incentives for workers who organise to share their automobile,[49] and the reduction of the width of side streets and speed limits, to make these more user-friendly for pedestrians and bicycles.[50]

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[47]R. Stone, Most Nations Miss the Mark on Emission - Control Plans, *Science*, vol. 266, December 23, 1994.
[48]See P. Berg, *et. al.*, *A Green City Program for the San Francisco Bay Area and Beyond,* San Francisco: 1986.
[49]Ver P. Berg, *et. al.*, *A Green City Program for the San Francisco Bay Area and Beyond,* San Francisco: 1986.
[50]*Ibidem.*

Finally, it is important to emphasize once again, the importance of urban design and urban form. It is important to point out the close relationship that exists between certain urban forms and problems with a city's roads and traffic. The expansion of cities via the phenomenon of suburbanisation has increased the distance that drivers have to cover,[51] worsening problems with streets and traffic. It has been proved that distortions in land markets can create excessive demand for transport.[52] Thus, more than meeting the new demand for urban transport, attempts should be made to prevent this from occurring.[53]

In the same vein, the design of cities in function of the automobile has caused their hidden costs to be ignored. For these reasons, zoning control policies and incentives for the mixed use of urban space are vital to achieving a sustainable system of roads and transport.[54]

A notable example is that of Curitiba, Brazil, whose transport plans are part of an integral approach that includes other aspects of sustainability. In this city, the channelling of urban growth along massive transport routes has achieved a significant reduction in the use of private transport. On a typical work day, 70% of employees use public transport and, as a result, gas consumption is 25% less than in other cities in Brazil.[55]

Alternative Toll Schemes.- The transport modal mix in the Mexico City metropolitan zone in terms of trip sections covered has deteriorated in the last few decades, to the point where modes of transport with low unitary capacity have a high amount of participation.[56] Thus, in a thirty-year time frame, the demand for trips in the metropolitan area should be

[51]A number of studies have shown that over the years the number of trips in automobile and distances have increased. For example, in the United States, the average driver drove 16% more kilometres to work than in 1969, 88% more to go shopping and 137% more for other activities. G.Quadri, El Nuevo Aeropuerto y su Significado, *La Jornada Ecológica,* 6 de junio 2000, p. 5.

[52]Newman and Kenworthy have shown that there is an inverse relationship between per capita fuel consumption and urban density.

[53]See International Union of Public Transport (1996); M. Renner, *Rethinking Transportation. State of the World*, 1989, Williams (1996); P. Berg, *et. al., A Green City Program for the San Francisco Bay Area and Beyond,* San Francisco: 1986.

[54]See *Urban Dynamics Research Program* (1999), *Habitat II* (1996), P. Berg, *et. al., A Green City Program for the San Francisco Bay Area and Beyond.*

[55]J. Rabinovitch & J. Leitman. Urban Planning in Curitiba, *Scientific American*, March, 1996: 26, p. 33.

[56] In the case of public transport, the problematic situation is worsened by old vehicles, whose contribution to the pollution problem is quite significant. See Sosa, 2000.

administrated via a modal mix of trip sections in which modes of transport with greater unitary capacity have a greater amount of participation.[57]

Thus, coherent price policies should encourage the use of subways linked with "feeder" networks, at the same time that they cut down on the use of collective vehicles, buses and taxis. For the purposes of this paper, the following changes are considered necessary within the modal mix of public transport:

TABLE 6.14
Modal Mix of Trip Sections
Within Public Transport
Current Vs. Desirable Situation, 2030

	Ruta - 100	Trolley	Subway	Small Bus	Taxi	Suburban	Other	ALL
CURRENT	8.13%	0.70%	15.78%	67.08%	3.10%	4.28%	0.94%	100.00%
DESIRABLE, 2030	17.52%	11.68%	58.41%	5.84%	0.47%	5.84%	0.23%	100.00%

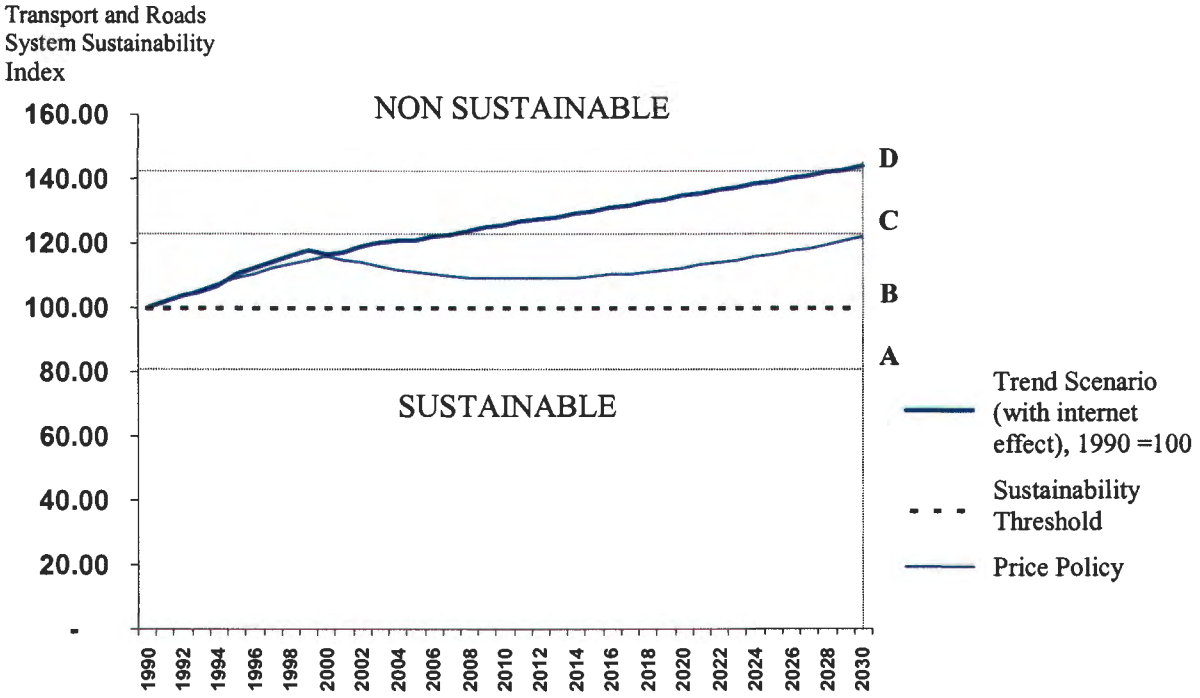
SOURCE: Own elaboration.

If in Mexico a Price Policy was implemented (together) or in conjunction with an improved and mst desired modes of transportation based on its best unitary capacity, in such a way that it would induce a change toward a suboptimal modal distribution of public transport, the index of sustainability for Transport and Road System would see a modification as demonstrated in Graph 6.17.

Graph 6.17 shows the effect of the proposed policy on the index of sustainability for Transport and Road System. Point "A" represents a non sustainable situation and "B" a barely sustainable situation. Thus, the effect of the price policy measured by the distance between "D" and "C" is the reduction of distance with respect to the goal of sustainability, (equal to 100).

[57] See *Estudio Integral de Transporte y Calidad del Aire en la Zona Metropolitana del Valle de México*, COMETRAVI, 1999... ; V. Ballinas, Megaciudad con aeropuerto en Hidalgo, *La Jornada,* October 30, 1995.

GRAPH 6.17
Implementation of Price Policy and Public Transport:
Effect on the Transport and Road System Rate of Sustainability



Source: Own elaboration, based on the construction of sustainability index.

The proposed policies are part of a basic scenario that takes into account the impact of greater Internet use. Furthermore, they implicitly lead to the assumption that price policies that reflect and internalise the negative externalities of transport in the Mexico City metropolitan zone should lead to a modal distribution that proportionately relates to the unitary capacity of each public transport option.

It should be taken into account that a system of tariffs that favours a modal redistribution that moves toward types of transport with higher unitary capacity is not the same thing as the indiscriminate use of subsidies, since such practices provoke financial imbalances that in the long term jeopardise these transport systems. This turns out to be especially

damaging in developing countries, since few of these have the resources to achieve both things: subsidies and the expansion of modes of transport.

This is an important factor in the long term, if one considers, for example, that in the case of the subway alone, the network proposed for the year 2020 should be made up by 14 subway lines with pneumatic tyres, three subway lines with rails and ten light-rail train lines, with a total length in service of 483 kilometres, to be developed in three stages: 2003, 2009 and 2020.[58]

Although it is true that this thesis does not consider the possible financial restrictions that could be faced with a change in the modal mix of transport, it is important to outline a few points that should govern the corresponding evaluations: 1) Review the prediction of demand in previous studies, 2) Determine whether there is an overestimation, 3) If there is a lot of demand, before undertaking costly investments, it is necessary to determine whether reductions can be made by other means (perhaps it has come about because of subsidies) such as price policies, 4) Analyse supply, 5) Analyse the composition of costs (functioning, capital, etc.) of the different options and express this in terms of passenger-kilometre, 6) Analyse necessary investments in relation to the corresponding public finances plan and the buying power of users and 7) Carry out an economic evaluation: shorter travelling time, convenience, comfort, security and less environmental impact.[59]

Price Policies for Most Congested Streets and Roads.-Another policy scenario to be analysed is the possibility of implementing a "road pricing" scheme, as it has been applied in other countries, such as Singapore. Nevertheless, it is necessarily one basic premise so that this kind of policy can be applied in a country such as Mexico: towards year 2030, Mexico City should be a much more digitalised metropolis for many reasons, such as an expected highest income level and higher average education years, as well as higher accessibility to these kind of technologies (Moore´s Law.)

[58] B. Navarro Benítez & S, Bacelis Roldán, El Metro como Sistema de Transportación Masiva, *La Ciudad de México en el fin del segundo milenio...*, pp. 378-383.
[59] W. A. Amstrong, *Sistemas de Trasnporte público urbano. Directrices para el Examen de Opciones*, Washington D.C.: Banco Mundial, 1987.

In this way, it is not a faraway assumption to consider the possibility of a more generalised Internet with important implications to the transport and road system sustainability level of Mexico City. One of these possibilities is associated to a higher monitoring capacity for the authorities.

And now, beginning from these premises, the proposed exercise consists of showing the effect of an increase in the taxes associated to the use of private cars, such as the respective "car property tax" as a function of the frequency of use and the roads associated to that use. The criteria that should be implicit in this policy are the road congestion in certain parts of the system as well as the disposition of public transport in that road.

Supposing that in a 15-year time frame the availability of public transport with greater unitary capacity can be improved in such a way that it is relatively homogenous in the principal corridors and intersections of the metropolitan area, a vehicle's passing through the intersections shown in Table 5.16 should be associated with a greater car tax charges.

TABLE 6.15
Intersections whose Level of Service
Makes Payment of Automovile Tax Necessary, derived from their use [60]

- **Periférico / Centenario**
- **Periferico / Autopista Peñón - Texcoco**
- **Periférico / Av. Pantitlán**
- **Periférico / Av. Xochiaca**
- **Periférico / Blvr. Centro**
- **Av. Ignacio Zaragoza / Circuito Interior**
- **Martín Carrera / Centenario**
- **Ferrocarril Hidalgo / Talismán**
- **Insurgentes Norte / Eje 2 Norte**
- **Av. Constituyentes / Acueducto**
- **Periférico / Legaria**
- **Vía Morelos / Av. Revolución**
- **Av. 100 Metros / Periférico Norte**
- **Av. Gustavo Baz / Mario Colín**
- **Aquiles Serdán / Calzada de las Armas**
- **Av. Mario Colín /Circunvalación**
- **Calzada Vallejo / Tequesquinahuac**
- **Mariano Escobedo / Av. Marina Nacional**
- **Mario Colín / Av. Toltecas**
- **Aquiles Serdán / Eje 4 Norte**
- **Río San Joaquín / Ingenieros Militares**

SOURCE: *Estudio Integral de Transporte y Calidad del Aire en la Zona Metropolitana del Valle de México*, COMETRAVI, 1999.

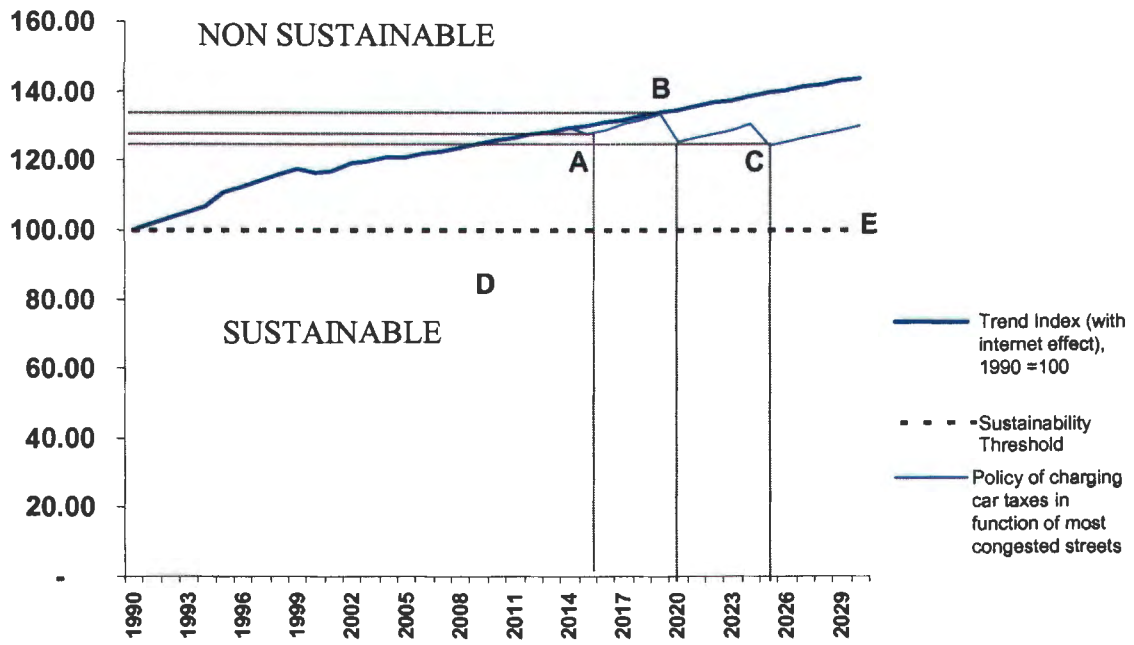
[60]The level of service of an intersection is a measure of its capacity to accommodate the cars that pass through and make turns there. Defining it as a function of delay, it is a measure of the frustration and discomfort of the driver, as well as of the consumption of fuel and the amount of time lost in the trip.

It is estimated that about 67% of the trip sections associated with private vehicles are related to the use of street corridors that involve the intersections mentioned above.

Thus, the application of the proposed policy would be equivalent to introducing a tax on 67% of trip sections in private cars. That is, on the basis of the estimates of the opportunity cost associated with the level of congestion derived from the modal participation of private transport, it could be said that the use of the mentioned intersections contributes 67% of the total cost of global congestion in the metropolitan area. Therefore, "fairer" price policies should distribute the 67% of the total cost of congestion between the users who produce 67% of the trip sections on the most congested streets.

Graph 6.18 shows the corresponding results, based on the alternative scenario of greater use of the Internet and the assumption that the implementation of this policy will be possible in a progressive manner, beginning in the year 2015. As well Graph 6.18 shows the behaviour of the Sustainability Index for Roads and Traffic with the application of this proposed policy. Points A, B and C represent the progressive application of a fee for the use of the streets with the most traffic. The result is a reduction of the distance with respect to a "barely sustainable" point such as E and a sustainable one such as D.

GRAPH 6.18
Charging of Automovile Tax in Function of Use of the Most Congested Intersections Effect on the Sustainability Indicator for Roads and Traffic

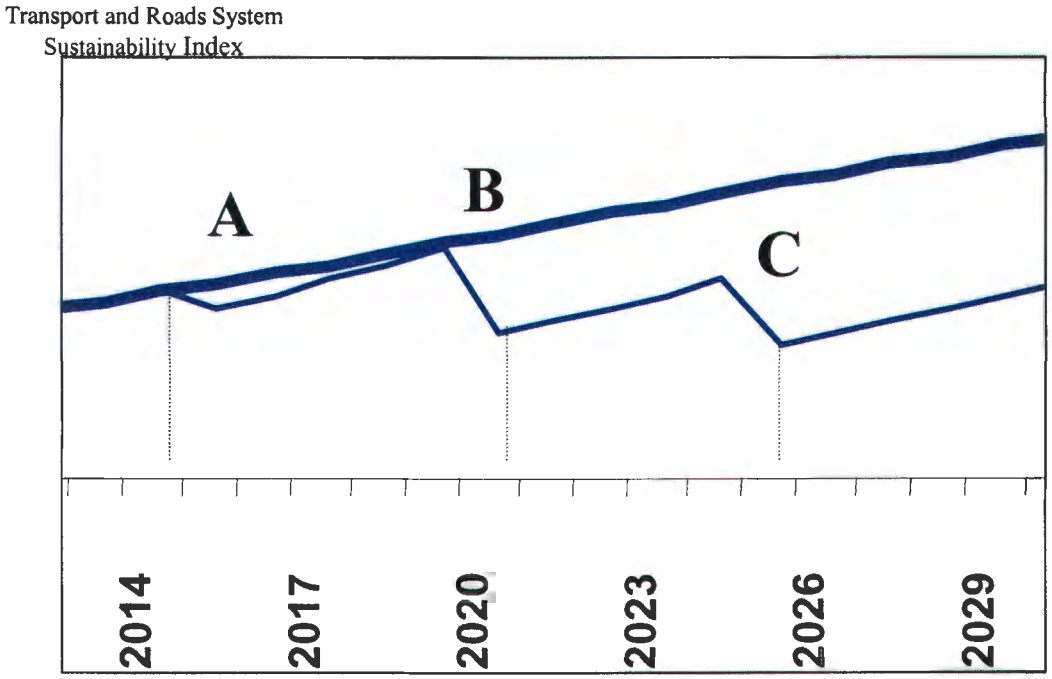


SOURCE: Own elaboration, based on constructed sustainability indicators.

Graph 6.19 shows in more detail the impact of progressively charging for the use of congested streets on the sustainability indicator of Roads and Traffic.

GRAPH 6.19

Details on Charging for the Use of the Most Congested Streets: Effect on the Sustainability Indicator for Roads and Traffic



SOURCE: Own elaboration based on the analysis of the sensitivity of constructed sustainability indicators.

Table 6.16 shows in detail the quantification of the effects that the policy of charging for the most congested streets has on the Sustainability Index of Roads and Traffic. The main change with respect to the Trend Scenario is the reduced participation of private transport in the demand for daily trip sections, along with the greater importance of public transport. The direct effect of this is a reduced weighted demand and, in consequence, a lower sustainability index.

TABLE 6.16
Construction of the Sustainability Index of Roads and Traffic
Charging for the Use of the Most Congested Streets

	Expected Demand of Segments of Daily Trips	Segments of Trips in Private Transport	Segments of Trips in Public Transport	Tendential Weighted Average Demand	Trend Index
2000	32,667,275	5,987,769	26,679,506	0.094	120
2005	33,342,490	6,830,326	22,395,266	0.093	119
2010	34,144,293	7,791,443	20,517,552	0.096	122
2015	34,298,450	6,379,340	20,127,596	0.082	104
2020	34,647,528	5,736,621	21,483,263	0.074	95
2025	34,902,652	5,435,693	24,346,853	0.071	90
2030	34,861,454	6,200,567	28,660,887	0.077	99

SOURCE: Table is by author, and is based on constructed sustainability indicators.

Importance of the Promotion of the Generalized Use of the Internet.- If the results presented in this study come even a little close to what will happen in Mexico City during the next thirty years, policy decisions by metropolitan authorities with respect to the promotion of the use of the Internet including digital technologies and broad band penetration will be of great relevance for the development of the economy and environment in the city.

It should be remembered that if Mexico City has the highest income per capita in the country, there exists inherent factors within the characteristics of an emerging economy like Mexico's that can foster the "universality of the Internet." For example, low indicators in

terms of telephone density will force the public sector to take a more active role in the promotion of these technologies. In this context, access to the net in public places like libraries, plazas and other community spaces will be of vital importance. It is urgent that authorities prepare for the initiative of required regulatory reforms necessary for the promotion and the use of the network as well as substantial user increase.

As mentioned in the previous chapter, within the sphere of "business to consumer" relationships there are concerns with regard to payments realized on the Internet, fear of fraudulent merchandise and use of private information of the user. In the case of the "business to business" relationship there are also concerns about the necessity of revealing sensitive information about production processes to suppliers or other client companies.

Regulation in terms of consumer protection and business codes will be very important to address these concerns and encourage growth of goods and service businesses through the network and hopefully bring the expected impact on daily travel in Mexico City.

With respect to policies associated with transportation and environmental contamination variables in Mexico City, the results of future studies on this issue will be evaluated in relation to cost and convenience of conventional measures including the expansion of the subway (metro) network, trams and trolleybuses or light trains, the improvement and expansion of bus lanes, the substitution of minibuses for auto buses and other measures designed to increase and improve the transportation network.

It is possible that the implementation of incentives designed to promote economic relations "business to business" and "business to consumer" through the internet may be less costly and more effective in the long-term than many previous designed measures.

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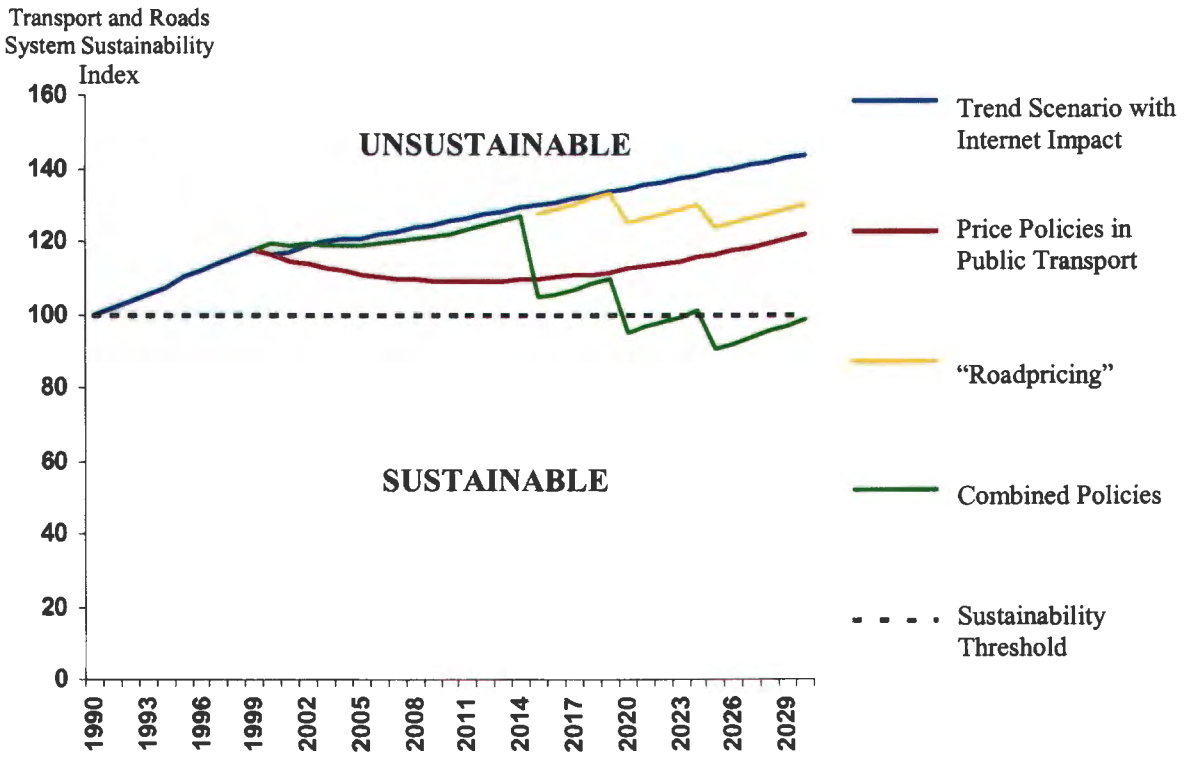
The policy options that have been mentioned in this chapter are vital to combat road infrastructure and transportation problems in Mexico City. However on top of whatever measure designed to help mitigate the problems related to demand of daily trips in Mexico City, problems should be addressed under a new principle; more than reacting to problems,

they should be avoided altogether. With this philosophy in mind, the use of digital technology could contribute in an important way to the slowing down or breaking the growth of the demand pattern of daily travel in Mexico City.

EFFECT OF COMBINED POLICIES ON ROAD AND TRANSPORT

If the two price policies that were proposed in earlier sections were combined (respecting the stages of each one); it would be possible to arrive at the threshold of sustainability in a span of thirty years. The corresponding result is illustrated below in Graph 6.20

GRAPH 6.20
Road and Transport Combined Policies:
Effect on the Sustainability Indicator

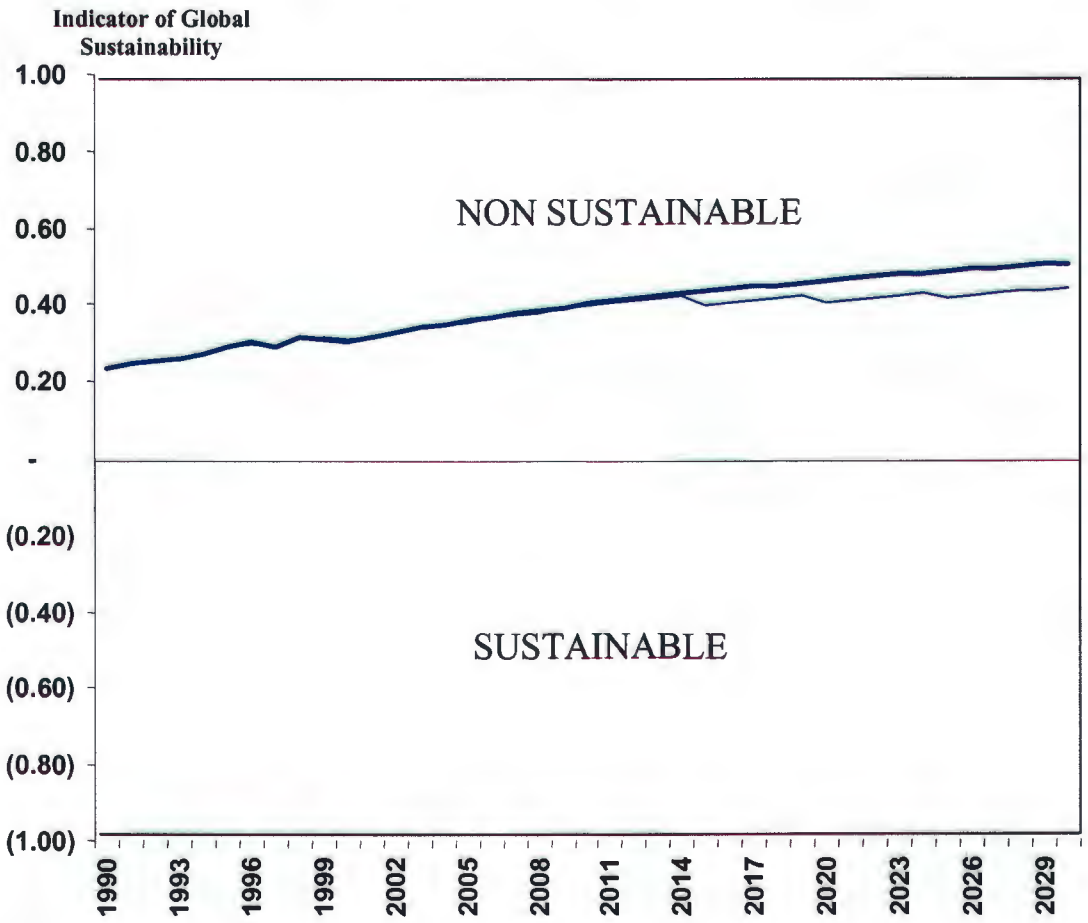


SOURCE: Own elaboration, based on analysis of sensibility of constructed indicators.

EFFECT OF POLICIES OF TRANSPORT AND ROAD INFRASTRUCTURE, ON THE INDICATOR OF GLOBAL SUSTAINABILITY

Assuming an equal weight for all variables within of the global indicator, including that of transport and roads system, the effect of combining the policies may look as follows: (Graph 6.21)

GRAPH 6.21
Road Infrastructure and Transit Policy:
Effect on the Indicator of Global Sustainability



SOURCE: Own elaboration, based on analysis of constructed indicators.

As can be seen in Table 6.17, the application of the combined policies designed to improve the road infrastructure and transport systems in Mexico City implies an improvement in the indicator of global sustainability which in the year 2000 registered 0% and in the year 2030 a little more than 6.42%.

TABLE 6.17

Percentage Annual Effect of Road Infrastructure and Transport Policies – on the Indicator of Global Sustainability, 2000 – 2030

	TREND	POLICY APPLICATION	% IMPROVEMENT
2000	0.300972826	0.3059	0.00%
2001	0.312784447	0.3157	0.00%
2002	0.327471019	0.3278	0.00%
2003	0.337989409	0.3368	0.12%
2004	0.347998293	0.3455	0.25%
2005	0.355898954	0.3533	0.26%
2006	0.365604386	0.3622	0.34%
2007	0.374794156	0.3707	0.41%
2008	0.383640665	0.3791	0.45%
2009	0.392177793	0.3874	0.48%
2010	0.40043658	0.3955	0.49%
2011	0.407036404	0.4023	0.47%
2012	0.413469208	0.4091	0.44%
2013	0.41971724	0.4158	0.39%
2014	0.425800755	0.4225	0.33%
2015	0.431738402	0.3954	3.64%
2016	0.437707839	0.4017	3.60%
2017	0.44354442	0.4080	3.56%
2018	0.449282699	0.4143	3.50%
2019	0.454936195	0.4206	3.43%
2020	0.460517419	0.4043	5.62%
2021	0.465789003	0.4102	5.56%
2022	0.470803645	0.4159	5.50%
2023	0.475647832	0.4215	5.42%
2024	0.480344085	0.4270	5.33%
2025	0.484912659	0.4156	6.93%
2026	0.489128632	0.4207	6.85%
2027	0.493341584	0.4258	6.75%
2028	0.497451088	0.4310	6.65%
2029	0.501470495	0.4361	6.53%
2030	0.505457283	0.4413	6.41%

SOURCE: Own elaboration, based on constructed indicators.

6.1.4 Air Pollution

In the last thirty years, atmospheric pollution has been one of the biggest challenges that Mexico City has ever faced. Although the problem continues to being a grave concern and there is a lot more around to cover, it is perhaps one of the few areas where success has been achieved by environmental authorities.

Beginning with the first measurements of this phenomena in 1986[61] and more concretely through the implementation of the Integral Program Against Atmospheric Contamination in the Valley of Mexico (IPAAC), whose main strategies focused on the improvement of combustibles, the reduction of automobiles, the modernization of technology and the control of industry and service emissions and finally the ecological restoration of many forests, great advancements were made in the reduction of the levels of smoke, sulphur dioxide, carbon dioxide, hydrocarbons and nitrogen oxide, elements generated by the destruction of forests, erosion of deforested zones, hidden garbage dumps, among other contributing factors.[62]

The continuation of these policies can be found in PROAIRE (Program For the Improvement of Air Quality in the Valley of Mexico , 1995 – 2000), particularly referring to the introduction of automobile technologies that have lower levels of contaminating emissions. However, despite these accomplishments, problems concerning the ozone and suspended particles persist as both remain outside acceptable levels for 24 hour periods, bringing serious health concerns to the population.

Therefore, both issues go hand in hand, the quality of air and the efficiency of transport systems, so that definite solutions to atmospheric contamination in Mexico City require an integrated approach; one that incorporates transportation planning, environmental considerations, and urban development issues.

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[61] *Programa para Mejorar la Calidad del Aire de la Zona Metropolitana del Valle de México, 2002 – 2010.*

[62] *Ibidem.*

Beginning with this indissoluble relationship, policies evaluated through our indicator of sustainability in terms of atmospheric contamination are designed to reflect policy changes with regard to road infrastructure and transport systems as well. However, it should be emphasized that there are other measures that should be applied, such as the improvement of technology, the operation of car parks or the improvement of combustibles.

DEFINITION OF THE SUSTAINABILITY INDEX

An index was created using from the total number of emissions in a given year, and which considered the total tonnage of contaminants that make-up suspended particles, including sulfur dioxide, carbon dioxide, nitrogen oxides and hydrocarbons (according to statistics presented in the previous chapter). These emission totals which were obtained from each of the modes of transportation, although pollution output from industry, services and business was taken into account, are directly related with the index of sustainability of road infrastructure and transportation that was presented in the previous chapter.

INDEX OF SUSTAINABILITY OF ATMOSPHERIC POLLUTION=100 * TC_t / TC_{1990}

Where

TC_t = Tonnage of Pollutants in a given year

TC_{1990} = Tonnage of Pollutants in base year (1990) which is to say, 3.4 million tons.

Total tonnage in given year is made-up in the following manner:

TC_t =
Dmetro*EUmetro + Dbus*EUbus + Dtrolleybus*EUtrolleybus + Dsuburban*EUsuburban + Dtaxi*EUtaxi + Dprivate*Euprivate + Dcollective bus*Eucollective bus +Dother*Euother +ECIND +ECSC
Dmetro = demand of trips portion in metro

Dbus= demand of portions of trips in autobus

Dtrolleybus= demand of portions of trips in trolleybus

Dsuburban= demand of portions of trips in transport suburban

Dtaxi= demand of portions of trips in taxi

Dparticular= demand of portions of trips in automobile

Dcollective bus= demand of portions of trips in collective bus transport

Dother= demand of portions of trips in other modes of transport

EUmetro = emissions units per portion of trip in metro

EUbus= emissions units per portion of trip in autobus

EUtrolleybus= emissions units per portion of trip in trolleybus

EUsuburban= emissions units per portion of trip in suburban transport

EUtaxi= emissions units per portion trip in taxi

EUparticular= emisions units per portion of trip in automobile

EUcollectivebus= demand of portions of trips in collective transport

EUothers= demand of portions of trips in other modes of transportation

ECIND= emissions totals attributed to industry

ECSC= emissions totals attributed to services and business

TREND SCENARIO

Projections were constructed according to emission levels obtained from the following table:

TABLE 6.18
Mexico City: Inventary of Emissions, 1994
(Tonnage per Year)

	TOTAL	%	(PST)	(SO2)	CO	NOx	HC
INDUSTRY	105,729	2.64%	6,323	26,053	9,433	31,518	32,824
SERVICES	413,013	10.30%	903	7,229	2,358	5,403	399,021
TRANSPORT	3,026,645	75.48%	18,968	12,185	2,346,350	91,725	554,936
SOIL AND VEGETATION	464,246	11.58%	425,420	-	-	-	38,979
TOTAL	4,009,629	100.00%	451,614	45,468	2,358,141	128,646	1,025,760

SOURCE: *Estudio Integral de Transporte y Calidad del Aire en la Zona Metropolitana del Valle de México*, Vol. 1, COMETRAVI, 1999.

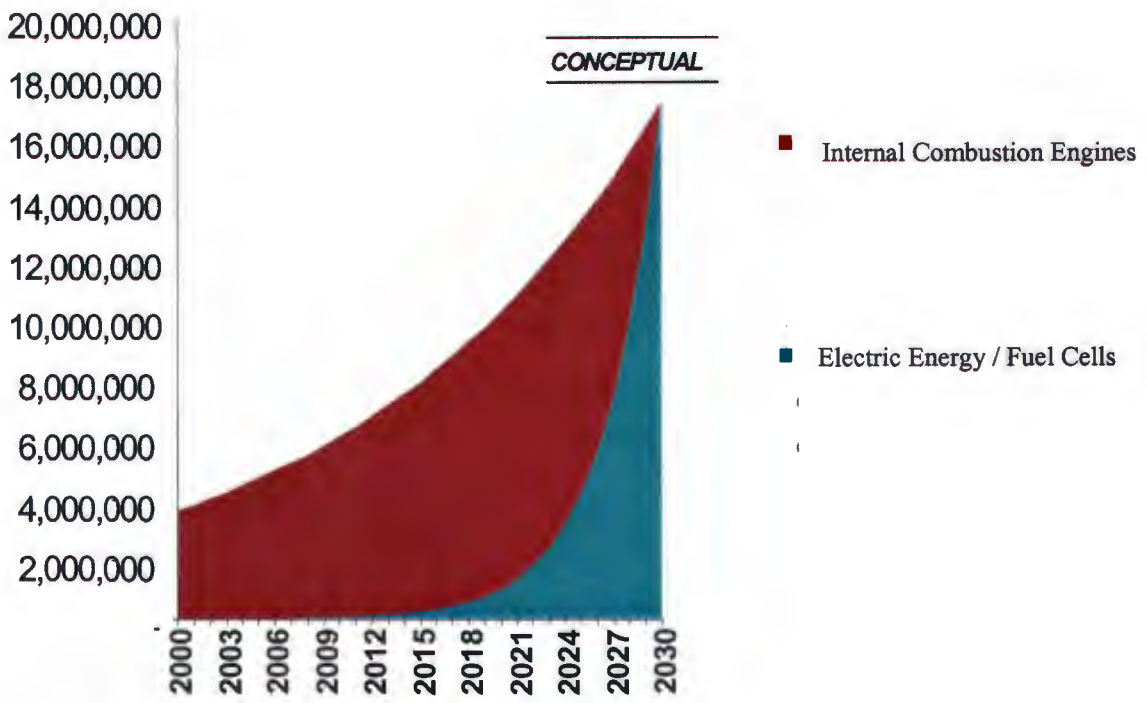
Industry and Services.- The number of industries, businesses and services was projected according to figures in Chapter 3 of this work. As well, it was supposed that emission units for the industry, service and business sectors will maintain their levels between the year 2000 and the year 2030.

Modes of Transportation.- The corresponding projections were obtained, taking into account emission units per each portion of travel and according to the mode of transportation. The projections of portions of travel are presented in the index of road infrastructure and transport.

Air Pollution.- Trend Scenario with Technological Considerations.- As has been mentioned on repeated occasions, one of the repercussions of the technological advances derived from digitalization and some advances in electrical mechanics is the introduction of this advanced technology in automobiles.

Automobiles powered by electrical energy or hydrogen cells will have a higher level of usage which signifies that circulating cars in Mexico City inside of thirty years will have a zero or close to zero level of contaminating emissions.

GRAPH 6.22
Total Number of Automobiles in the Metropolitan Zone of Mexico City, 2000 to 2030



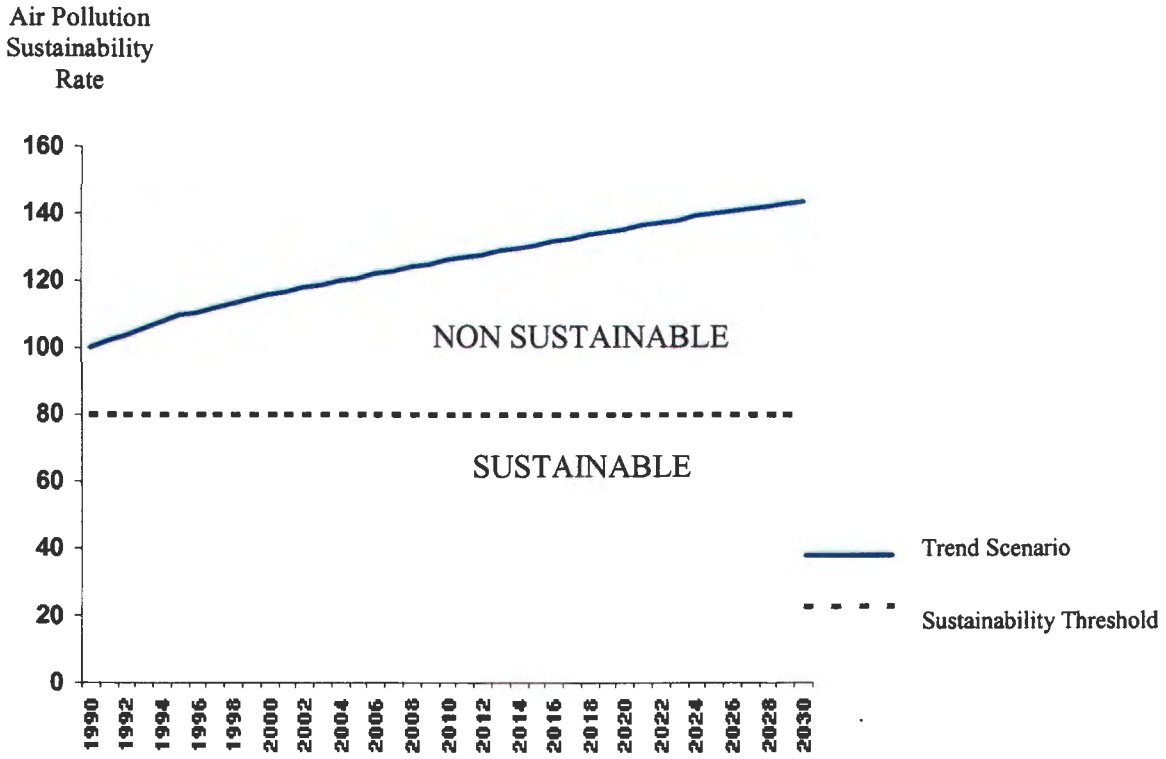
SOURCE: Own elaboration.

THRESHOLD OF SUSTAINABILITY

Taking into account planned objectives in the study " Integral Study of Transport and Air Quality in the Metropolitan Zone of the Valley of Mexico," realized by COMETRAVI in 1997 and published in 1999, the suggested maximum level of emissions-as an objective-for the year 2030 in Mexico City was 2.8 million tons of contaminants,[63] including all the sources mentioned.

[63]A very similar figure registered in 1990.

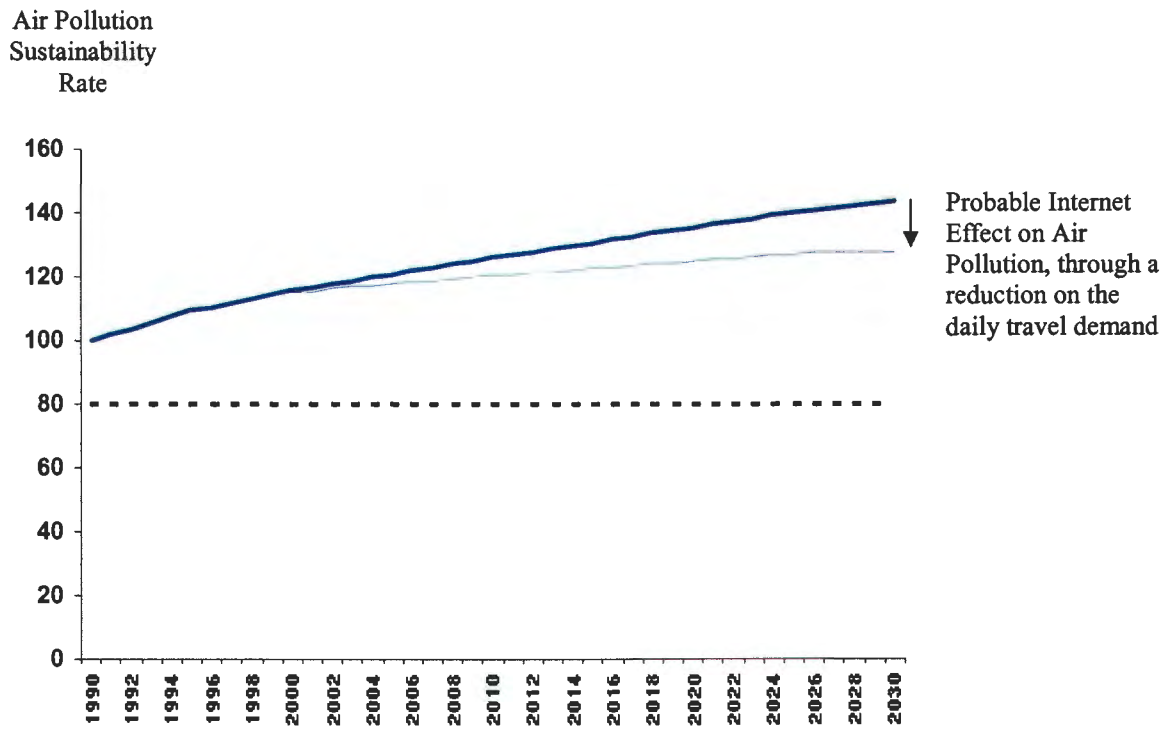
GRAPH 6.23
Air Pollution in Mexico City:
Threshold of Sustainability Vs. Trend Scenario
(1990=100)



SOURCE: Own elaboration, based on indexes of constructed sustainability.

Due to the existing link between the index of road infrastructure, transport and the index of environmental contamination, the possible effects of the "internet" in terms of the reduction of traffic can translate into lower emission levels.

GRAPH 6.24
Air Pollution in Mexico City: Impact of "Internet"
(1990=100)



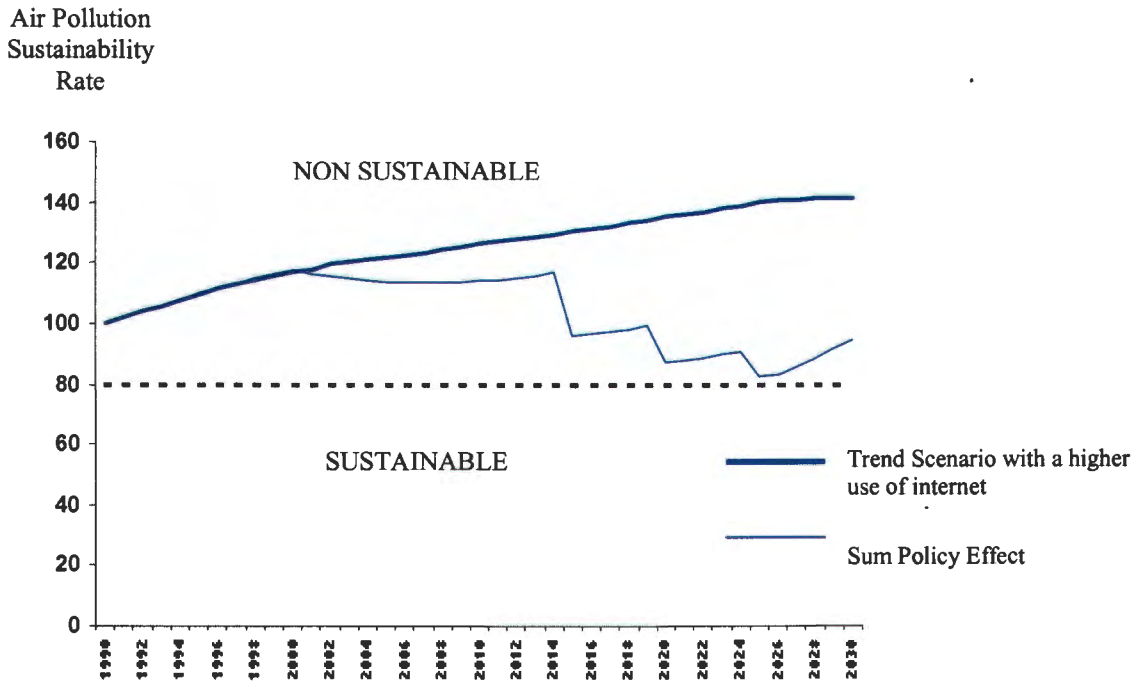
SOURCE: Own elaboration based on indexes of constructed sustainability.

ANTIPOLLUTION POLICY SCENARIOS

Effects Derived from the Application of Policies of Road Infrastructure and Transport.- Taking into account the consideration of different modes of transportation in the indicator of sustainability of road infrastructure, and transit is a function of the unit capacity of each of the modes of transportation, and the use of these modes of transportation at a higher unit capacity implies the use of "less motors for more people , more trips and more portions of travel," which suggest that the policies described in the previous section fulfil as well, the objective of improving the indicator of sustainability of atmospheric contamination.

Graph 6.25 shows the effect of the combined policies of transport and road infrastructure in the indicator of sustainability of environmental contamination

GRAPH 6.25
Combined Policies of Road Infrastructure and Transport: Effect on the Indicator of Sustainability of Air Pollution

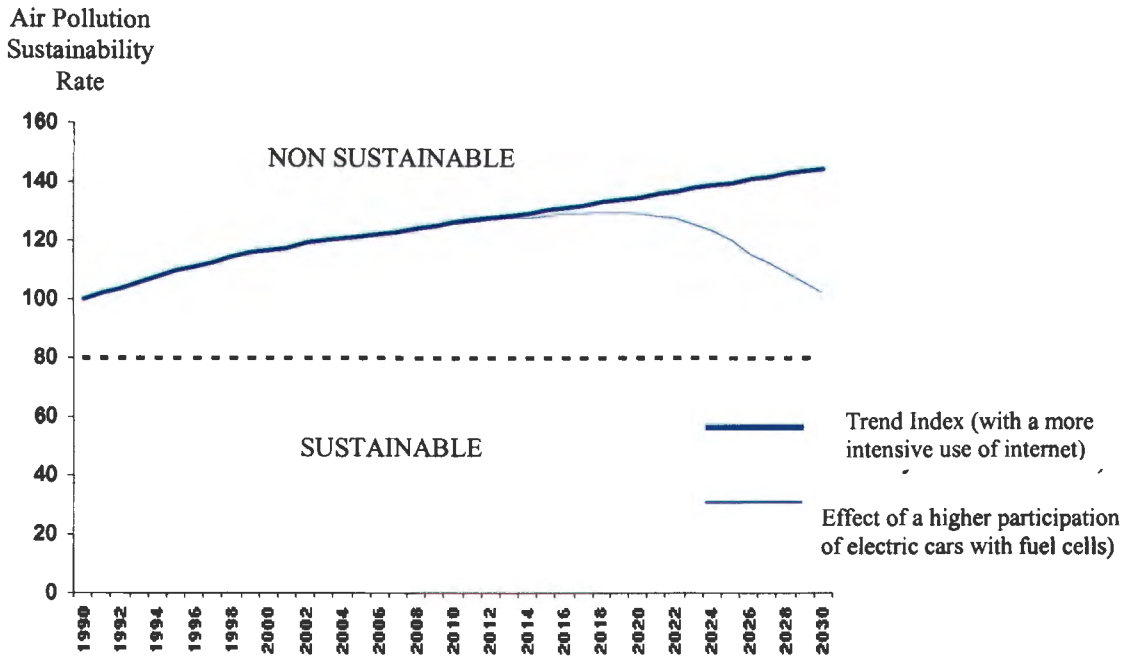


SOURCE: By author based on analysis of sensibility of indicators of constructed sustainability.

Improved Penetration of Automobiles Powered by Electricity and Hydrogen Fuel Cells.- As mentioned in previous sections it is possible that technological advances may permit in the next thirty years that the majority of automobiles in circulation be powered by electrical energy or hydrogen cells, reducing contaminating emissions.

Graph 6.26, shows an exercise that outlines the effects in the event this possibility materializes.

GRAPH 6.26
Substitution of Combustion Autos Powered by Gasoline:
Effect on the Indicator of Sustainability of Environmental Pollution

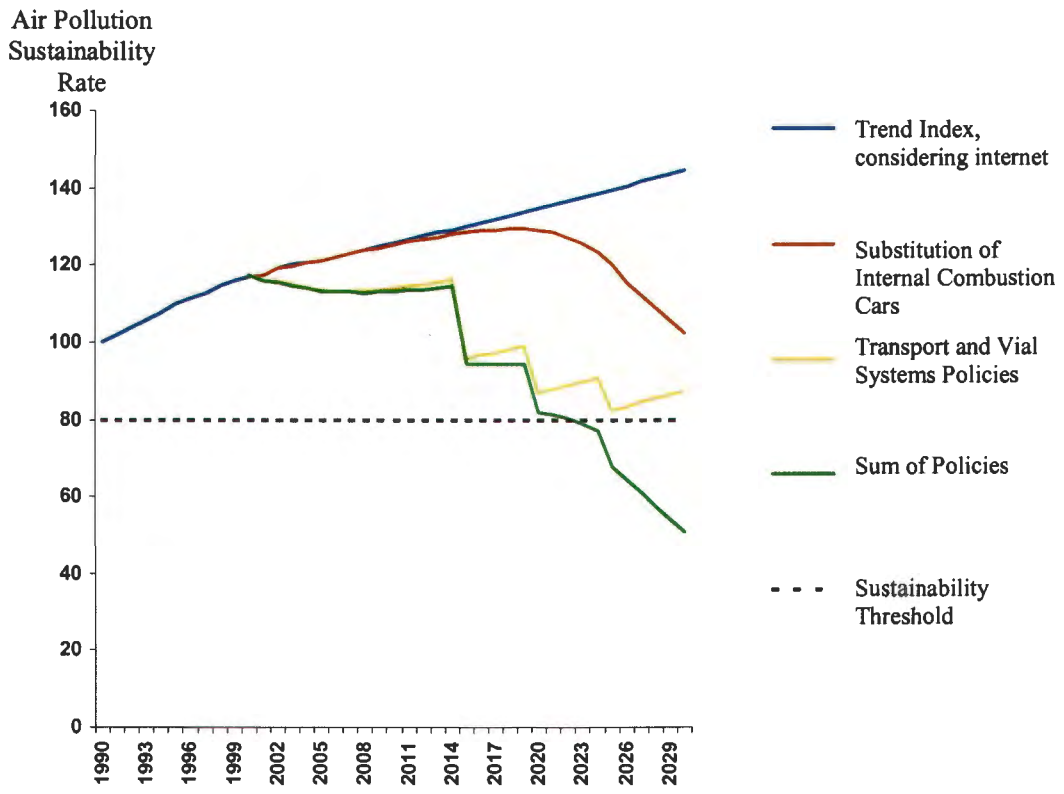


SOURCE: Own elaboration based on analysis of sensibility of indicators of construed sustainability.

Combined Policies and Effect of the Substitution of Internal Combustion Automobiles: Graph 6.27 shows the effect of the combination of the policies of road infrastructure, transit and the substitution of autos of internal combustion on the indicator of sustainability of environmental contamination. As seen in the case of combining both policies, Mexico City in thirty years could even surpass the threshold of environmental sustainability.[64]

[64] In a few decades the vehicle renewal program initiated in Mexico City could be considered the precursor to the introduction of vehicles with hydrogen cells. It should be taken into account that this would not be the solution for road and transit problems.

GRAPH 6.27
Combined Policies of Transport and Roads System:
Effect on the Indicator of Sustainability of Environmental Pollution

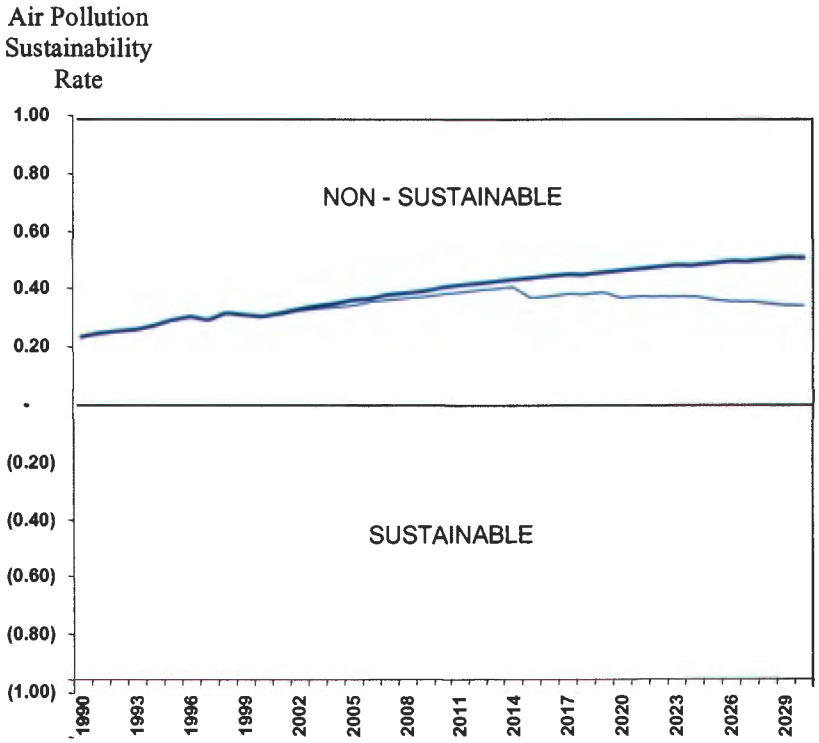


SOURCE: Own elaboration based on analysis of sensibility of indicators of construed sustainability.

THE EFFECT OF POLLUTION ABATEMENT POLICIES ON THE INDICATOR OF GLOBAL SUSTAINABILITY

Again, supposing that within of the indicator of global sustainability is given relatively equal weight to all considered variables including the variable of contamination, and the effect of the combination of pollution control policies would be the following:

GRAPH 6.28
Pollution Policies:
Effect on the Indicator of Global Sustainability



SOURCE: Own elaboration based on analysis of sensibility of indicators of constructed sustainability.

As can be seen in Table 6.19, the application of the combination of policies that reduce atmospheric contamination in Mexico City Metropolitan Zone shows an improvement in the global indicator of sustainability that is at 0% in the year 2000 and a little more than 16% in the year 2030.

TABLE 6.19
Percentage Effect of Pollution Control Policies on the Global Sustainability Indicator 2000 to 2030

	TREND	APPLICATION OF POLLUTION POLICIES	% IMPROVEMENT
2000	0.300972826	0.3019	0.00%
2001	0.312784447	0.3101	0.00%
2002	0.327471019	0.3211	0.00%
2003	0.337989409	0.3286	0.94%
2004	0.347998293	0.3360	1.20%
2005	0.355898954	0.3417	1.42%
2006	0.365604386	0.3492	1.64%
2007	0.374794156	0.3565	1.83%
2008	0.383640665	0.3637	2.00%
2009	0.392177793	0.3707	2.15%
2010	0.40043658	0.3776	2.28%
2011	0.407036404	0.3833	2.38%
2012	0.413469208	0.3889	2.46%
2013	0.41971724	0.3944	2.53%
2014	0.425800755	0.3998	2.60%
2015	0.431738402	0.3675	6.42%
2016	0.437707839	0.3720	6.57%
2017	0.44354442	0.3763	6.72%
2018	0.449282699	0.3803	6.89%
2019	0.454936195	0.3840	7.09%
2020	0.460517419	0.3658	9.47%
2021	0.465789003	0.3682	9.76%
2022	0.470803645	0.3698	10.10%
2023	0.475647832	0.3704	10.52%
2024	0.480344085	0.3698	11.05%
2025	0.484912659	0.3558	12.91%
2026	0.489128632	0.3525	13.66%
2027	0.493341584	0.3491	14.42%
2028	0.497451088	0.3456	15.19%
2029	0.501470495	0.3419	15.95%
2030	0.505457283	0.3383	16.72%

SOURCE: Own elaboration based on constructed indicators, and using Excel 5.0

6.1.5 Management of Solid Waste

Perhaps only after the problems related to the water balance and air quality, the management of solid wastes comes next as far as its urgency in Mexico City. Inadequate management of solid wastes encourages the formation of lixivials, high concentrations of biogas and the proliferation of harmful fauna (rodents and others) between other harmful processes distinct to the natural environment; water, ground and even air. As well the consequences for health in many cases are still unknown.

Taking into account one of the above-mentioned principles of Daily, which suggests that pollutants and wastes should not be emitted at a higher rate than the natural systems can absorb, the construction of an indicator must have a focus on the balance between the generation and the capacity of absorption. This as well is congruent with one of the most orthodox analytical frameworks from an economic point of view, which suggests that waste generated over and above the capacity of absorption should bring negative externalities that would be susceptible to monetary penalties. Therefore, and the same as the rest of the indicators, the focus of said index should be the "balance" and the mechanisms of the market.

DEFINITION OF THE SOLID WASTE MANAGEMENT RATE

The index was built based on two fundamental parts: 1) The total volume of solid wastes that should be generated in Mexico City on the one hand and 2) The capacity of management of wastes generated through recycling processes. (land fills, open air waste disposal)

Solid Waste Management Sustainability Index = CRS_t / GRS_t

where

CRS_t = The Capacity of The Management of Solid Waste which depends on the possibilities of recycling garbage, waste in lavatories and other variable related with the treatment of solid wastes

GRS_t = Generation of solid wastes that depend on kilos produced per habitant, which is a growing function of the level of income per capita

And where "t" corresponds to the variables of the period in question

SOLID WASTE: TREND SCENARIO

The average amount of solid waste generated per inhabitant in the Federal District was obtained for 1987 and 1997. The value corresponds to 1997 (0.66 tons per habitant or 1.8 Kg. daily per habitant) and is used as a figure for all of the MCMZ.

Incorporating Federal District statistics, the level of growth of the generation of wastes was calculated per capita between 1987 and 1997 (equivalent to 1.44% annual). This rate was used to project the growth of the volume of waste solids with an eye on the year 2030.

The following is a summary of obtained results:

TABLE 6.20
Volume of Solid Waste Towards 2030

YEAR	POPULATION	Population Growth	Volume of Generated Solid Waste	Tons per inhabitant Per year	Daily Kg. Per inhabitant
1997	17,491,610	2.09%	11,497,771	0.66	1.80
2000	18,532,334	1.75%	12,715,742	0.69	1.88
2005	20,063,104	1.50%	14,786,178	0.74	2.02
2010	21,454,400	1.25%	16,983,232	0.79	2.17
2015	22,671,152	1.05%	19,276,305	0.85	2.33
2020	23,872,454	1.03%	21,801,855	0.91	2.50
2025	25,118,966	1.02%	24,640,207	0.98	2.69
2030	26,411,448	1.00%	27,827,936	1.05	2.89

SOURCE: Estimates by author based on figures from *Estadísticas del Medio Ambiente del Distrito Federal y Zona Metropolitana, 1999* ,México: SEMARNAP / INEGI, 1999, p. 231.

In terms of the capacity of the management of waste it was supposed that tonnage per capita of annual generation of garbage should have been approximately 0.25 in 1990 and that the quantity of recycled garbage was only 5%. Starting from this year it was supposed that the generation of waste per capita should be maintained a constant and the total volume of solid wastes should increase according to the proportion of the population, given for the possibilities of recycling the year before. Additionally, it was supposed that recycling would increase until it reached 90% in the year 2030.

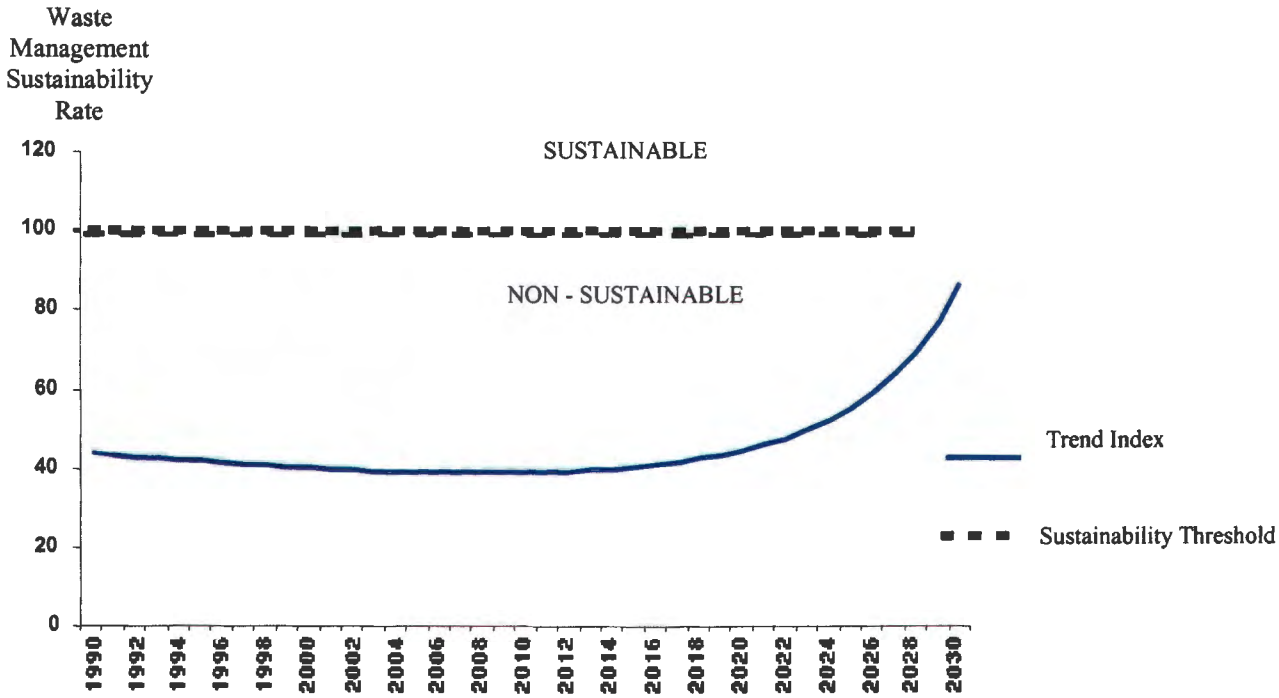
SUSTAINABILITY THRESHOLD

As explained at the beginning of this section, the threshold of sustainability simply occurs when the index takes a value of 100 (the generation of waste is at least equal to the capacity of management whether it be recycling or other methods).

In this way, Mexico City will be in a situation of sustainability when the index reaches higher than 100, which is to say that when the capacity of waste management is higher than

the yearly generation of waste. In contrast to a situation that is not sustainable when the index is less than 100, and more solid wastes are generated annually that can be managed through recycling.

GRAPH 6.29
Management of Solid Waste in Mexico City:
Threshold of Sustainability Vs. Trend Scenario
(Supply=Demand: Index =100)



SOURCE: Own elaboration, based on constructed indicators of sustainability.

SOLID WASTE MANAGEMENT: POLICY SCENARIOS

To create polices to promote better management of solid wastes in Mexico City three stages must be identified: –the generation, collection and final disposal of waste. Additionally, it must be kept in mind that there exists an opportunity cost between facility and convenience of the applied policies, depending on each stage. For example a policy designed to change the habits of the generation of waste may be high impact but also difficult to change cultural and custom variables. On the other hand, a policy designed to improve waste collection or final disposal of waste can contribute in a positive way but it will not address

the problem in full. In whatever case, the proposed policies should be evaluated with closer detail to determine with precision the advantages and disadvantages as well as costs and benefits.

Implementation of Waste Collection Quota -One policy option is the implementation of a ceiling on the quantity of waste per home to be collected without any cost. Any extra waste over this quota would have a cost that will be based on social and economic evaluations that would determine the cost of absorbing the waste via landfills, recycling or other processes like composting or incineration.

In the case of Mexico City each inhabitant generates around 600 kg annually of waste; which will increase to 1000 kg by the year 2030 in contrast with 700 kg produced in more industrialized economies like the United States or Canada. Therefore, it is desirable that the level of solid waste in Mexico City does not increase any more. An adequate benchmark quota for waste collection could be 1.82 kilos per person each day.

In terms of policy implementation, it is supposed that the figure of 1.82 Kg. of waste per day per habitant is maintained also on the "generation of waste" side without any change in the "capacity to absorb" garbage, however the underlying thesis is that waste over the quota would be penalized in proportion to the necessary cost for the extra waste to be reabsorbed.

Additionally, it is necessary that this policy be accompanied with the idea of creating "markets of solid waste", in such a way that an important proportion of extra wastes in collection could be absorbed through an increase in the rate of recycling.[65] As well, this can be accomplished if commercial value for waste products increases in Mexico City.[66]

[65]What is more desirable than an increase in the rate of recycling is an increase in the rate of reusage of solid wastes, in such a way that waste quotas would not be surpassed. About the difference between reusage and recycling, see P. Berg, *et. al., A Greeen City Program for the San Francisco Bay Area and Beyond.*
[66] A. Deffis, *Vivienda Social. Conjuntos Habitacionales Artificiales,* México, 2000.

Other Measures.- With respect to the creation of markets, the participation of the public sector could be very determining. For example municipal authorities can buy part of the paper waste with the idea of recycling and using it for their own paper needs. Another measure along these same lines would be to initiate the creation of markets.[67]

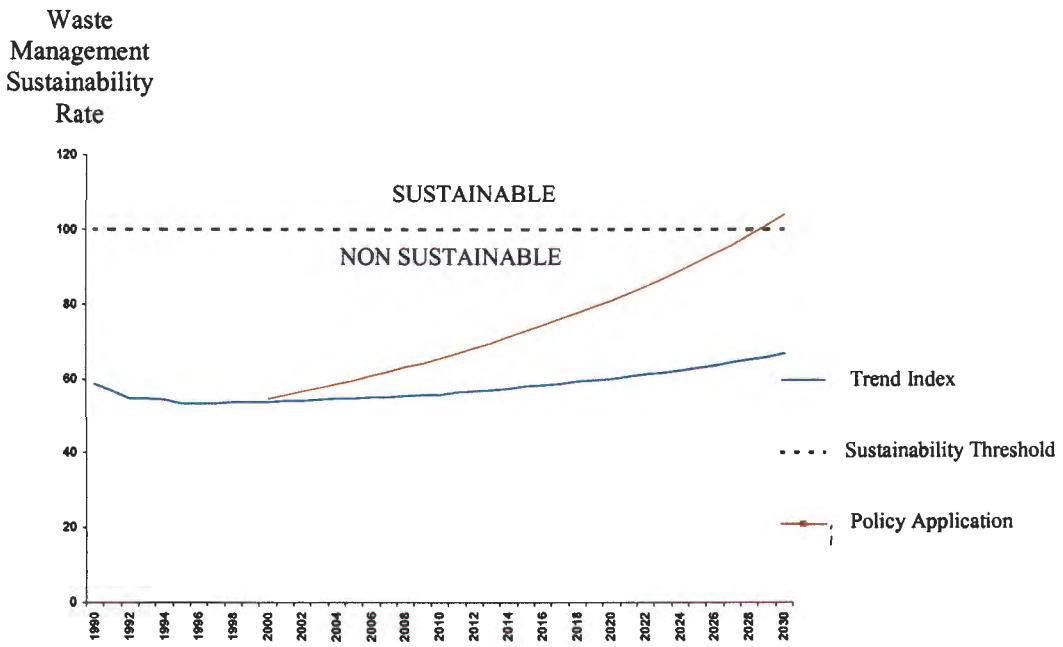
Still, another measure would be to evaluate through the indicator of sustainability the imposition of taxes on the production of materials "difficult to recycle" in such a way that its cost would internalize the cost of its treatment as waste.[68]

In whatever case what must be taken into account is the implementation of waste collection, cleaning, transport, storage, classification, selling and re-utilizing waste and transforming waste into merchandise whose production could generate important earnings.[69]

The Graph 6.30 shows the effect of the policy of quotas on waste collection on the indicator of sustainability of the management of solid wastes.

[67]P. Berg, *et. al., A Greeen City Program for the San Francisco Bay Área and Beyond.*
[68] *Ibidem.*
[69] G. Castillo, Las emisiones contribuyen a formar 5% del ozono: datos del IMP, *La Jornada*, 26 agosto 1996.

GRAPH 6.30
Quotas of Waste Collection:
Effect on the Indicator of Sustainability of the Management of Solid Waste

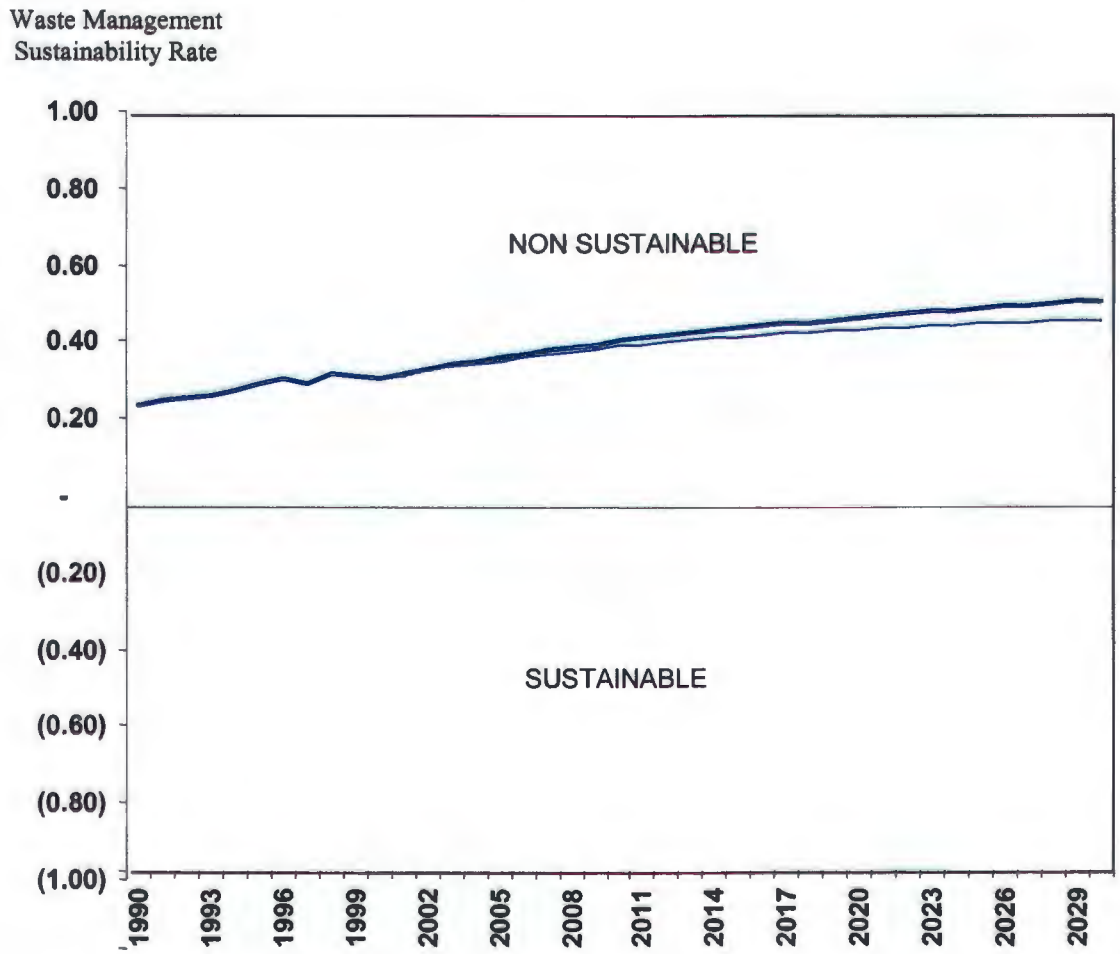


SOURCE: Own elaboration based on analysis of sensibility of indicators of constructed sustainability .

THE EFFECTS OF SOLID WASTE MANAGEMENT POLICY ON THE INDICATOR OF GLOBAL SUSTAINABILITY

Graph 6.31 shows the effect of the quota policy for waste collection on the indicator of global sustainability. Again, it is important to emphasize the present results show the seven variables of sustainability carrying the same weight toward the centre area of the global indicator of sustainability.

GRAPH 6.31
Quotas of Waste Collection:
Effect on the Indicator of Global Sustainability



SOURCE: Own elaboration based on analysis of sensibility of indicators of constructed sustainability.

As can be seen in Table 6.21, the application of the combined policy designed to improve the management of solid waste in Mexico City, suggests an improvement in the indicator of global sustainability that was 0% in the year 2000 and until recently a little more than 6.41% in the year 2030.

TABLE 6.21
Effects of Annual Percentage of Policies of Solid Waste on Indicator of Global Sustainability, 2000 to 2030

	TREND	POLICY APPLICATION	% IMPROVEMENT
2000	0.300972826	0.2999	0.00%
2001	0.312784447	0.3105	0.00%
2002	0.327471019	0.3241	0.00%
2003	0.337989409	0.3334	0.46%
2004	0.347998293	0.3422	0.58%
2005	0.355898954	0.3489	0.70%
2006	0.365604386	0.3573	0.83%
2007	0.374794156	0.3653	0.95%
2008	0.383640665	0.3728	1.09%
2009	0.392177793	0.3800	1.22%
2010	0.40043658	0.3869	1.36%
2011	0.407036404	0.3920	1.50%
2012	0.413469208	0.3970	1.65%
2013	0.41971724	0.4017	1.80%
2014	0.425800755	0.4062	1.96%
2015	0.431738402	0.4105	2.12%
2016	0.437707839	0.4148	2.29%
2017	0.44354442	0.4189	2.46%
2018	0.449282699	0.4229	2.64%
2019	0.454936195	0.4268	2.82%
2020	0.460517419	0.4305	3.00%
2021	0.465789003	0.4339	3.19%
2022	0.470803645	0.4369	3.39%
2023	0.475647832	0.4396	3.60%
2024	0.480344085	0.4422	3.82%
2025	0.484912659	0.4445	4.04%
2026	0.489128632	0.4464	4.28%
2027	0.493341584	0.4482	4.52%
2028	0.497451088	0.4497	4.77%
2029	0.501470495	0.4511	5.03%
2030	0.505457283	0.4524	5.31%

SOURCE: Own elaboration based on constructed indicators.

6.1.6 Housing Provision

DEFINITION OF INDEX OF SUSTAINAIBLITY

As mentioned in the initial diagnostic on chapter 4 of the variables of sustainability the determining aspects in terms of housing are attention to demand, quality of housing and the mitigation of the cycles of expansion and densification of the urban area. With this assumptions the following index was constructed

$$\text{Index of Sustainability} = [100 * (PV_t / DV_t)^{\beta} \ (DP_t)^{\alpha}] / [\ (1)^{\beta} \ (DP_d)^{\alpha}\ ]$$

where

PV_t = Provision of housing in the year "t"

DV_t = Demand for housing in the year "t"

DP_t = Population Density in the year "t"

DP_d = Desirable population density

β = The coefficient that measures the importance relative assigned to the issue of the balance between the supply and demand for housing (Initially a value of 0.5 was given)

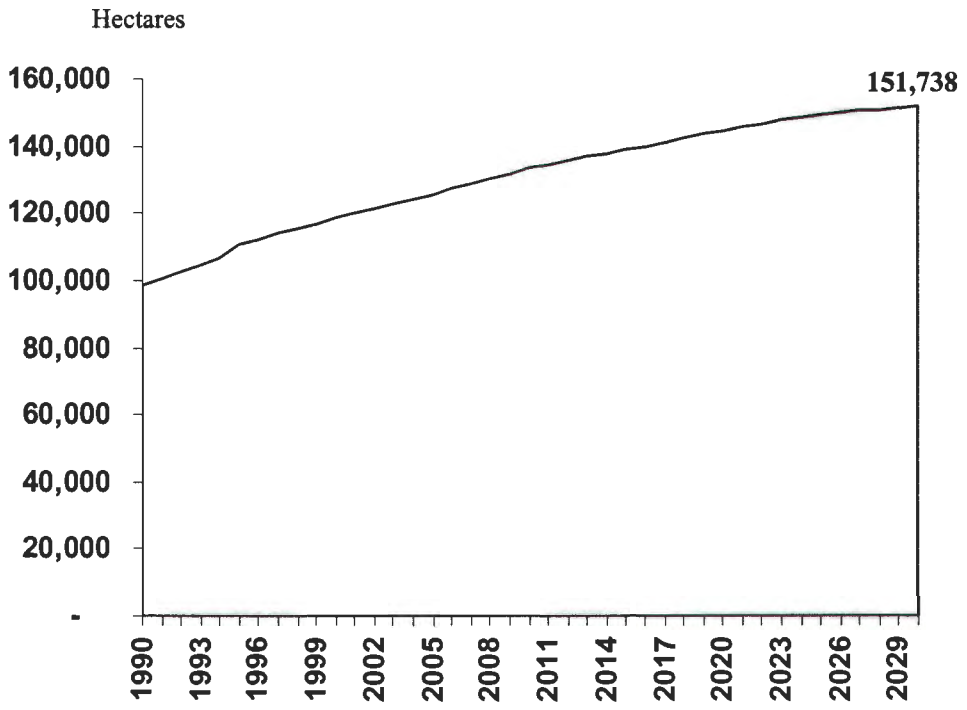
α = The coefficient that measures the relative importance assigned to the issue of population density (initially given a value of 0.5)

THRESHOLD OF SUSTAINABILITY

With regard to the threshold of sustainability, supply of housing should be at least equal to the demand derived from demographic characteristics of the population and based on trends like smaller nuclear families. As well, urban space per person should be 65 m^2 approximately (minimum registered in Mexico City between 1930 and 1990), in such a way that the desirable urban surface in the next thirty years should not pass 152,000

hectares (see Graph 6.32) The result of this is a desirable population density of 154 Pop /Hectare.[70]

GRAPH 6.32
Desired Urban Area in Mexico City, 1990-2030



SOURCE: Own elaboration.

PROVISION OF SUSTAINABLE HOUSING: TREND SCENARIO

It was assumed that the availability of housing between the year 2000 and 2030 will continue at the pace of 100,000 residential units each year. The expected growth rate of the population will help close in on the threshold of sustainability. As well the existence of an opening of approximately 1,000,000 residential units and the expected reduction in residents per housing unit, are the two factors that will help null the force of such low magnitudes.

[70]Some authors like Garza, consider 125 Pop. /Hectares a desirable density. See G. Garza, Ámbitos de Expansión Territorial, *La Ciudad de México en el fin del segundo milenio,* pp. 237-246.

TABLE 6.22
Housing Provisions to the Year 2030

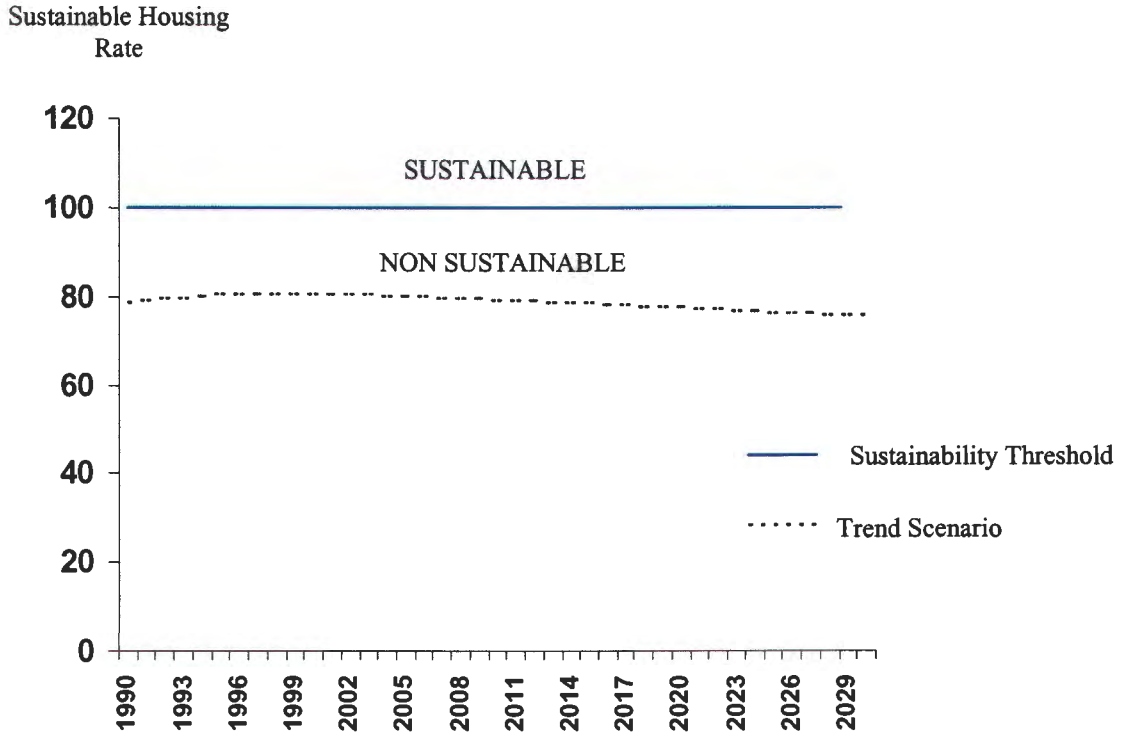
Year	Inhabitants Per House (desirable)	Population	HOUSING NEEDS	Year	Inhabitants Per House (desirable)	Population	HOUSING NEEDS
1990	4.81	15,138,037	4,149,756				
1991	4.73	15,453,801	4,269,447	2011	3.42	20,699,192	7,058,157
1992	4.65	15,776,151	4,393,686	2012	3.36	20,866,362	7,211,564
1993	4.57	16,105,225	4,522,646	2013	3.30	21,034,882	7,368,855
1994	4.50	16,441,163	4,656,506	2014	3.25	21,204,762	7,530,128
1995	4.48	17,034,527	4,800,533	2015	3.19	21,376,015	7,695,486
1996	4.41	17,269,085	4,918,779	2016	3.14	21,548,651	7,865,031
1997	4.33	17,506,872	5,040,704	2017	3.09	21,722,682	8,038,869
1998	4.26	17,747,933	5,166,423	2018	3.03	21,898,117	8,217,109
1999	4.19	17,992,314	5,296,053	2019	2.98	22,074,970	8,399,863
2000	4.12	18,240,060	5,429,716	2020	2.93	22,253,251	8,587,244
2001	4.05	18,457,362	5,559,176	2021	2.88	22,415,476	8,773,303
2002	3.98	18,677,254	5,692,419	2022	2.84	22,562,976	8,958,314
2003	3.91	18,899,765	5,829,556	2023	2.79	22,696,992	9,142,543
2004	3.85	19,124,926	5,970,701	2024	2.74	22,818,681	9,326,247
2005	3.78	19,352,771	6,115,971	2025	2.69	22,929,112	9,509,677
2006	3.72	19,583,329	6,265,486	2026	2.65	23,029,275	9,693,069
2007	3.66	19,816,635	6,419,371	2027	2.60	23,120,083	9,876,654
2008	3.60	20,052,720	6,577,754	2028	2.56	23,202,373	10,060,650
2009	3.53	20,291,617	6,740,765	2029	2.52	23,276,917	10,245,267
2010	3.48	20,533,361	6,908,540	2030	2.48	23,344,420	10,430,704

SOURCE: Author based on CONAPO hypothesis, and own conjectures about the number of desirable persons per residence.

On the other hand, it was supposed that urban space per person will be maintained at 79 m^2, equivalent to the average registered between 1930 and 1990 in Mexico City. This suggests a density population of 127 Pop / Hectares and an urban surface of 184,000 Hectares.[71]

[71]This is consistenct with statements by academics like Javier Delgado from the National Autonomous Univerisity of México (UNAM). See L. Alcántara, "Será Insuficiente el DF en 50 Años", *El Universal*, 8 de junio de 2000, p. 7 B.

GRAPH 6.33
Housing in Mexico City:
Threshold of Sustainability Vs. Trend Scenario
(1990=100)

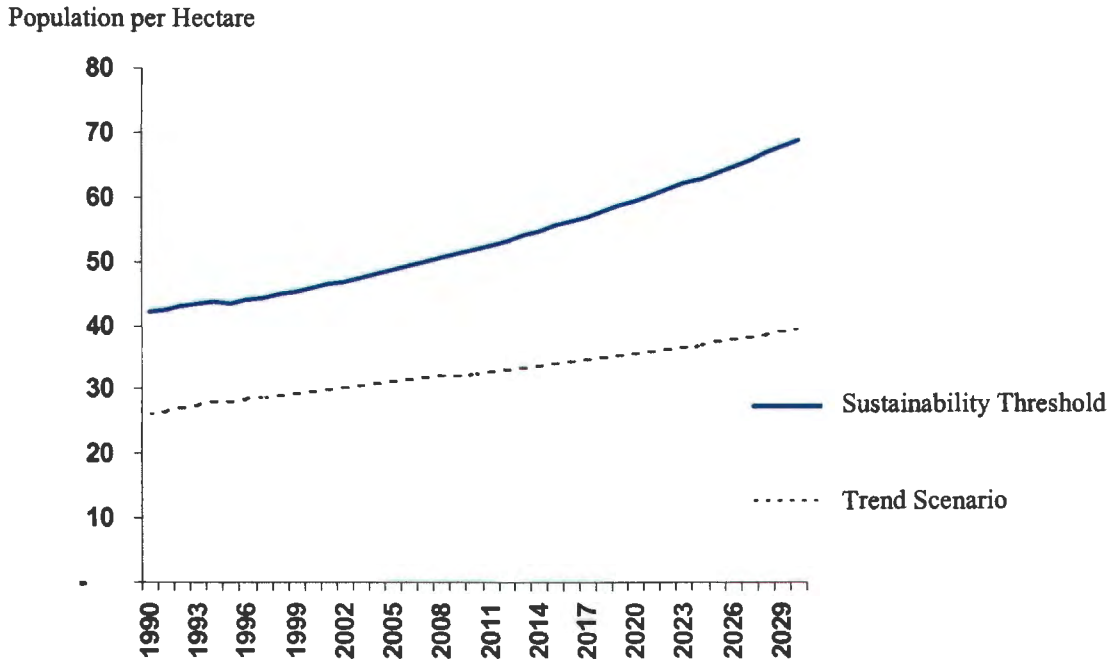


SOURCE: Own elaboration.

Housing Density in Mexico City.- Concerning the analysis done in terms of absolute quantity of available housing in Mexico City between the year 2000 and 2030, it is necessary to take into account the results in terms of corresponding housing density. In this sense, housing density registered in Mexico City was 26.34 housing units per hectare in 1990 and approximately 28.24 in 1995, which signifies a growth rate of 1.4%.

The difference between the trend scenario and threshold of sustainability in terms of housing density is presented below.

GRAPH 6.34
Housing Density in Mexico City:
Threshold of Sustainability vs Trend Scenario
(1990=100)



SOURCE: Own elaboration.

HOUSING PROVISION: POLICY SCENARIOS

Global Trends in Housing Availability.- In developing countries the ability of the public sector to provide housing for lower income groups has failed for diverse reasons. In some cases, chosen locations have been inappropriate while in other cases, the application of regulations has been unrealistic, putting the targeted population outside of the market.

The result of lack of housing has produced the proliferation of irregular settlements (squatter), developed in a clandestine manner by the private sector. More than half of the

population of Turkey lives in this type of settlement and in Sao Paulo, Brazil the percentage of irregular settlements has increased to 19% in 1993.

The public sector has had more success when they have worked along side local concerned communities. One successful example is in Indonesia where communities make a request for construction materials to build and install what the community needs like foundations and drainage systems. Other successful examples have occurred in Colombia, Guatemala, and Sri Lanka, among other countries. The key is the initiative and participation of community members.

Since housing is considered a private good, availability is best achieved through market mechanisms, except when security and social measures stipulate otherwise. The public sector needs to strengthen property rights, secure financing, subsidies, building and infrastructure regulations. The experience in the Russian Federation and Eastern European countries show that investment in the infrastructure for its own sake does not stimulate construction of housing but contributes toward an institutional framework that helps protect and value property rights. This increases incentives to improve housing and infrastructure. Only property rights that function well can encourage an adequate supply of housing.

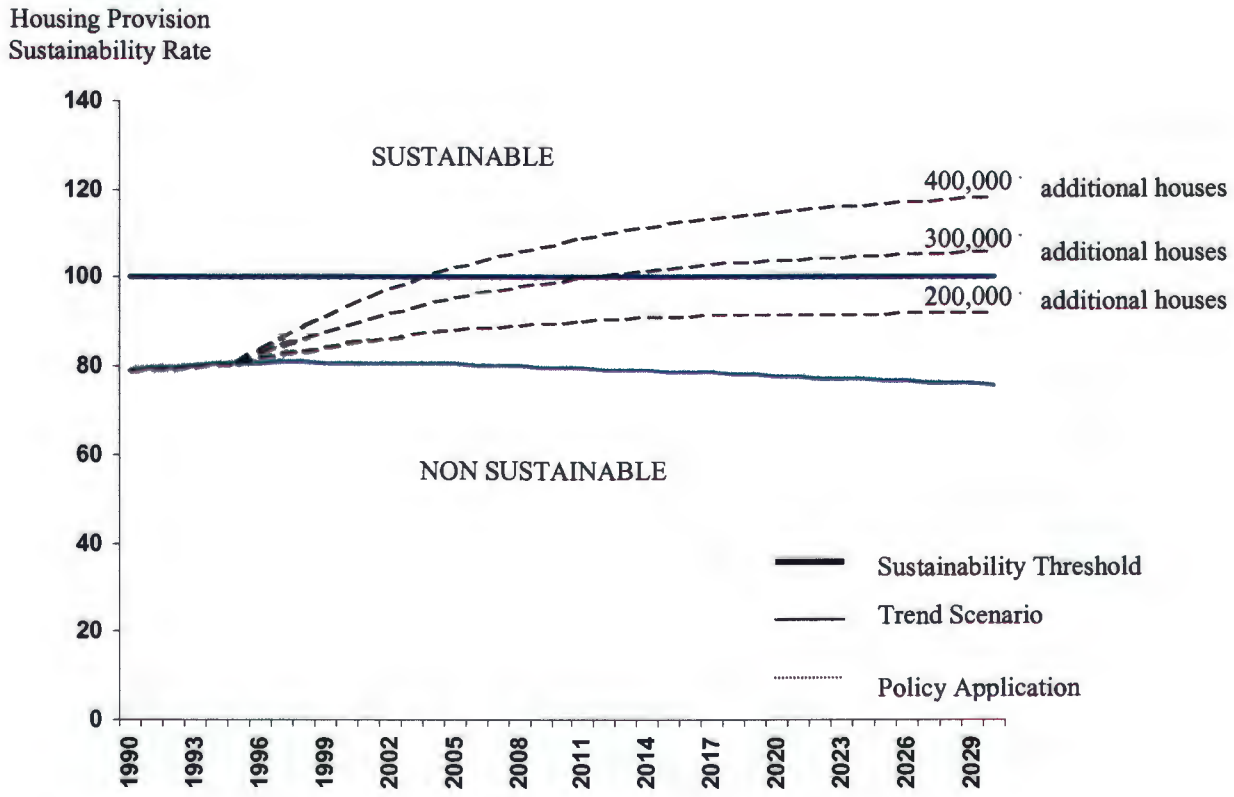
The availability of housing is not just a question of quantity but also a question of quality. In this sense it is necessary to take into account criteria such as comfort, hygiene, the use of eco-technology with the object of making a home produce and save as the house is the cell in the city and of immersed in existing urban problems.

"The objective to be reached is the use of environmentally friendly residences set-up to collect and recycle water, use solar energy, regulate inside and outside temperatures that help food gardens, recycle garbage and the use of garbage for commercial ends, rationing commercial energy, all of these processes may help produce a higher level of common wealth and generate employment."[72]

[72]A. Deffis, Armando, *Vivienda Social. Conjuntos Habitacionales Autosuficientes.*

Direct Subsidies for Housing.- Although a more detailed analysis of a housing subsidy policy requires considerations concerning financial restrictions and relative housing prices with respect to other goods, the objective of the illustrated exercise in Graph 6.35 is to demonstrate possible effects derived from different yearly increments of available housing on the index of sustainability.

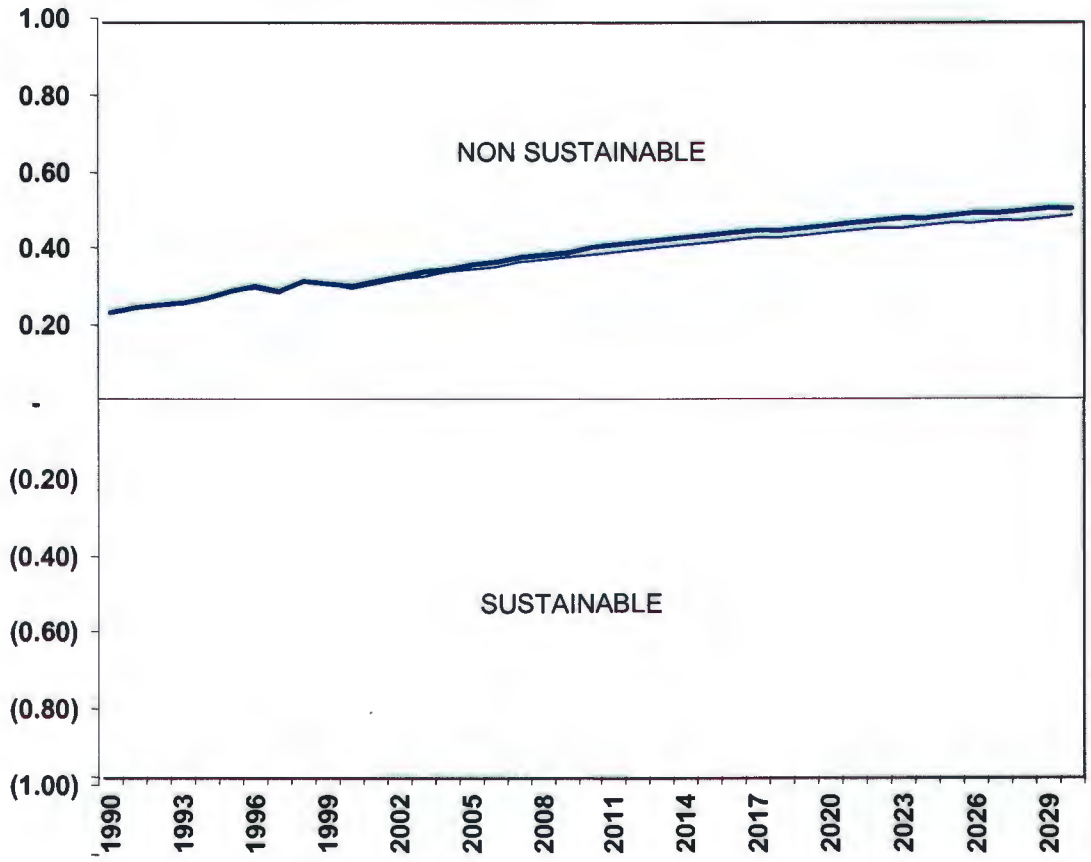
GRAPH 6.35
Scenarios of Housing Subsidies:
Effect on the Housing Provision Indicator of Sustainability



Source: Own elaboration based on sensitivity analysis of constructed indicators of sustainability.

Effects of Housing Subsidy Policy on the Indicator of Global Sustainability.- Graph 6.36 shows the effect of the subsidy policy which increases the annual availability of housing to 200,000 on the indicator of global sustainability. It is important to point out that the present results suggest that the seven variables of sustainability have the same weight at the centre of the indicator of global sustainability.

GRAPH 6.36
Housing Subsidies:
Effect on the Indicator of Global Sustainability



SOURCE: Own elaboration, based on sensitivity analysis of constructed indicators of sustainability.

As can be seem in Table 6.23, the application of a policy subsidy on housing in Mexico City suggests an improvement on the indicator of global sustainability that at present is at 0% and at a little more than 2.35% in the year 2030

TABLE 6.23
Effects on Annual Percentage of Housing Policy on the Indicator of Global Sustainability, 2000 to 2030

	TENDENTIAL	POLICY APPLICATION	% IMPROVEMENT
2000	0.300972826	0.2945	0.00%
2001	0.312784447	0.3052	0.00%
2002	0.327471019	0.3188	0.00%
2003	0.337989409	0.3284	0.96%
2004	0.347998293	0.3375	1.05%
2005	0.355898954	0.3445	1.14%
2006	0.365604386	0.3534	1.22%
2007	0.374794156	0.3618	1.30%
2008	0.383640665	0.3699	1.37%
2009	0.392177793	0.3778	1.44%
2010	0.40043658	0.3854	1.51%
2011	0.407036404	0.3913	1.57%
2012	0.413469208	0.3972	1.63%
2013	0.41971724	0.4028	1.69%
2014	0.425800755	0.4084	1.74%
2015	0.431738402	0.4138	1.80%
2016	0.437707839	0.4193	1.85%
2017	0.44354442	0.4246	1.89%
2018	0.449282699	0.4299	1.94%
2019	0.454936195	0.4351	1.98%
2020	0.460517419	0.4403	2.02%
2021	0.465789003	0.4452	2.06%
2022	0.470803645	0.4499	2.09%
2023	0.475647832	0.4544	2.13%
2024	0.480344085	0.4587	2.16%
2025	0.484912659	0.4629	2.20%
2026	0.489128632	0.4668	2.23%
2027	0.493341584	0.4707	2.26%
2028	0.497451088	0.4746	2.29%
2029	0.501470495	0.4783	2.32%
2030	0.505457283	0.4820	2.35%

SOURCE: Own elaboration, based on constructed indicators.

As well in relation to policies of available housing, it is of extreme importance to implement urban redensification programs in Mexico City with the goal of using existing urban equipment, and infrastructure mainly in central zones of the city and to provide better quality housing within the framework of our sustainable development strategy. This type of program has been implemented in many countries around the world and in many cases has generated urban spaces of mixed use that are favourable to other variables like transportation, urban expansion, amenities, and green areas.

Since the end of the 1980s some effort has been made to redensify the zones around the Paseo de la Reforma, la Alameda and the Historic Centre (or CBD), however, market tendencies have pointed in the opposite direction and have complicated the task at hand.

In this sense, more effort is needed as policies of this nature are vital in the case of Mexico City. Even though there are services spread throughout the central zones , it is estimated that their contribution to GNP is almost nil which suggests that its contribution in terms of jobs, a fiscal base and housing is as well, practically nil.

6.1.7 Energy Use and Energy Transition

As we discussed in previous section (5.2.4) to encourage the energy transition in the MCMZ will have a comprehensive impact upon the overall sustainability of the city.

DEFINITION OF THE INDEX OF ENVIRONMENTAL SUSTAINABILITY

Index of Sustainability in the Use of Energy = $100 * EPN_t / EPN_{1990}$

where

EPN_t = Total Energy Utilized, Considered and Standarized in the year "t"

EPN_{1990} = Total Energy Utilized, Considered and Standarized in the base year (1990)

And in turn:

$EPN_t = (PET_t + GN_t*0.5 + OT_t*0.5)\ ETU_t$

Where PET_t = Consumption of oil

GN_t = Consumption of natural gas

OT_t = Consumption of other energy

ETU_t = Total energy utilized

In this way, energy sources considered in accordance to this would have a level of environmental cleanliness. According to the 1999 International Report on Energy, the use of natural gas in place of oil reduces polluting emissions over 50%. Taking this into account, natural gas is a much more desirable source both indexes considered the consumption of natural gas and other sources including electrical and solar power with 0.5.

Based on statistics of the initial situation of variables of sustainability it was supposed that the volumes of energy production at a national level by primary sources are actually very similar to the real consumption of Mexico City in such a way that they were used as estimates for the year of 1996. However, it is supposed that given the stage of economic development in Mexico City, the intensity of the use of energy (rate of growth in the use of energy with respect to the rate of growth of economic activities) will have a tendency to decline in a similar way found in transitional economies toward a higher level of participation of the service sector.

Taking into account our hypothesis of population growth and economic growth, the total consumption of energy in Mexico City was projected. This result varied between the trend scenario and the threshold of sustainability according to those figures described below.

USE OF ENERGY: TREND SCENARIO

The significant difference with respect to the threshold of sustainability is that it is determined by the intensity of the use of energy. With respect to the latter, intensity and composition figures were used for each source that the 1999 International Report on Energy pointed out for Mexico as a country. This is to say, that tentatively, it is supposed that the use of energy in Mexico is similar to the industrialized economies moving toward the service sector prominence.

As well, it was supposed that the conversion of electrical generation plants to a base of combustible fuels in Mexico City will continue in such a way that participation of the electrical sector in terms of the consumption of natural gas will continue to increase to a rate of 2.6% annually, similar to the rate registered between 1991 and 1996.

THRESHOLD OF ENVIRONMENTAL SUSTAINABILITY

It was supposed that during the next thirty years, the consumption of total energy and its composition by source, will behave more or less in accordance with the expected growth trend/a decreasing world level of consumption for industrialized economies.

As well an important growth in the use of natural gas has been observed in comparison to the use of petroleum and other sources of energy and in general the relation between an increase in economic activity and the energetic consumption which is lower than in the trend scenario.

TABLE 6.24

Intensity of Energy Use
(Growth of Energy Consumption / Growth of GNP)

	2000 2005	2005- 2010	2010 - 2015	2015 -2020
TREND SCENARIO	0.74	0.48	0.51	0.51
SUSTAINABILITY THRESHOLD	0.54	0.43	0.42	0.41

SOURCE: Own elaboration.

TABLE 6.25

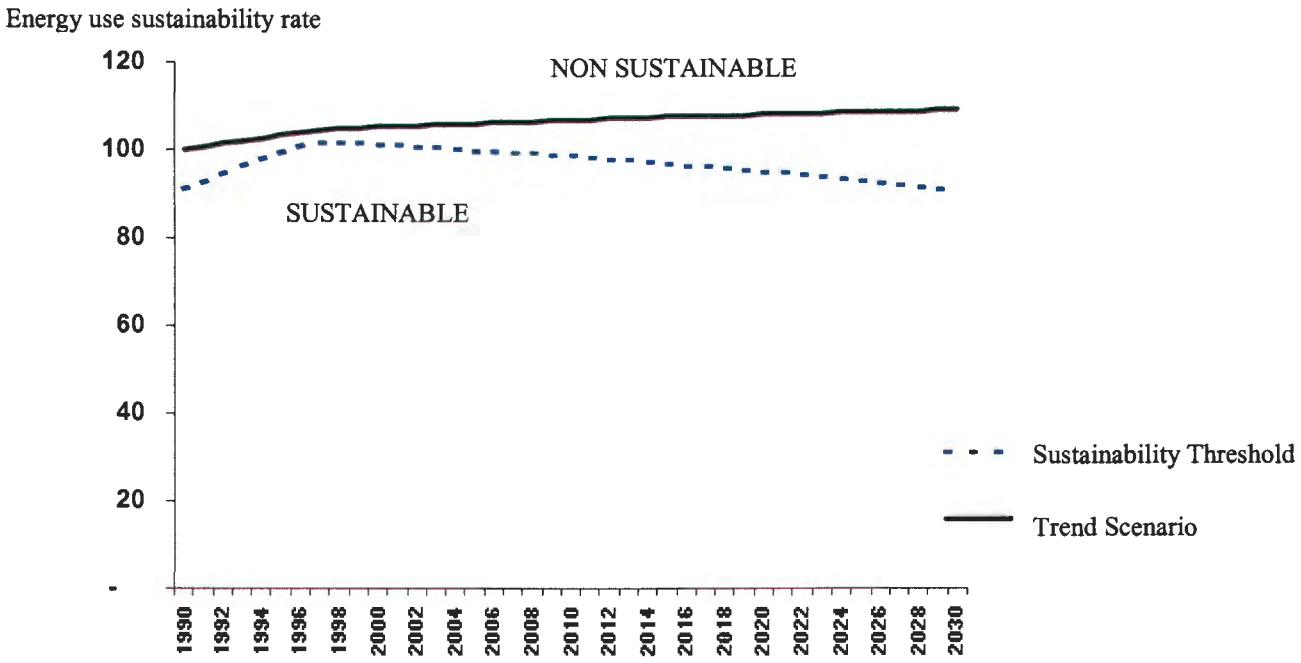
Measure of Annual Consumption Growth Rate, 1999 to 2030

	Natural Gas	Petroleum
Trend Scenario	1.11%	1.08%
Sustainability Threshold	3.65%	1.58%

SOURCE: Own elaboration.

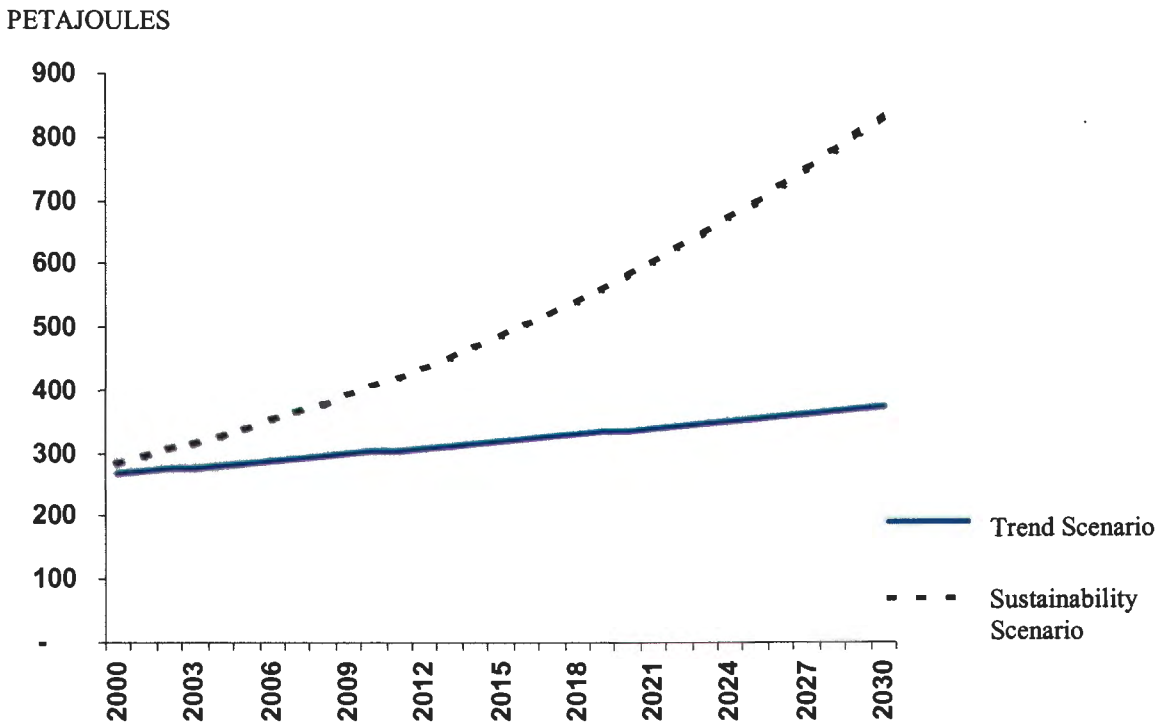
GRAPH 6.37

Energy Use in Mexico City: Threshold of Sustainability Vs. Trend Scenario (1990=100)



SOURCE: Own elaboration.

GRAPH 6.38
Consumption of Natural Gas in Mexico City:
Threshold of Sustainability Vs. Trend Scenario (Petajoules)



SOURCE: Own elaboration.

ENERGY USE: POLICY SCENARIOS

World Trends.- Some of the problems that face many cities in the world with regard to the successful implementation of their energy distribution projects, and whose solutions are outlined in applied policies, include the following:

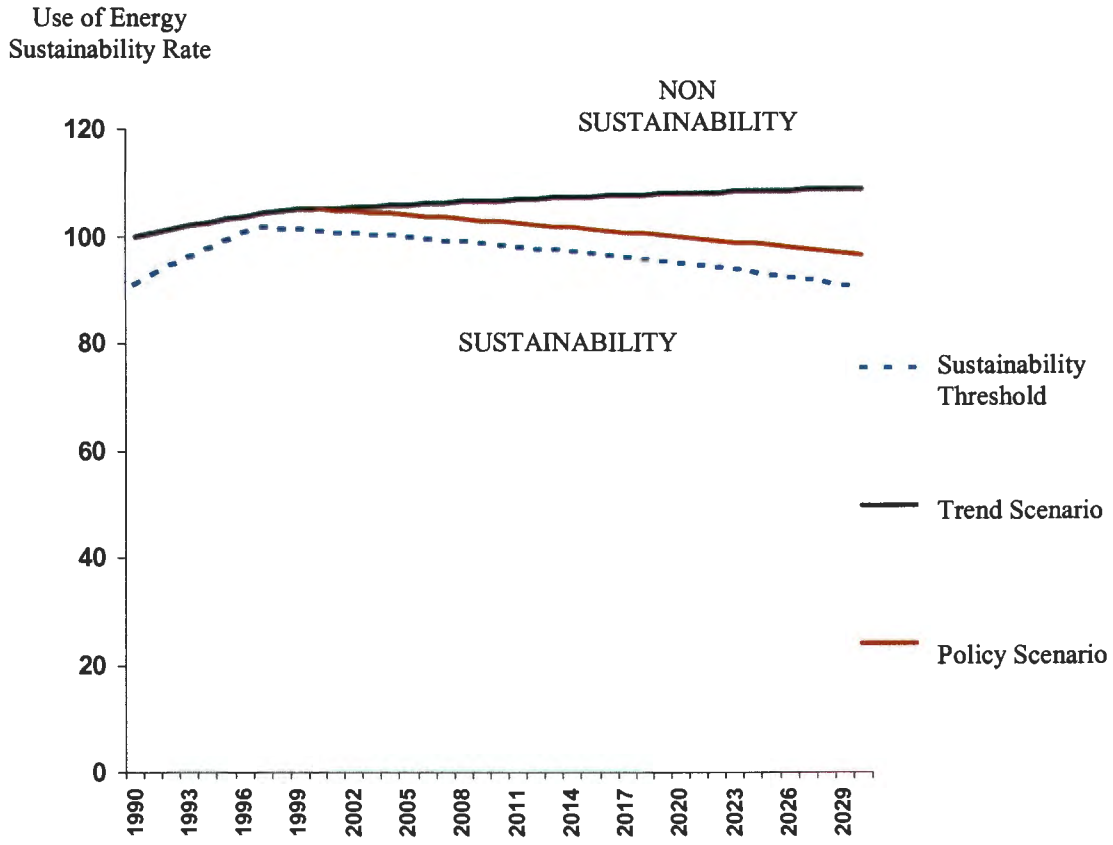
- Low technical capacity of human resources
- Low level private sector participation through property or contraction of services
- Unclear Legal structures and regulations

Considering the trend scenario proposed in previous sections where in the year 2030 natural gas will represent only 11% of total of all energy sources in contrast to 28% of industrialized countries. It is possible that the neglect of the three problems mentioned in the previous section represents a determing factor of this trend.

To avoid this, it is necessary to make sure that people are familiar with the advantages of the use of natural gas and that an accessible distribution is available and sustainable in the long-term with a clear and adequate regulatory framework. The object, with an eye toward the year 2030, must be the progressive increase of the use of natural gas until a percentage of 35% is reached.

The underlined hypothesis in the exercise of the policy illustrated in the Graph 6.39 is the possibility of guaranteeing the existence of an adequate system for the distribution of natural gas, accompanied by the necessary information campaigns that would help the level of users reach 35% in thirty years.

GRAPH 6.39
Improvement of Integrated System of Natural Gas Distribution: Effect on the Indicator of Sustainability of Energy Consumption



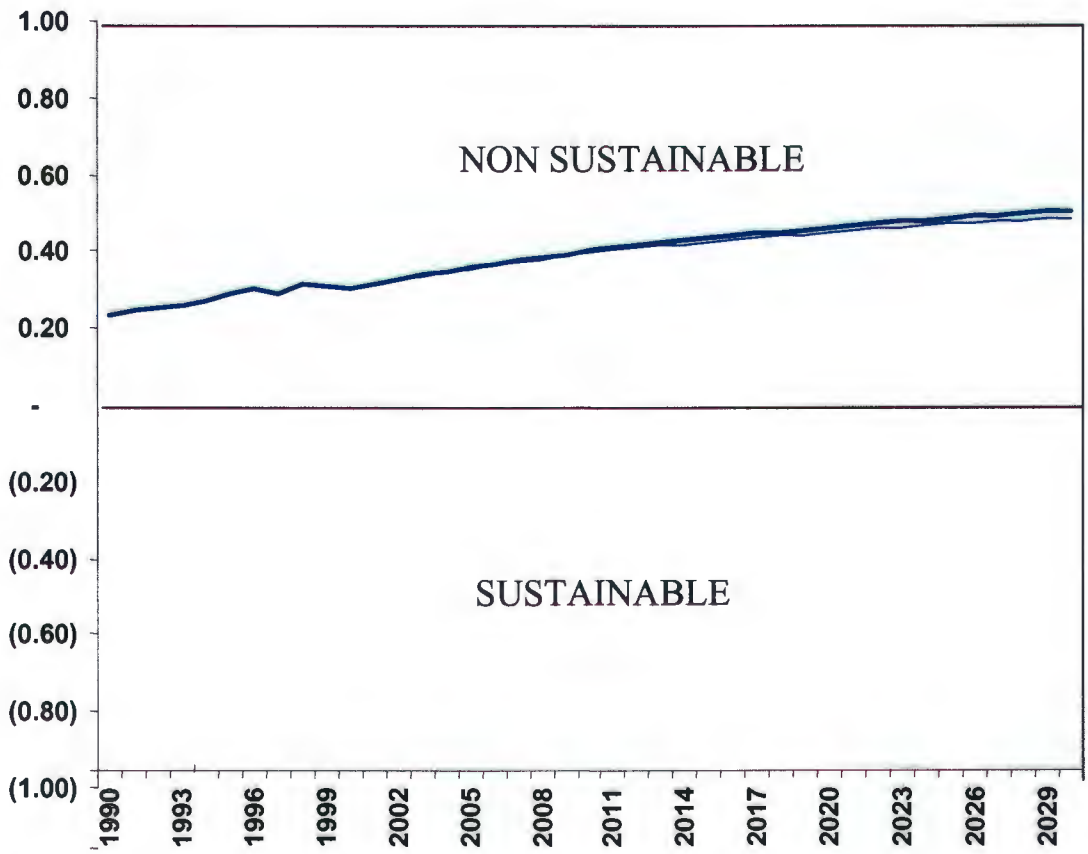
SOURCE: Own elaboration, based on analysis of constructed indicators.

Impact of Housing Provision with "Eco - technologies".- As mentioned previously, it is desirable that the provision of housing be equipped with ecotechnology designed to save water and energy. In this way the increase in the supply of housing with these characteristics could imply a change in the indicators of sustainability of water and energy in Mexico City.

EFFECT OF ENERGY CONSUMPTION POLICIES ON THE GLOBAL SUSTAINABILITY INDICATOR

The Graph 6.40 shows the effect of the policy of an improved natural gas system. It is important to point our that the results suggest that the seven variables of sustainability have the same weight at the centre of the global indicator of sustainability.

GRAPH 6.40
Improvement in the Distribution System of Natural Gas: Effect on the Global Sustainability Indicator



SOURCE: Own elaboration, based on analysis of constructed indicators.

As can be seen in Table 6.26, the application of the policy of housing subsidies in Mexico City implies an improvement on the indicator of global sustainability which was at 0% in the year 2000 and by the year 2030 registers a little under 2.35%.

TABLE 6.26
Percentage Annual Effect of Energy Policies on the Indicator of Global Sustainability, 2000 to 2030

	TREND	POLICY APPLICATION	% IMPROVEMENT
2000	0.300972826	0.3010	0.00%
2001	0.312784447	0.3122	0.00%
2002	0.327471019	0.3263	0.00%
2003	0.337989409	0.3362	0.18%
2004	0.347998293	0.3457	0.23%
2005	0.355898954	0.3530	0.29%
2006	0.365604386	0.3621	0.35%
2007	0.374794156	0.3707	0.41%
2008	0.383640665	0.3789	0.47%
2009	0.392177793	0.3869	0.53%
2010	0.40043658	0.3945	0.59%
2011	0.407036404	0.4005	0.65%
2012	0.413469208	0.4064	0.71%
2013	0.41971724	0.4120	0.77%
2014	0.425800755	0.4174	0.84%
2015	0.431738402	0.4228	0.90%
2016	0.437707839	0.4281	0.96%
2017	0.44354442	0.4333	1.03%
2018	0.449282699	0.4384	1.09%
2019	0.454936195	0.4434	1.16%
2020	0.460517419	0.4483	1.23%
2021	0.465789003	0.4529	1.29%
2022	0.470803645	0.4572	1.36%
2023	0.475647832	0.4613	1.43%
2024	0.480344085	0.4653	1.51%
2025	0.484912659	0.4691	1.58%
2026	0.489128632	0.4726	1.65%
2027	0.493341584	0.4760	1.73%
2028	0.497451088	0.4794	1.81%
2029	0.501470495	0.4826	1.89%
2030	0.505457283	0.4858	1.97%

SOURCE: By author based on constructed indicators.

6.1.8 Global Sustainability Indicator

As we discussed before the indicators of sustainability that correspond to the seven variables considered in this work were constructed separately. It is possible to arrive at a global sustainability indicator given the following formula:

GLOBAL SUSTAINABILITY INDICATOR =

$$a\,(BA_t) + b\,(BAV_t) + c\,(BVV_t) + d\,(BVT_t) + e\,(BCA_t) + f\,(BDS_t) + g\,(BEN_t)$$

where

(BA_t) = gap ratio of the indicator of water with respect to the threshold of sustainability

(BAV_t) =gap ratio of the indicator of green areas with respect to the threshold of sustainability

(BVV_t) =gap ratio of the indicator of housing with respect to the threshold of sustainability

(BVT_t) =gap ratio of the indicator of transport and road infrastructure with respect to the threshold of sustainability

(BCA_t) =gap ratio of the indicator of environmental pollution with respect to the threshold of sustainability

(BDS_t) =gap ratio of the indicator of solid waste with respect to the threshold of sustainability

(BEN_t) =gap ratio of the indicator of energy with respect to the threshold of sustainability

furthermore:

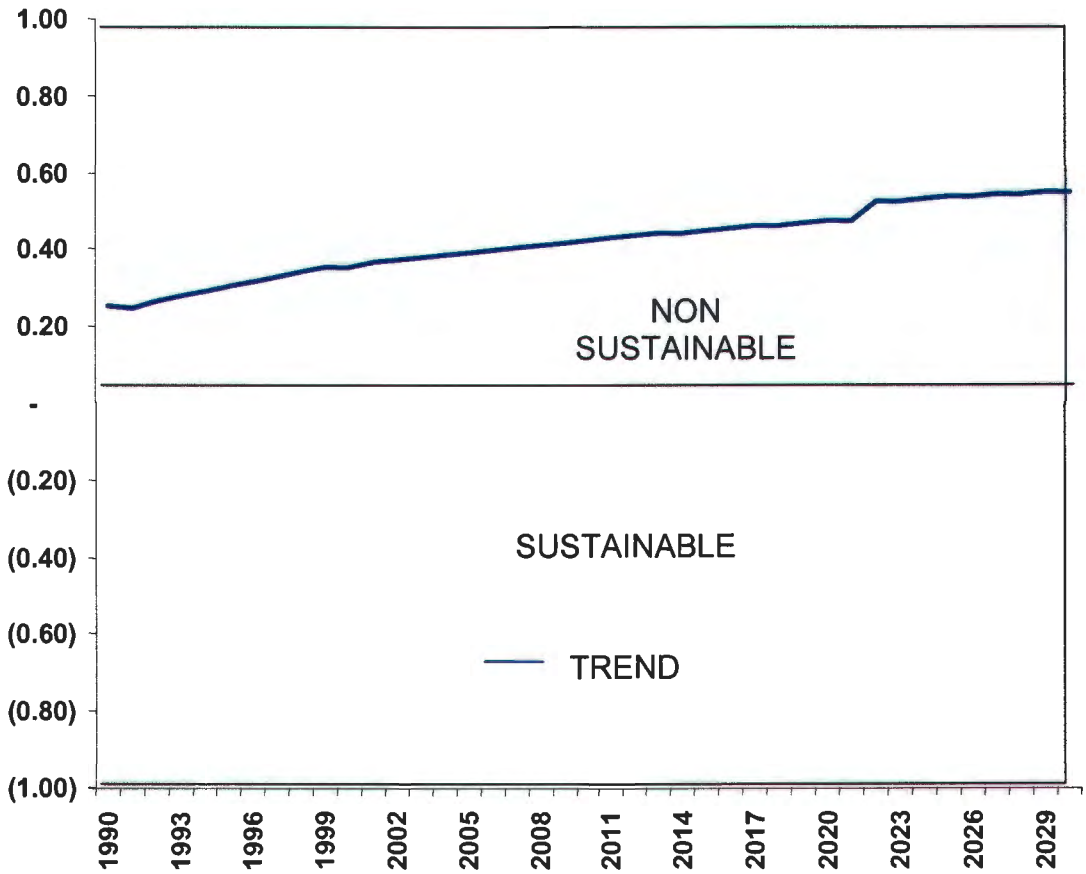
a = relative weight given to the problem of water inside the global indicator
b= relative weight given to the problem of green areas inside the global indicator
c= relative weight given to the problem of housing inside the global indicator
d=relative weight given to the problem of transport and road infrastructure inside the global indicator
e=relative weight given to the problem of environmental pollution inside the global indicator
f=relative weight given to the problem of solid waste management inside the global indicator
g= relative weight given to the problem of energy inside the global indicator

and where the following condition should be met:
$a + b + c + d + e + f + g = 1$

In this way, the ideal is that in none of the indicators of sustainability exists a gap with respect to each threshold of sustainability. As well, it is important to point out that the relative weight of each variable can be modified following the perceptions of the whims of politics or based on the opinion of the population about problems considered the most important for the MZMC.

This indicator is mostly an instrument for policy purposes, rather than an empirical valid one. If toward the centre of the global indicator of sustainability, the same weight is assigned to each of the variables of sustainability, the trend therefore would be the following:

GRAPH 6.41
Global Sustainability Indicator



SOURCE: By author based on constructed indicators of sustainability

GLOBAL RESULTS ON SUSTAINBILITY

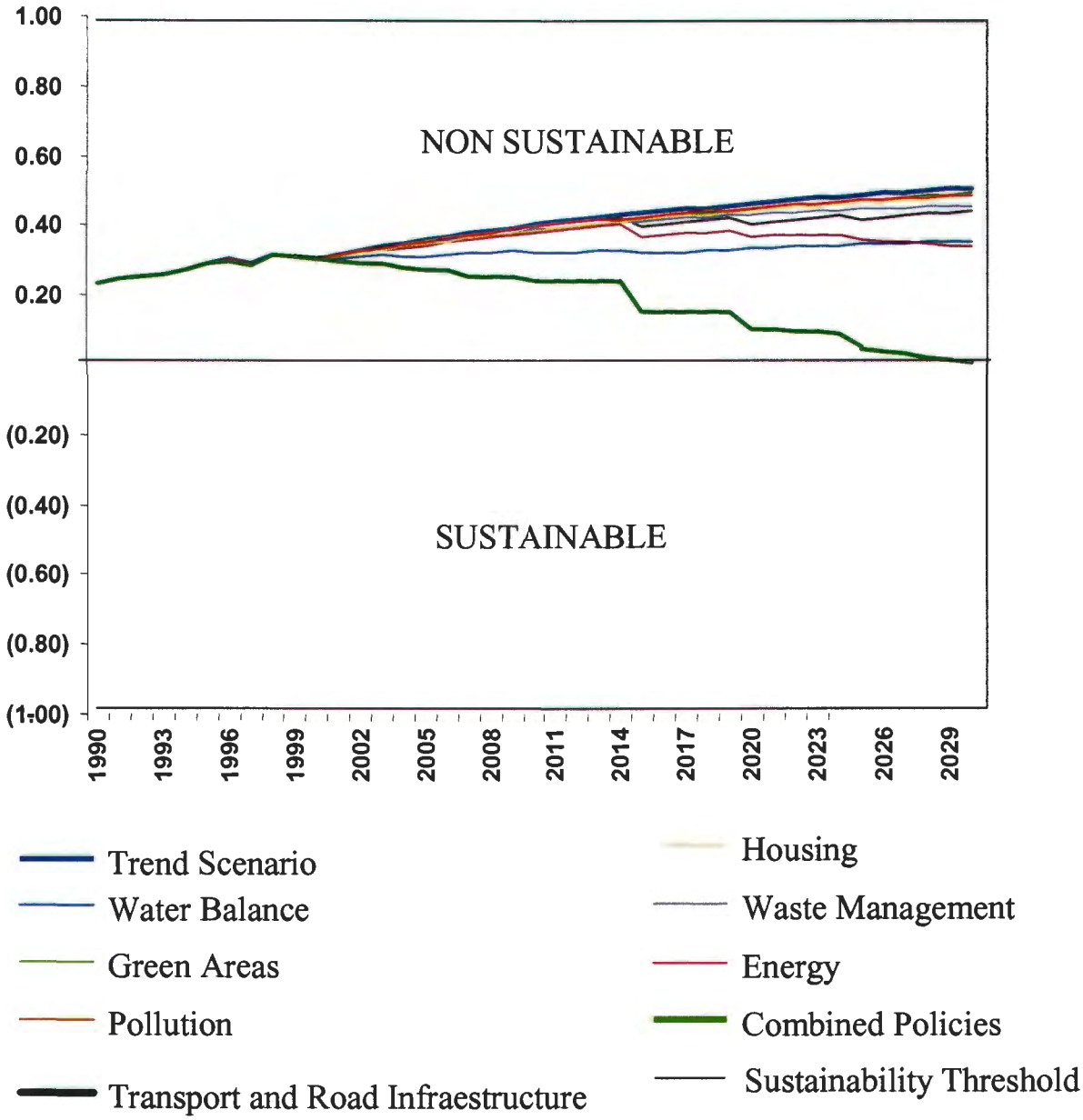
We can, as an example, assign an equal weight to each of the seven variables (a) or, alternatively we could range by importance the weight of each variable (b). Thus, we could see:

a) Combined Policies with Equal Relative Weight for Each Variable

Taking the constructed global indicator of sustainability as a base, it is possible to apply the obtained result to all of the proposed policies for the seven variables considered vital in terms of sustainability. In this sense, Graph 6.42 demonstrates the corresponding impact, assuming the same weight is assigned for the seven considered variables.

As can be seen, in spite of the modest participation of some policies in the improvement of the global indicator of sustainability, the combination of all suggests that in the year 2030 the threshold of sustainability will be reached.

GRAPH 6.42
Combined Proposed Policies:
Effect over the Global Indicator

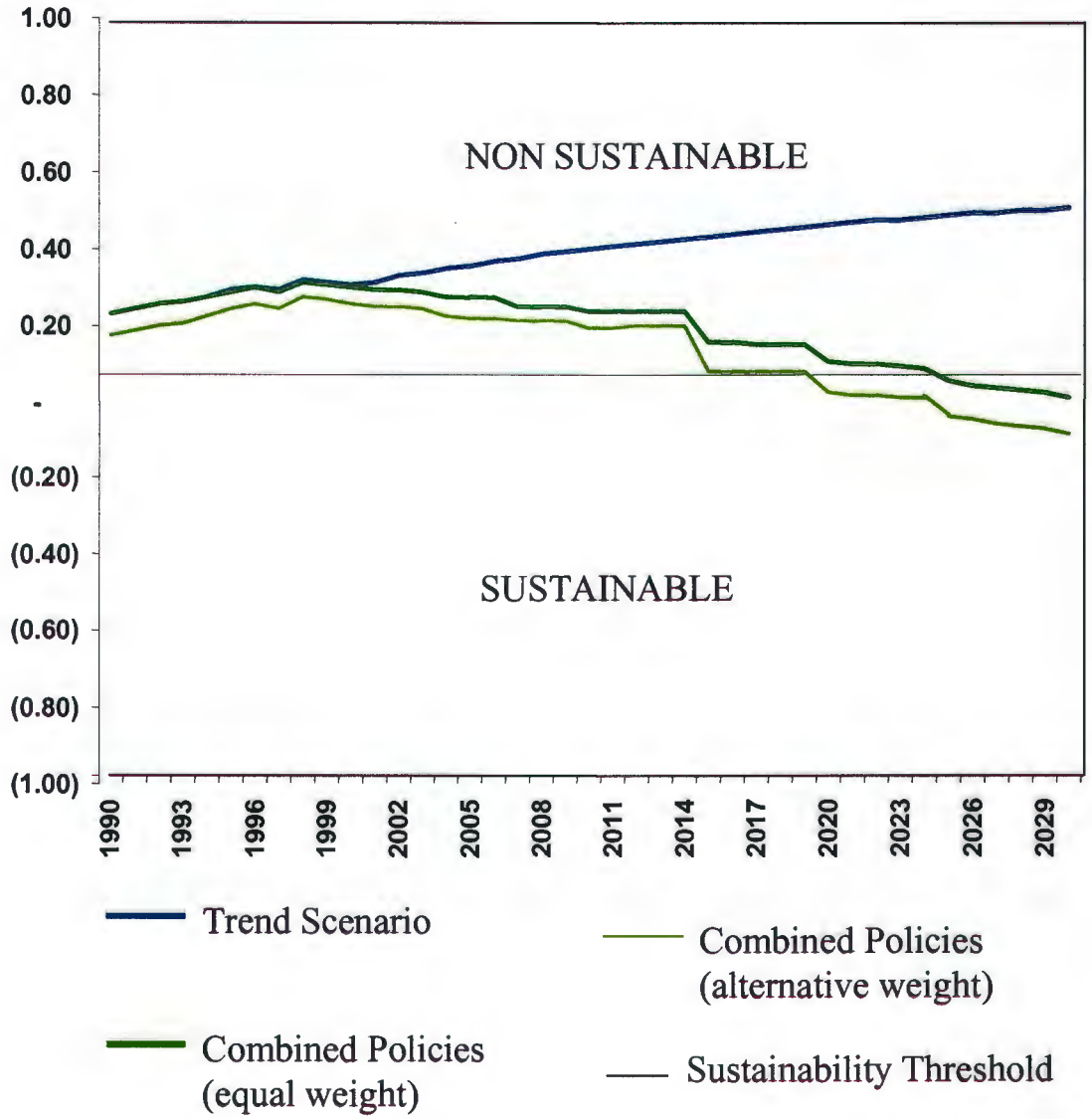


SOURCE: By author based on analysis of constructed indicators of sustainability

b) Combination of Policies with Alternative Weight

However, it is important to take into account that in reality, not all the variables have the same importance weight because there are problems related with the sustainability of the MCMZ that are more serious than others. Therefore, an alternative value ordering is considered allowing for the distinct consideration of each variable located toward the centre of the global indicator of sustainability. For example, the problems of water supply, transit, pollution and housing could be considered as more important in such a way that together they represent 80% of the problems of sustainability of the MCMZ. The results derived from this new supposition are shown in Graph 6.43.

GRAPH 6.43
Combined Proposed Policies with Alternative Value Ordering: Effect over the Global Indicator



SOURCE: By author based on analysis of constructed indicators

6.1.9 Indicators Relative to Globalization and Mexico City as a "World City"

In previous sections (5.1) we discussed at length the issue of the other main challenge that Mexico City is facing. In this section we attempt a rough to measure some proxy variables that could stand for Globalisation. They must be analyzed within the main considerations of the 5.1 section above.

In narrow and strictly economic terms, globalization can be defined as a process through which the world economy moves toward the integration into one simple world market; it would have three main components: labor, capital and goods and services. Thus a national economy that theoretically is globalized is one that permits the free entry and exit of these three components and these movements imply competition with other countries that are either globalized or in the process of globalization.

Although merely in economic terms, there are repercussions of this phenomenon in the cultural, social, political and environmental arenas. For this reason the expression of the advance of globalization in terms of benefits for its agents that participate in the local or regional economy is difficult to measure overall. Foreign trade as a percentage of GNP, the quantity of internet connections that exist, the quantity of visitors from abroad or the quantity of university graduates in a given moment gives an idea of just how globalized a country is habitants are, but not of how much of this "globalisation process" is or not definitive.

Perhaps the only alternative is through economic variables like GNP per capita, however due to the fact that this variable is determined by other factors of an internal nature including the disposable resources and the public policy, it is difficult to determine how much from the variation in this indicator is due to external factors and as a consequence, how much well being is generated (see sections 4.1 and 5.3)

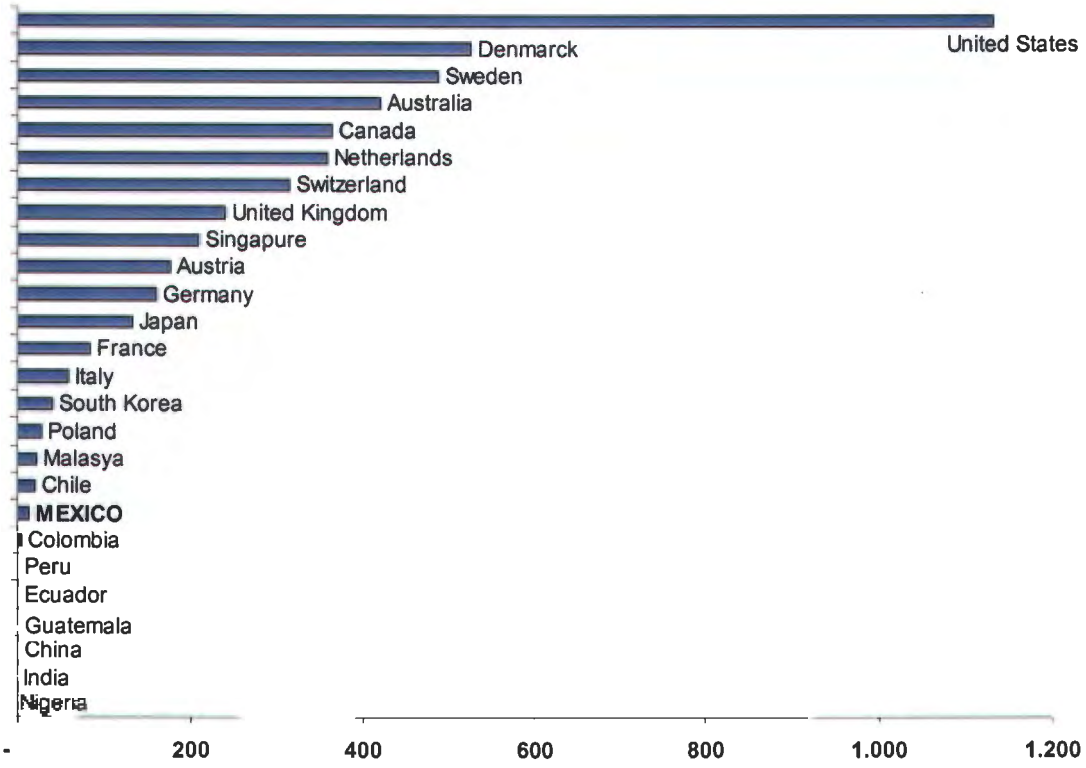
With this in mind, the development of an indicator of globalization to determine the domestic economic scene must be construed with variables directly related with this process, but always taking into account its relationship with the increase or decrease of the wellbeing of the corresponding population.

The methodology utilized is the following:

Information was taken about a set of variables that we assume to be directly related with the globalization process including:

- Yearly Commercial Passengers from the Mexico City International Airport (IAMC) that are foreigners.
- Number of foreign tourists that visit Mexico City
- Internet Connections per capita.
- Yearly University Graduates

GRAPH 6.44
Selected Countries: Internet Connections per 10,000 Habitants



SOURCE: World Bank, 1999.

Through international and national comparisons a correlation was obtained of each of the variables using GNP per capita. A combination of correlations was done to calculate the consideration of each of the variables of the indicator in the following manner.

$P_i = COR_i / SCOR_i$

Where,

P_i = Consideration of the variable "i" in the globalization indicator

COR_i = Correlation of the variable "i" with the GNP per capita

$SCOR_i$= Sum of Correlations of all the variables that compose the indicator, with GNP per capita.

In this manner, the index that measures the level of globalization of an economy is put together in the following manner.

$$IG_t = 100*(Pi_{PPI}*(PPI_t) + Pi_{TE}*(TE_t) + P_{iGRAD}*(GRAD_t) + P_{iCONX}*(CONX_t)) /$$

$$(P_{iPPI}*(PPI_b) + P_{i\,TE}*(TE_b) + P_{iGRAD}*(GRAD_b) + P_{iCONX}*(CONX_b))$$

where,

IG_t =

P_i = Consideration of the variable "i" in the indicator of globalization.

$P_{iPPI} + P_{iTE} + P_{iGRAD} + P_{iCONX} = 1$

PPI= Yearly millions of international passengers at the IAMC

TE= Foreign tourist visiting Mexico City

GRAD= University graduates

CONX= Internet connections (in 100,000)

"t"= variable corresponding to the year "t"

"b"=variable corresponding to the year "b"

Estimated values for corresponding correlations were the following:

Foreign Tourists Vs. GNP per capita = 0.29 (based on international comparisons)

Graduates Vs. GNP per capita = 0.35 (based on international comparisons)

International Passengers Vs. GNP per capita = 0.42 (base on national statistics)

Internet Connections Vs. GNP per capita = 0.49 (based on international statistics, see Graph 5.42)

Sum of Correlations = 1.55

Based on these results, the following values were considered adequate:

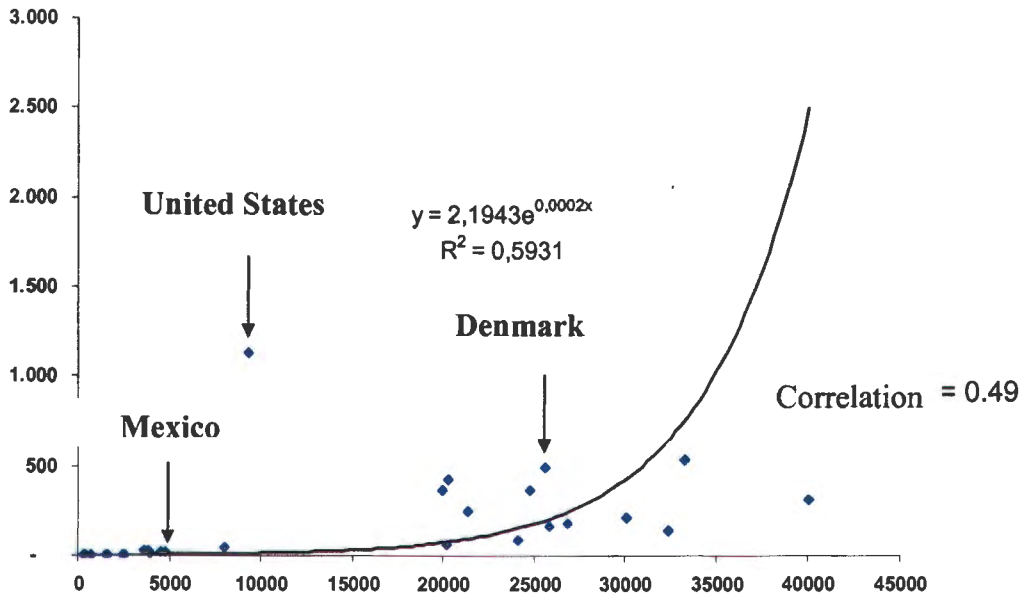
$P_{iPPI} = 0.27$

$P_{iTE} = 0.18$

$P_{iGRAD} = 0.22$

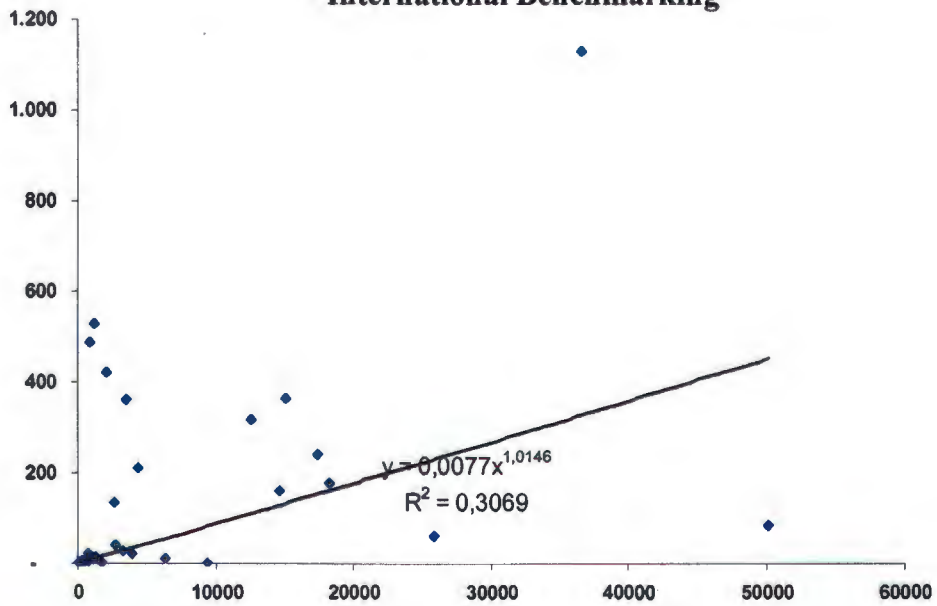
$P_{iCONX} = 0.31$

GRAPH 6.45
GNP per Capita Vs. Internet Connections per 10,000 Habitants: "International Benchmarking"



SOURCE: Own elaboration, based on *Entering the 21st Century, World Development Report 1999 /2000.* World Bank.

GRAPH 6.46
GNP per Capita Vs. Foreign Tourists Arrivals: "International Benchmarking"



SOURCE: Own elaboration, based on statistics from World Trade Organisation (WTO).

In accordance with historic values of the utilized variables and some future estimates, the evolution of the globalisation indicator was graphed as shown in Graph 6.47

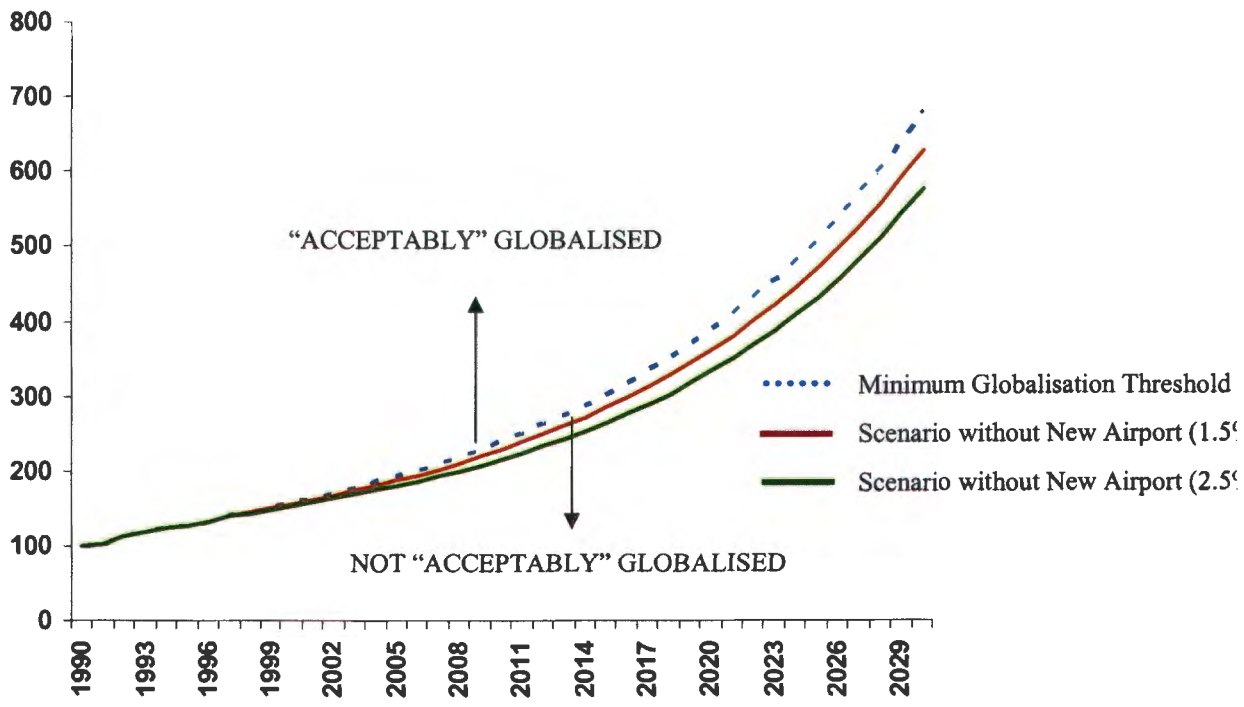
Assuming that Mexico was characterised by an "adequate" globalisation process along the last decade, future growth, based on past patterns of the globalisation variables chosen, may be also representative of an "adequate future globalisation process". In this way, the evolution of the globalisation process shown in Graph 6.47 can be considered as a proxy of the "globalisation threshold" or the "minimum globalisation requirements".

For example, a lower value for the globalisation indicator may be a consequence of a lower growth rate of the Internet connections or a slower growth in the number of international passengers that use the IAMC.

For example, if the project for the New International Airport of Texcoco cannot be completed, the international passengers' growth rate will be inevitably diminished and Mexico City will not be consolidated as one of the main hubs of North America. Graph

6.47 shows the way in which the general globalisation indicator may be affected. A growth rate of 1.5% instead of the estimated 3.25% in the number of international passengers is equivalent to a globalisation indicator that is 15% lower in comparison to the "globalisation threshold" in year 2030. In a similar way, a 2.5% growth of the international passengers may diminish the globalisation indicator in 8%

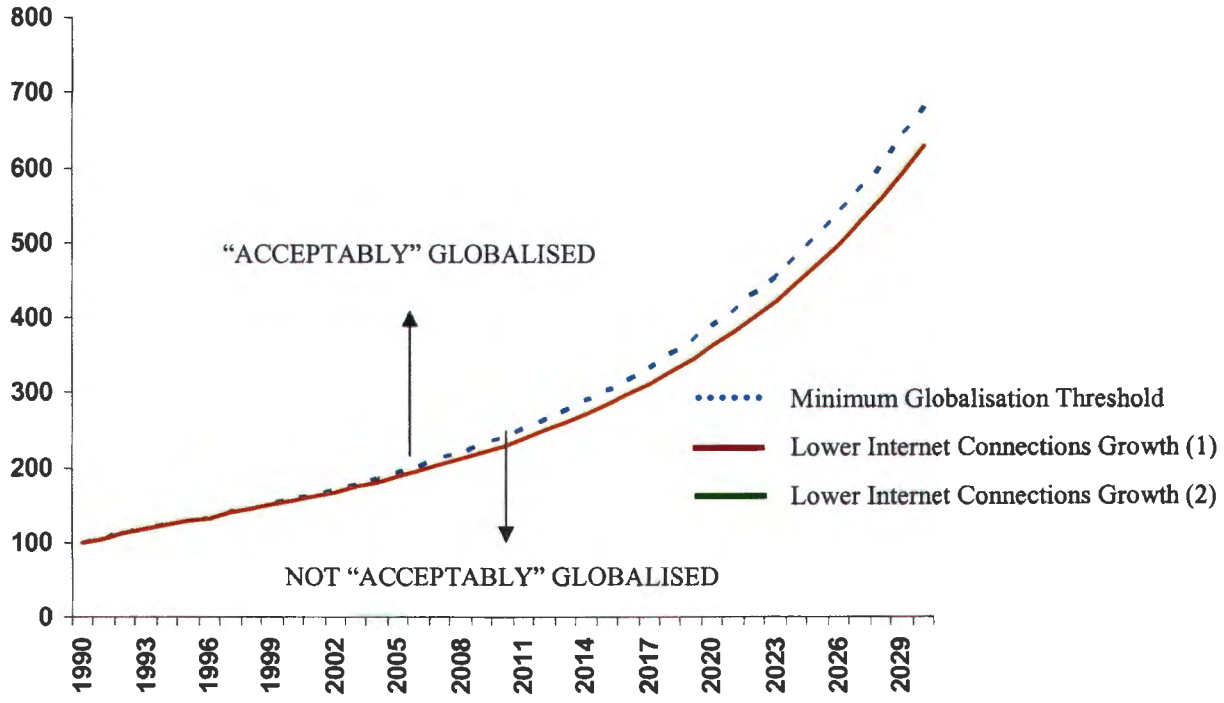
GRAPH 6.47
General Globalization Indicator:
New Airport, Alternative Scenarios



SOURCE: Own elaboration, based on statistics from Garza, 2000.

A change in the Internet connections growth rate may have a similar effect. For example an annual growth rate of 5% instead of the assumed 10% may have an effect of diminishing the globalisation indicator value in 33%

GRAPH 6.48
General Globalization Indicator
Internet Connections: Alternative Scenarios



SOURCE: Own elaboration, based on constructed globalisation indicator.

As we mentioned on section 5.1 and as we will see deeply on Chapter 7, the level of globalisation will be determinant for the sustainability of Mexico City for the following three decades. The "general globalisation indicator" that was previously developed is just a first methodological approach to measure the globalisation process through simple and measurable variables for the MCMZ, such as sustainability variables were also analysed. Nevertheless, future works should tackle the challenge of measuring the specific relations between sustainability indicators and globalisation indicators.

This work has presented some basic hypothesis in specific issues such as the relations between urban transportation and digitalisation levels, but there are other variables such as housing, water usage or public green areas that will certainly be affected by globalisation processes. It is difficult to determine the direction and magnitude of the implied changes, but something is true: globalisation and urbanisation, both patterns go together. More over, with the application of adequate policies such as the ones that have been analysed along all this chapter, globalisation and sustainable urban development may go together.

Future works about Mexico City will certainly take different "research paths", but one of the most important should be the analysis of a basic hypothesis that has been argued along this work: for Mexico City, globalisation means specialisation of the commerce and service sector which goes hand to hand with lower levels of environmental stress or intensity. Following these ideas, there are certain elements that should be part of the "proposed objective image" of Mexico City towards 2030 (see Chapter 7):

- New International Airport and communications hub.
- Annular Roads and radial trains.
- Technopoles.
- Massive connection of optical fibers, wide access and bandwidth availability for telecommunications.

CHAPTER 7

GLOBALIZATION, SUSTAINABILITY AND URBAN FORM IN MEXICO: A VISION TOWARDS 2030

7.1 Towards a Sustainable Urban Form for Mexico City (MCMZ)

THE DEBATE AND THEORIES ON SUSTAINABLE URBAN FORM

The discussion about ideal urban form is as ancient as utopian thought on the ideal city. Only in the past century has a more systematic and analytical approach to the concept of urban form begun to be taken, ranging from socio-economic analysis (concentric cities of multiple nuclei), to architectural[1] and even mathematical analysis, which looks at the diverse dynamics of urban form and compares them to a "fractal."[2] But only in the last few years has there been a more solid debate that analytically incorporates environmental issues and the concept of sustainability, and that in some way resurrects the classic works of McHarg[3] and other researchers about the need to consider the natural landscape and to strike a balance between natural cycles and the working of ecosystems.

As a starting-point, we look at the most recent debate on the subject, which uses the concept of sustainability employed in the present work, and which in one way or another considers almost all previous studies. This leads us to more decidedly include the spatial dimension and the location restrictions specific to every city, which, in turn, presents us with the task of going from abstract sustainability concepts, such as a vector of distributive inter-temporal and inter-generational preferences, to seeing cities for what they really are: centres of intense consumption of energy and natural materials and producers of pollution and waste. This is why the debate about sustainable urban forms must begin with them

[1] A. E. J. Morris, *History of Urban Form,* 1994; See also L. Mumford, *op. cit.,* 1938, 1961.
[2] B. Michael & P. Longley, *Fractal Cities,* San Diego Ca.: Academic Press, 1994.
[3] I. L. McHarg, *Design with Nature,* New York City: The American Museum of Natural History, The Natural History Press, 1969, pp. 175-186.

including the use of renewable resources (water, forests, biomass, soil, etc), the minimization of the use of non-renewable resources (fossil fuels, loss of biodiversity, impoverishment of natural ecosystems) and the reduction of polluting emissions such as photochemical pollutants and greenhouse gases, among others. Any discussion should also consider the mitigating role that could be played by new telecommunication technologies – which allow for lower intra-urban concentration and – by less polluting energy consumed in transport. Here it is important to emphasize the work of Batten,[4] who points out that globalization and new information technologies are encouraging a nodal or polycentric configuration in cities that saves energy, which he calls "Network Cities;" formerly independent areas (or cities themselves) now complement each other or become interconnected in corridors of diverse activities.

Another very important dimension of the discussion of sustainable urban form has to do with the concept of the "compact city," which came about in the early 1990s with the pioneering work of M.J. Breheny[5] and somewhat later with that of C. Pugh,[6] both of whom address questions of sustainability as well as operative economic and environmental considerations. Breheny especially focuses on the concept of the compact city (the typical European high-density model) and the contradictions it produces in terms of green areas, a lack of decentralization and extremely high density, among other things. Breheny and some of his co-authors end up favouring the urban form of "concentrated decentralization," that is, the promotion of a few urban and suburban centres and sub-centres. But before going any further, we need to analyse the concept of the compact city since some of its elements are needed to describe the urban form that would be most desirable for us.

In their important trilogy of books about the compact city, M. Jenks and his colleagues[7] carry out a thorough study. However, their analysis proved to be inconclusive with respect

[4] D. Batten, Network Cities: Creative Urban Agglomerations for the 21st. Century, Urban Studies 1995 as cited in J. R. Short & K. Yeong-Hyun, *Globalization and the City.* New York: Longman, 1999.
[5] M. J. Brehny, (ed) *Sustainable Development and Urban Form*, 1992.
[6] Pugh, C. (ed). *Sustainability, The Environment and Urbanization...*, pp. 135- 178.
[7] J., M. Burton, & K. Williams, *The Compact City: A sustainable urban form?* 1996; K. Williams, Jenks, K. & Burton, E., (eds) *Achieving a Sustainable Urban Form;* and M.Jenks, R. Burgess, *Compact cities: Sustainable Urban Form for Developing Countries*, 2000.

to whether the compact city is adaptable in developing countries which often already have extremely dense central areas, with attendant negative effects on the environment such as high levels of pollution, "islands of heat," overcrowding and congestion, among others. Of course, positive aspects such as mixed land use and the vitality of compact cities are also recognized. But in many developing countries there is a spontaneous emergence of a combined process of a compact, dense centre (although often with decreasing density as in the case of Mexico City) and a low-density area extending to the suburbs; for the analysis of this process as it occurred in Mexico, we used the Turner model.[8] The issue is more complicated in our case, since the MCMZ does not lend itself to typical comparative analysis of developed and developing countries: Mexico and its megalopolis have an intermediate "status" which complicates their easy classification. There are, in fact, no reliable comparable statistics on the density of different cities around the world. Nonetheless, it behoves us to cite the excellent empiric work of Harry W. Richardson et al.,[9] who attempted to make an approximate comparison of urban densities in different cities around the world; Mexico City was found to have a density (and a standard deviation) fairly close to the mean of cities in developed countries.[10] But in the same work it was observed that other cities have similar mixes of high and low density independent of whether they are in developed or developing countries. This suggests that local, geographic, historic and even cultural characteristics also play an important role in the determination of densities, as we explained in section 4.3 of this thesis. In Mexico City's case, one intuitively notices a hybrid situation, with a compact centre and sub-centres of relative density, and that an adequate mix of the positive aspects of high-density (compactness) and greater de-concentration could be achieved.

With these considerations in mind, and with an approach that is more practical than theoretical, G. Haughton and C. Hunter[11] explicitly describe the characteristics and advantages of the urban form of concentrated decentralization, where an "old," high-density

[8] X. Kasperson & Turner, *Regions at Risk,* Tokyo, New York, Paris: United Nations University Press, 1995.
[9] In Jenks and Burguess (eds), *Achieving a Sustainable Urban Form...*, pp. 25-32.
[10] Its density and ratio between density and surface is similar to Milan and Tokyo, and is not far from that of Paris, For example, see Richardson, pp. 28 and 29.
[11] G. Haughton & C. Hunter, *Sustainable Cities*, 1994. Kingsley Publishers, London.

city centre and a number of similar sub-centres are separated by areas of much lower density, allowing for more green zones, less congestion and a healthy combination of mixed land use. This vision has the support of the "New Urbanism" movement,[12] which has especially gained momentum in California, and which advocates compact cities with mixed land use combined with plentiful green areas.

A final question considered here is whether this kind of urban form is truly functional as an analytical model for Mexico City. Brunn and Williams[13] analyse the urban form of Latin American cities and have found that they very much coincide with the classic model (1925) of the Chicago School and its principal author E.W. Burgess (Mexico City is no exception). According to these authors, the Latin American city is likely to have a basic structure of three concentric zones or rings. The first central ring is called the "Zone of Maturity," or the Central Business District (CBD), which in Mexico City is the "Historic Centre" or, in Spanish, the "Centro Histórico." The second ring, or "Zone of In Situ Accretion," grows after the relative demographic, urbanistic-architectural maturation of the first ring and is primarily composed of middle to upper-middle class housing. The third ring, or Zone of Peripheral Squatter Settlements, consists of precarious "barrios" or neighbourhoods that will mature much later on. The city also has "spines" or great avenues with characteristics similar to those of the original central ring, with businesses and upper-class housing at their peripheral ends (in Mexico City, Insurgentes Avenue and Reforma are examples). At some point (perhaps in the 1950s) Mexico City followed this model quite well; the farther you went from the city centre, the more the disamenities grew, a pattern that was interrupted only by the so-called spines or by some geographical accident. It seems intuitively evident to us that this model, despite its excessive simplification, functions within the urban form of concentrated decentralization.

The analysis of urban rings carried out in section 4.2 of this thesis was based on the abundant information contained in Pick and Butler's *Mexico Megacity*[14] and on a variety of

[12] L. Donlyn, *Places: The Promise of New Urbanism*, California: Berkeley, 2000.
[13] S. D. Brunn & J.F. Williams, *Cities of the World*...,pp. 25- 31 and 224- 265.
[14] Pick and Butler, *Mexico Megacity*, 1997.

Mexican census statistics;[15] the result is a robust confirmation of the model that was adopted intuitively. Thus, based on this information (Chapter 3), we can construct our proposal for a sustainable urban form for the MCMZ. But before this model is proposed, we should recall the description made in section 2.3 of the Mexico Basin's strictly environmental characteristics and the negative effects of urbanization.

The ecosystems of the Mexico Basin are well defined, as are the bio-geochemichal cycles on which they depend, and to a certain degree they maintain their basic appearance, with the exception of the slightly more than 1,500 square kilometres of the intensely urbanised zone, as seen in Chapter 2.3. The three most perceivable, well-known effects of increased urbanization on the environment are: (1) the alteration of soil, with the loss and fragmentation of forests and wildlife habitats and the loss of biodiversity, (2) the impact on the water cycle, with increased run-off, a greater possibility of flooding, erosion and lower water quality, the reduced replenishment of aquifer systems, the depletion of water tables, the intrusion of saltwater and the sinking of the ground, and (3) excessive energy consumption, with increased atmospheric pollution, islands of heat and the depletion of non-renewable resources.

For these reasons, it can be proposed that outside the urban sprawl, in these fore-mentioned ecosystems, preservation and restoration efforts should continue in order to safeguard the city's ecology. This is especially necessary in the mountainous zones to the south of the basin – in the Sierra Nevada, the Chihinautzín-Ajusco mountains and parts of the Sierra de las Cruces – as well as in the foothills of the east and the remaining five lacustrine areas. This would mainly include the restoration of Texcoco (see sections 2.2 and 6.4.1) and some important wetlands to the north (Zumpango) and the south (Tláhuac), which connect with the Chalco and Xochimilco lakebeds.

[15] CONAPO and INEGI.

SIX PRECONDITIONS FOR A SUSTAINABLE URBAN FORM IN THE MZMC

According to what has been discussed throughout this thesis, a desirable urban form must meet six relevant conditions:

1. It should be based on a "holistic," integral vision that considers the entire Basin of Mexico, including Mexico City and its Megalopolis, (that is, the entire MZMC). Furthermore, this must be analytically coherent with the dynamics of the "Megalopolitan" formation of the Central Mexican region and its "crown" of cities around the MZMC.

2. It should have a solid, empirical basis, supported by the "urban rings" theory (Chapter 4 and 5).

3. It should be functional in terms of the dynamics of the environment and local ecosystems, and, in accordance with the classical principles of Ian McHarg mentioned previously, it should work with –and not against– natural processes, especially water cycles, flora and plants, wildlife and natural climates,[16] as described in Chapter 2.

4. It should be consistent with Mexico City's history, as well as with its urban form and dynamics, and should never contradict these, much less destroy the urban memory maintained in landscape and architecture (as described in Chapter 3).

5. Additionally, it should be functional in terms of the city's real dynamics, such as its advanced demographic transition, new technologies, transportation systems and telecommunications, as well as the challenges of globalization and other elements identified in the indicators of sustainability and factors of globalization (described in Chapter 5 and 6).

[16] M. Hough, *Cities and natural process*, 1995.

6. It should gradually take shape, with an eye toward the year 2030, and in accord with the indicators and policies described above.

In contrast to the urban concentric ring model, the polinuclear model being proposed here will optimise the use of urban infrastructure, reduce the population's demand for transport, curb land-use changes and limit corresponding urban expansion. This model, itself derived from the concentrated decentralization thesis, represents an opportunity to bring about the reconfiguration of the city with the urban development-transportation-environment trinomial as our basis.

In this context, the redensification and renewal of the MCMZ's central delegations or districts is vital to consolidating a great urban centre, around which other sub-centres should gravitate, allowing a balance to be struck between the supply of housing, services, green areas and infrastructure, on the one hand, and job opportunities and development, on the other. This balance would be made possible through territorial ordering programs that allow mixed land use, complemented by programs that build or rehabilitate housing in areas with employment opportunities, or that bring about greater economic activity in places with lower rates of occupied population to housing and/or economic units to housing (see Table 7.1).

TABLE 7.1
Relation between Economic Activity and Housing, 1995

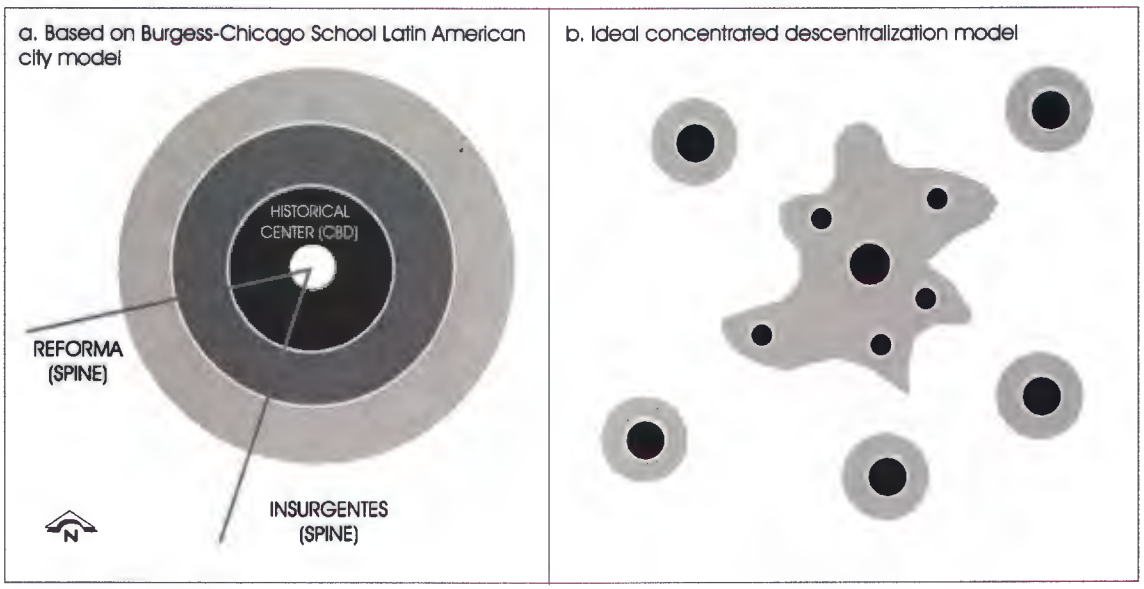
	Entities	Economic Units / Housing	Working Population / Housing
	MCMZ	0,1469	0,7374
Third Urban Ring	Acolman	0,1276	0,3941
	Atenco	0,1064	0,2928
	Chalco	0,1484	0,3815
	Ixtapaluca	0,0985	0,2984
	Jaltenco	0,0961	0,1943
	Melchor Ocampo	0,1312	0,2847
	Nextlalpan	0,0823	0,1470
	Nicolás Romero	0,0979	0,2152
	Tecamac	0,1278	0,3301
	Teoloyucan	0,1135	0,2492
	Tepotzotlán	0,1022	0,9012
	Texcoco	0,1424	0,4668
	Tultepec	0,0962	0,3797
	Zumpango	0,1375	0,3116
	Tlalmanalco	0,0984	0,3883
	Milpa Alta	0,2279	0,2403
Second Urban Ring	Atizapan de Zaragoza	0,7973	3,4351
	Coacoalco	0,0859	0,2412
	Cuautitlán	0,1630	0,8873
	Chicoloapan	0,1466	0,3129
	Chimalhuacán	0,1245	0,1967
	Ecatepec	0,1301	0,4188
	Huixquilucan	0,0718	0,2644
	Naucalpan	0,1072	0,8472
	Nezahualcoyotl	0,1501	0,3152
	La Paz	0,1358	0,5080
	Tultitlán	0,0886	0,3663
	Cuautitlán Itzcalli	0,0934	0,7418
	Coyoacán	0,1060	0,6401
	Cuajimalpa	0,1154	0,6629
	Iztapalapa	0,1374	0,5582
	Magdalena Contreras	0,0834	0,2422
	Tláhuac	0,1235	0,3320
	Tlalpan	0,1016	0,5428
	Xochimilco	0,1324	0,4517
First Urban Rin g	Tlanepantla	0,1213	0,9335
	Azcapotzalco	0,1453	1,2733
	Gustavo A. Madero	0,1357	0,5125
	Iztacalco	0,1507	0,9187
	Benito Juárez	0,2103	1,9263
	Cuauhtémoc	0,4087	2,5391
	Miguel Hidalgo	0,2270	2,9588
	Venustiano Carranza	0,2515	0,8714

SOURCE: Economic Census, INEGI, Mexico, 1994 and Population Content, 1995.

THE CONCEPTUAL POLICENTRIC MODEL OF CONCENTRATED DESCENTRALIZATION

Based on the analysis of Haughton and C. Hunter,[17] we constructed a polycentric model of concentrated decentralization for the MCMZ which, as we already mentioned, is itself based on the concentric rings model of the Chicago School (Burgess), whose empirical validation was carried out by Pick and Butler.[18] This is adequately described in the following diagrams, which combine the spatial conceptualisation of the socio-economic information generated by the urban form we propose:

FIGURE 7.1
Concentric Rings Model vs. Concentrated Decentralization Model



SOURCE: by author

[17] Op.cit. pp. 286-296.
[18] Pick and Butler. *Mexico Megacity*. 1997.

It is important to emphasize that one of the keys to making the polycentric model contribute to facing the two important challenges of the city – globalization and environmental sustainability – is that the sub-centres grow large enough to generate economies of scale capable of profitably generating information technologies and providing professional and specialized services, but not so large that they represent an excessive burden on environmental capital.

As tentatively listed in Map 7.1 and Table 7.2, the urban sub-centres could be located in the following areas: Tlalpan - Coyoacan, (south), Naucalpan - Tlalnepantla (north), Santa Fe (west) and Texcoco (east). The choice of the first two centres can be justified by their existing infrastructure, as in the case of the Historic Centre (CBD), while the latter two locations are chosen due to the need to consolidate these areas in socio-economic, environmental and urban terms, so as to avoid unregulated urban sprawl and to fulfil our global paradigms of sustainability.

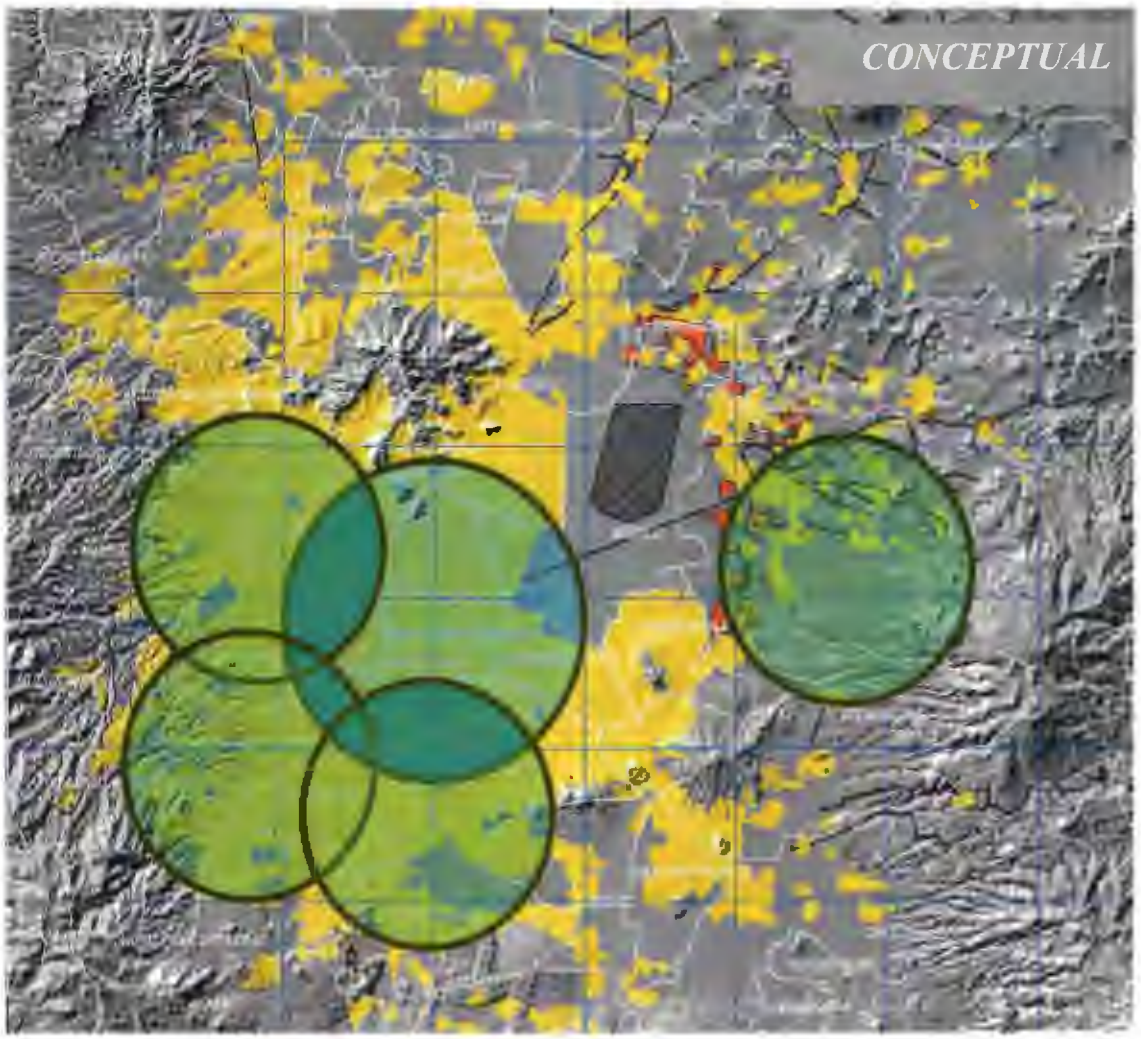
TABLE 7.2
Polycentric Model: Five Urban Sub-Centres of MCMZ

URBAN CENTER / SUB-CENTRE	MAIN MUNICIPALITIES / D.F. DELEGATIONS
Santa Fe (west)	• Cuajimapla • Huixquilucan
Coyoacán – Tlalpan (south)	• Coyoacán • Tlalpan • Xochimilco
Naucalpan – Tlalnepantla (north)	• Naucalpan • Tlalnepantla • Cuautitlán Izcalli • Atizapán de Zaragoza
Texcoco (east)	• Atenco • Chicoloapan • Chimalhuacán • Texcoco
"Centro Histórico" o Central Business District (CBD)	• Azcapotzalco • Benito Juárez • Cuauhtémoc • Gustavo A. Madero • Iztacalco • Miguel Hidalgo • Venustiano Carranza

SOURCE: by author.

MAP 7.1

Urban Development: the Polycentric Model



SOURCE: by author

It is worth mentioning that, in the context of adequate environmental and urban planning, a New International Airport of Mexico City built in Texcoco (NAICM for its initials in Spanish), along with the recuperation of lakes and the "green" reconfiguration of the existing airport, could play a central role in the development and urban ordering of the eastern MZMC, and thereby help to consolidate both the Historic Centre (CBD), which is made up by Mexico City's central delegations (see Table 7.2), and Texcoco, one of the four urban sub-centres proposed above. As a matter of fact, this would be the most ambitious and important urban (and ecological) project ever attempted in Mexico City.

A significant portion of the population growth expected in the municipalities surrounding the NAICM would be channelled, in coordination with existing urban regeneration programs, into the central delegations, especially Venustiano Carranza and Gustavo A. Madero, and into suburban municipalities such as Ecatepec and Nezahualcóyotl. It is important to point out that the Government of the Federal District and these delegations have plans to attract new residents to the MCMZ's central ring through corresponding urban development programs, considered to be a top priority.

As part of the strategy to attract people to the central delegations, there are plans for zoning that favours residential land use (in its different modalities). One of the priorities of the Urban Development Program of the Federal District is to "recycle" and restore abandoned, rundown areas where there is access to services and transportation, for the purpose of providing low-income housing.

In comparison to the trend scenario shown in the Tables 7.3, 7.4 and 7.5, the alternative scenario in which the polycentric model is consolidated would allow for a much smaller urban sprawl (184,000 hectares in the first, against 206,000 in the second) and, of course, a higher population density (118 people per hectare in the first, against 105 in the second).

It is important to emphasize that, according to the trend scenario, if urban sub-centres fail to consolidate themselves in terms of services and infrastructure, they will become more

spread out, or, to put it another way, they will be "lost" as part of the model of evolving urban growth (urban rings). For example, Texcoco reaches a density of 54 people per hectare and a surface area of 26,200 hectares in the trend scenario, in contrast to 74 people per hectare and a surface area of 20,600 hectares in the polycentric scenario (see Table 7.3 and 7.4; Graph 7.1.) A much smaller difference, probably due the area's geographic limitations, can be observed in the case of Santa Fe, which in the trend scenario has a density of 61 people per hectare and a surface area of 7,800 hectares, while in the polycentric scenario it reaches 77 people per hectare and a surface area of 6,711 hectares. (See Table 7.3, Table 7.4, and Graph 7.1).

The most relevant difference in population density is found for Mexico City's Historic Centre (CBD), which reaches a density of 147 people per hectare and a surface area of 26,500 hectares in the trend scenario, in contrast to 164 people per hectare and a surface area of 26,400 hectares in the polycentric scenario. (See Table 7.1, Table 7.2, and Graph 7.1.)

TABLE 7.3
Trend Scenario: Results Summary

Population	1995	2000	2010	2020	2030
First Urban Ring	4.604.528,00	4.616.512,00	4.511.647,00	4.707.828,00	4.728.241,16
Second Urban Ring	9.736.042,00	10.597.342,00	11.916.701,00	13.104.814,00	13.246.883,83
Third Urban Ring	1.279.475,00	1.540.562,00	2.030.288,00	2.283.387,00	2.310.424,95
	-	-	-	-	-
Santa Fe	305.094,00	351.579,00	432.224,00	470.902,00	475.011,28
Naucalpan - Tlalnepantla	2.397.957,00	2.626.041,00	3.034.310,00	3.428.880,00	3.471.055,20
Texcoco	859.980,00	968.451,00	1.123.547,00	1.371.352,00	1.413.573,26
Coyoacán - Tlalpan	1.538.319,00	1.659.953,00	1.832.133,00	1.881.803,00	1.886.843,47
Central Delegations	3.891.385,00	3.898.423,00	3.793.953,00	3.896.808,00	3.907.245,63
	-	-	-	-	-
TOTAL MCMZ	16.659.107,00	17.854.164,00	19.822.886,00	21.567.299,00	21.749.969,23
AGR		0,70%	1,05%	0,85%	0,08%

Urban Area (Hectares)	1995	2000	2010	2020	2030
First Urban Ring	32.607,00	32.826,33	32.826,33	33.647,17	33.647,17
Second Urban Ring	81.363,00	90.368,60	105.186,85	120.611,07	120.611,07
Third Urban Ring	16.230,00	20.446,06	28.725,40	33.253,74	33.253,74
	-	-	-	-	-
Santa Fe	4.664,00	5.528,84	7.062,22	7.799,47	7.799,47
Naucalpan - Tlalnepantla	22.705,00	24.255,46	26.925,57	30.172,94	30.172,94
Texcoco	11.725,00	13.574,22	16.810,73	26.204,64	26.204,64
Coyoacán - Tlalpan	15.911,00	17.498,94	20.070,25	20.596,84	20.596,84
Central Delegations	26.108,00	26.268,28	26.268,28	26.518,17	26.518,17
	-	-	-	-	-
TOTAL MCMZ	144.829,00	159.653,52	185.936,07	206.720,63	206.720,63
AGR		0,98%	1,54%	1,07%	0,00%

Densities	1995	2000	2010	2020	2030
First Urban Ring	141,21	140,63	137,44	139,92	140,52
Second Urban Ring	119,66	117,27	113,29	108,65	109,83
Third Urban Ring	78,83	75,35	70,68	68,67	69,48
	-	-	-	-	-
Santa Fe	65,41	63,59	61,20	60,38	60,90
Naucalpan - Tlalnepantla	105,61	108,27	112,69	113,64	115,04
Texcoco	73,35	71,34	66,84	52,33	53,94
Coyoacán - Tlalpan	96,68	94,86	91,29	91,36	91,61
Central Delegations	149,05	148,41	144,43	146,95	147,34
TOTAL MCMZ	115,03	111,83	106,61	104,33	105,21
AGR					

SOURCE: By author, based on projections from CONAPO-2020.
METODOLOGICAL NOTE: Urban surface area was calculated supposing that the elasticity of the percentage increase of urban sprawl with respect to a one percent increase in the population is 1.31. Population growth between 2020 and 2030 was calculated extrapolating the performance of the growth rate between 1995 and 2020.

TABLE 7.4
Polycentric Scenario: Results Summary

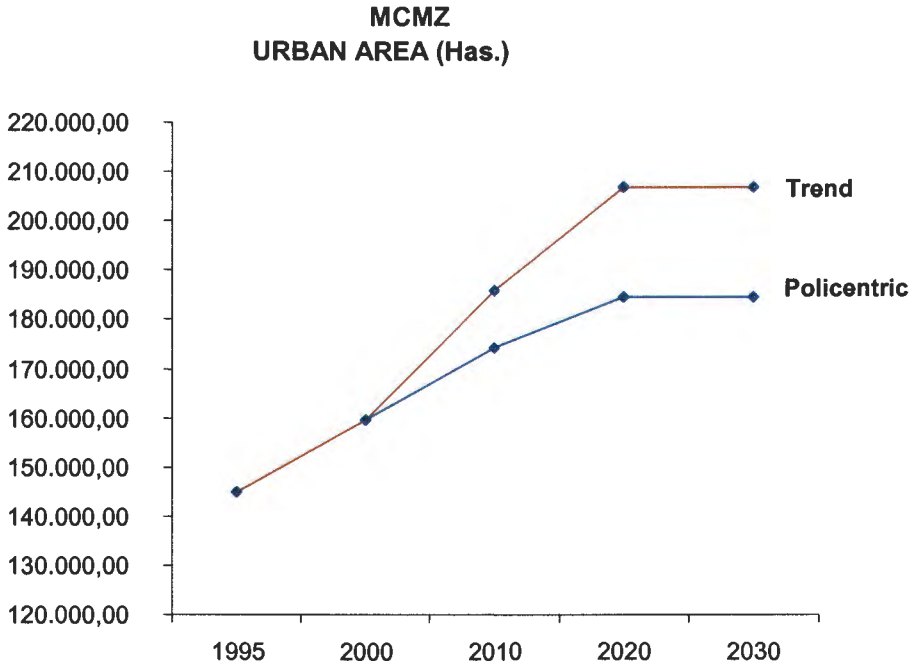
Population	1995	2000	2010	2020	2030
First Urban Ring	4.604.528,00	4.616.512,00	4.688.651,11	5.061.836,23	5.259.253,50
Second Urban Ring	9.736.042,00	10.597.342,00	11.793.386,79	12.858.185,58	12.876.941,21
Third Urban Ring	1.279.475,00	1.540.562,00	1.981.914,56	2.186.640,13	2.165.304,64
Santa Fe	305.094,00	351.579,00	445.704,08	497.862,15	515.451,50
Naucalpan - Tlalnepantla	2.397.957,00	2.626.041,00	3.134.996,42	3.630.252,84	3.773.114,46
Texcoco	859.980,00	968.451,00	1.160.678,89	1.445.615,78	1.524.968,92
Coyoacán - Tlalpan	1.538.319,00	1.659.953,00	1.895.778,13	2.009.093,26	2.077.778,86
Central Delegations	3.891.385,00	3.898.423,00	3.943.424,49	4.195.750,97	4.355.660,09
	-	-	-	-	-
TOTAL MCMZ	16.659.107,00	17.854.164,00	19.822.886,00	21.567.299,00	21.749.969,23
AGR		0,70%	1,05%	0,85%	0,08%

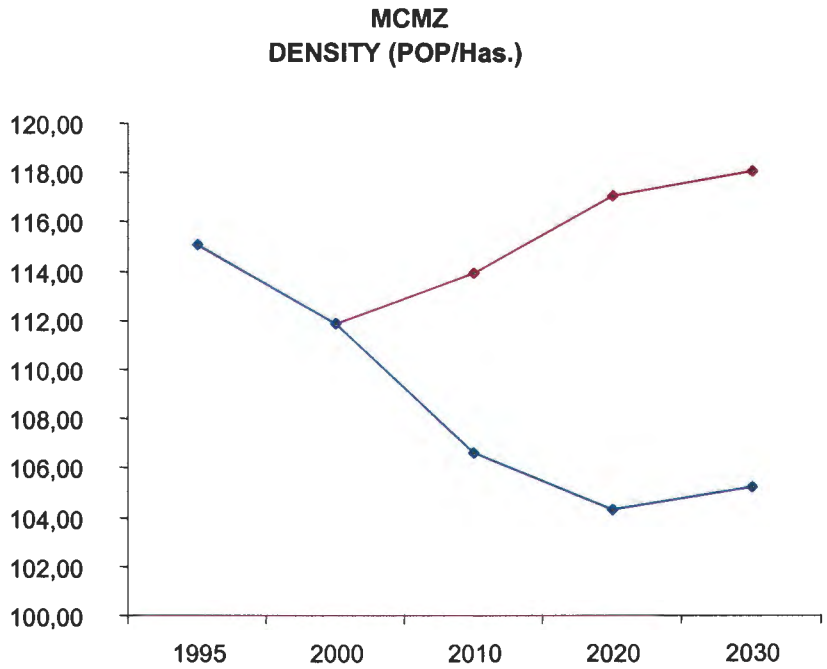
Urban Area (Hectares)	1995	2000	2010	2020	2030
First Urban Ring	32.607,00	32.826,33	32.826,33	33.532,72	33.532,72
Second Urban Ring	81.363,00	90.368,60	98.504,60	107.795,53	107.795,53
Third Urban Ring	16.230,00	20.446,06	24.933,34	27.053,88	27.053,88
Santa Fe	4.664,00	5.528,84	6.359,91	6.711,78	6.711,78
Naucalpan - Tlalnepantla	22.705,00	24.255,46	25.702,62	27.611,23	27.611,23
Texcoco	11.725,00	13.574,22	15.328,36	20.631,58	20.631,58
Coyoacán - Tlalpan	15.911,00	17.498,94	18.892,55	19.155,28	19.155,28
Central Delegations	26.108,00	26.268,28	26.268,28	26.403,72	26.403,72
TOTAL MCMZ	144.829,00	159.653,52	174.002,99	184.288,73	184.288,73
AGR		0,98%	0,86%	0,58%	0,00%

Densities	1995	2000	2010	2020	2030
First Urban Ring	141,21	140,63	142,83	150,95	156,84
Second Urban Ring	119,66	117,27	119,72	119,28	119,46
Third Urban Ring	78,83	75,35	79,49	80,83	80,04
Santa Fe	65,41	63,59	70,08	74,18	76,80
Naucalpan - Tlalnepantla	105,61	108,27	121,97	131,48	136,65
Texcoco	73,35	71,34	75,72	70,07	73,91
Coyoacán - Tlalpan	96,68	94,86	100,35	104,88	108,47
Central Delegations	149,05	148,41	150,12	158,91	164,96
TOTAL MCMZ	115,03	111,83	113,92	117,03	118,02

SOURCE: By author, based on projections from CONAPO to year 2020.
METHODOLOGICAL NOTE: Urban surface area was calculated supposing that the elasticity of the percentage increase of urban sprawl with respect to a one percent increase in the population is 1.31. Population growth between 2020 and 2030 was calculated extrapolating the performance of the growth rate between 1995 and 2020. Additionally, it was supposed that the population that left central areas between 1980 and 1995 contributed to a redensification of the Historic Centre and to the consolidation of the new urban sub-centres of Santa Fe, Naucalpan - Tlalnepantla, Coyoacan - Tlalpan and Texcoco, taking into account delegations and municipalities that make up each of these. The distribution between each nucleus was carried out in direct proportion to the population in the year 2000, as if it actually followed a "gravitational" pattern.

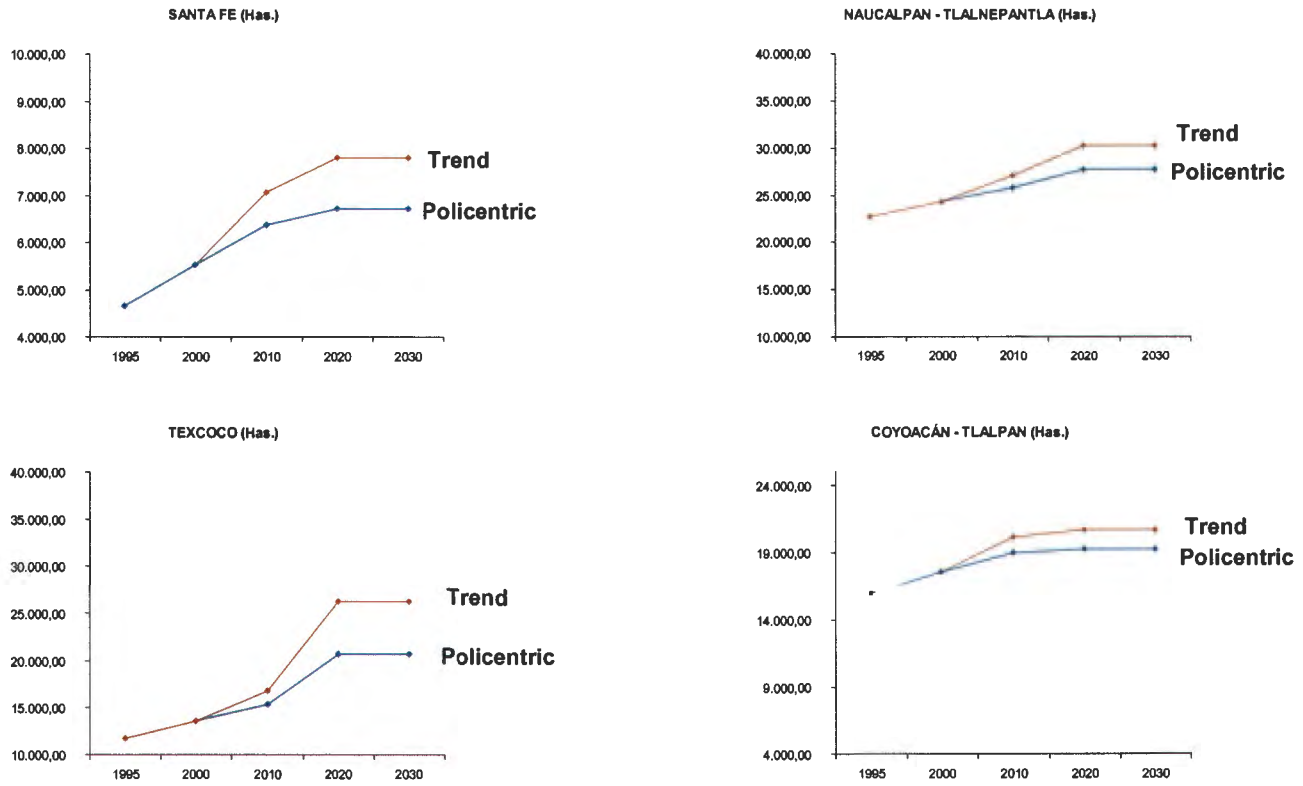
GRAPH 7.1
Growth Scenarios for Mexico City, 2000 to 2030





SOURCE: By author, based on constructed projection models (see methodological notes for Tables 7.3 and 7.4).

GRAPH 7.2
Growth Scenarios of Urban Sub-Centres, 2000 to 2030



SOURCE: by author, based on model projections (see methodological notes for Tables 7.3 and 7.4).

TABLE 7.5
Total Growth of Urban Area by Urban Municipality / Delegation, 2000 - 2030

		Trend Scenario				Policentric Scenari		
MUNICIPALITY / DELEGATION	Surface (Has.)	2000 - 2010	2010 - 2020	2020 - 2030	Surface (Has.), 2030	2000 - 2010	2010 - 2020	2020 - 2030
MCMZ	144.829,00	16,5%	11,2%	0,0%	206.720,63	8,99%	5,91%	0,00%
Federal District	71.018,00	7,7%	2,0%	0,0%	82.748,68	4,29%	1,06%	0,00%
Álvaro Obregón	8.547,00	7,0%	3,6%	0,0%	10.103,52	3,79%	1,92%	0,00%
Azcapotzalco	2.988,00	0,0%	0,0%	0,0%	2.988,00	0,00%	0,00%	0,00%
Benito Juárez	2.420,00	0,0%	0,0%	0,0%	2.420,00	0,00%	0,00%	0,00%
Coyoacán	5.243,00	0,0%	0,0%	0,0%	5.243,00	0,00%	0,00%	0,00%
Cuajimalpa	2.607,00	17,4%	3,6%	0,0%	3.577,29	9,43%	1,93%	0,00%
Cuauhtémoc	3.420,00	0,0%	0,0%	0,0%	3.420,00	0,00%	0,00%	0,00%
Gustavo A. Madero	6.876,00	0,0%	3,6%	0,0%	7.286,17	0,00%	1,92%	0,00%
Iztacalco	2.908,00	0,0%	0,0%	0,0%	2.908,00	0,00%	0,00%	0,00%
Iztapalapa	10.010,00	2,2%	0,0%	0,0%	10.777,00	2,17%	0,00%	0,00%
M. Contreras	2.955,00	10,8%	3,6%	0,0%	3.698,06	5,86%	1,92%	0,00%
Miguel Hidalgo	4.251,00	0,0%	0,0%	0,0%	4.251,00	0,00%	0,00%	0,00%
Milpa Alta	1.919,00	22,0%	3,6%	0,0%	2.802,84	11,94%	1,92%	0,00%
Tláhuac	2.961,00	28,1%	3,6%	0,0%	4.676,95	15,23%	1,92%	0,00%
Tlalpan	6.359,00	16,9%	3,6%	0,0%	8.667,78	9,16%	1,92%	0,00%
Venustiano Carranza	3.245,00	0,0%	0,0%	0,0%	3.245,00	0,00%	0,00%	0,00%
Xochimilco	4.309,00	26,7%	3,6%	0,0%	6.686,06	14,47%	1,92%	0,00%
Metropolitan Municipalities	73.811,00	24,3%	18,3%	0,0%	123.971,95	13,18%	9,90%	0,00%
Acolman	769,00	36,6%	17,0%	0,0%	1.527,13	19,92%	9,23%	0,00%
Atizapán de Zaragoza	4.656,00	0,0%	0,0%	0,0%	4.656,00	0,00%	0,00%	0,00%
Atenco	3.783,00	0,0%	0,0%	0,0%	3.783,00	0,00%	0,00%	0,00%
Coacalco	1.669,00	51,3%	4,4%	0,0%	3.500,00	27,82%	9,23%	0,00%
Cuautitlán	504,00	22,9%	17,0%	0,0%	837,94	12,41%	9,23%	0,00%
Cuautitlán Izcalli	4.453,00	40,0%	17,0%	0,0%	9.195,95	21,69%	9,23%	0,00%
Chalco	2.317,00	53,4%	17,0%	0,0%	5.569,20	28,92%	9,23%	0,00%
Chicoloapan	755,00	0,0%	791,4%	0,0%	8.259,00	0,00%	466,57%	0,00%
Chimalhuacán	2.812,00	23,5%	17,0%	0,0%	4.713,07	12,74%	9,23%	0,00%
Ecatepec	10.973,00	15,7%	13,6%	0,0%	16.003,00	6,48%	9,23%	0,00%
Huixquilucan	2.057,00	39,5%	17,0%	0,0%	4.222,18	21,41%	9,23%	0,00%
Ixtapaluca	1.918,00	53,4%	17,0%	0,0%	4.610,13	28,92%	9,23%	0,00%
Jaltenco								
Melchor Ocampo								
Naucalpan	7.097,00	5,7%	17,0%	0,0%	9.191,98	3,10%	9,23%	0,00%
Nezahualcóyotl	6.533,00	0,0%	4,4%	0,0%	6.823,00	0,00%	4,44%	0,00%
Nicolás Romero	2.909,00	41,6%	17,0%	0,0%	6.118,12	22,52%	9,23%	0,00%
Paz, La	1.524,00	51,4%	12,4%	0,0%	3.444,00	27,87%	9,23%	0,00%
Tecámac	1.692,00	27,9%	17,0%	0,0%	3.004,29	15,10%	9,23%	0,00%
Teoloyucan	678,00	43,3%	17,0%	0,0%	1.454,52	23,44%	9,23%	0,00%
Tepotzotlán	726,00	53,4%	17,0%	0,0%	1.745,01	28,92%	9,23%	0,00%
Texcoco	2.058,00	32,6%	17,0%	0,0%	3.880,37	17,65%	9,23%	0,00%
Tlalnepantla	6.499,00	0,0%	8,7%	0,0%	7.129,00	0,00%	8,71%	0,00%
Tultepec	745,00	53,4%	17,0%	0,0%	1.790,68	28,92%	9,23%	0,00%
Tultitlán	3.075,00	53,4%	6,3%	0,0%	6.718,00	28,92%	9,23%	0,00%
Valle de Chalco	2.384,00	28,4%	0,0%	0,0%	4.098,00	28,36%	0,00%	0,00%
Zumpango	1.225,00	38,9%	17,0%	0,0%	2.498,46	21,09%	9,23%	0,00%
First Urban Ring	32.607,00	0,0%	2,5%	0,0%	33.647,17	0,00%	2,15%	0,00%
Second Urban Ring	81.383,00	16,4%	14,7%	0,0%	120.611,07	9,00%	9,43%	0,00%
Third Urban Rng	16.230,00	40,5%	15,6%	0,0%	33.253,74	21,95%	8,50%	0,00%
Santa Fe	4.664,00	27,7%	10,4%	0,0%	7.799,47	15,03%	5,53%	0,00%
Naucalpan - Tlalnepantla	22.705,00	11,0%	12,1%	0,0%	30.172,94	5,97%	7,43%	0,00%
Texcoco	11.725,00	23,8%	55,9%	0,0%	26.204,64	12,92%	34,60%	0,00%
Coyoacán - Tlalpan	15.911,00	14,7%	2,6%	0,0%	20.596,84	7,96%	1,39%	0,00%
Central Delegations	26.108,00	0,0%	1,0%	0,0%	26.518,17	0,00%	0,52%	0,00%
TOTAL	144.829,00	16,5%	11,2%	0,0%	206.720,63	8,99%	5,91%	0,00%

SOURCE: by author, based on model of projections (see methodological notes for Tables 7.3 and 7.4).

THE POLYCENTRIC MODEL: COMPARISON WITH OTHER URBAN PROGRAMS

The Reordering of the Valley of Mexico

Unlike the strategy contained in the Organization Program of the Metropolitan Zone of the Valley of Mexico (POZMVM, for its initials in Spanish) of 1998, which proposes to "halt the extensive growth of the metropolis, fill vacant lots in delegations and municipalities, support the expansion of cities located in the regional crown, and create alternatives to the metropolis by building new cities and corridors, particularly to the east and northeast of the State of Mexico...,"[19] the polycentric model's optimal use of urban land and infrastructure makes it much more advantageous in terms of environmental sustainability.

The urban polycentric model is in accord with the argument to be made in section 7.2 of this thesis that Mexico City should not be developed at the expense of the crown cities, but rather it should function as a great supply centre for commerce and professional and specialized services. Thus, the objective "to support the de-concentration of Mexico City's population toward the central region…," stated in the POZMVM, is contrary to the aim of utilising existing infrastructure, above all in the city's central delegations.

Similarly, the concentration of specialized services in two metropolitan nodes on the east and northeast sides of the city, as the POZMVM proposes, would proscribe the possible use of ignored infrastructure in other parts of the city. For example, to carry out research and development, and even to set up a series of technopoles, one has to consider the Universidad Iberoamericana (UIA) and the Centre for Economic Research and Education (CIDE) in Cuajimalpa, the National Autonomous University of Mexico (UNAM), the Monterrey Institute of Technology and Higher Studies (ITESM), the Colegio de México and the Autonomous University of Mexico (UAM) in the Coyoacán –Tlalpan – Xochimilco corridor, and the University of Chapingo (UACH) to the east of the Valley of Mexico.

[19] J. Iracheta, *La Ciudad de México en el fin del segundo milenio,* México: Departamento del Distrito Federal, El Colegio de México, 2001.

The POZMVM also fails to consider the business and hotel infrastructure that already exists in the centre and northeast side of the city, which is a key part of consolidating a large urban centre in the delegations Miguel Hidalgo, Venustiano Carranza, Benito Juárez and Gustavo A. Madero, among others.

On the other hand, the POZMVM ascribes importance to the so-called Hidalgo Project –a plan to spur urban development northeast into Zapotlán de Juarez, Tizayuca and other adjacent municipalities, in what would accentuate the trend scenario rather than attain a programmatic scenario. The plan would do little to reach objectives of environmental sustainability pertaining to water, soil, housing and atmospheric pollution since it would induce the construction of road infrastructure, in turn setting off the expansion of urban sprawl in the form of squatter settlements on large tracts of productive, environmentally valuable land. If this were to take place, the third ring's problems with reducing its growth rate, which remains higher than that of the first and second rings, could be seriously exacerbated.

It is worth mentioning that the POZMVM does not voice approval for either of the two sites considered as options for the New International Airport of Mexico City (NAICM), and, between which, the government chose Texcoco. On the other hand, the implementation of the Hidalgo Project depended a great deal on the airport being located in this state. However, it is important to mention that the Texcoco location would be more apt to stimulate organized urban growth for Mexico City, particularly to the east. As mentioned previously, this option would help bring the urban polycentric model to fruition by encouraging the consolidation of one of the fore-mentioned principal urban sub-centres and would represent a barrier against the spread of illegal squatter settlements, which have cropped up in the Federal Zone of Texcoco in the last few decades.

Finally, the POZMVM's recommendations on water and other environmental variables are insufficient. To mention just one example, far from calling for a transition toward a new hydraulic model, "the program suggests moving ahead with inter-sectorial coordination to make use of aquiferous resources and to operate the hydraulic system of the Valley of Mexico, which should be planned according to the urban development strategy."[20] The problem here is the absence of a strategy that privileges water recycling and aquifer recharge, which would require the establishment of a Low Environmental Impact Zone around the perimeter of the Mexico Basin, a question to be addressed later on when the corresponding objective is discussed.

The Metropolitan Plan of The Valley of Cuautitlán - Texcoco

It is not a coincidence that two of the urban sub-centres that have been considered in this thesis are found in the state of Mexico (Naucalpan - Tlalnepantla and Texcoco) and another is located in both the Federal District and the State of Mexico (Santa Fe); in a span of thirty years a good portion of the demand for housing and urban land will be in this area (see Table 7.3 and Table 7.4.)

Historically, "the processes of land appropriation in the Cuautitlán – Texcoco (VCT) zone have made possible a significant means of massive access to land through the illegal real estate market...,"[21] to such an extent that 12% of the urban area of the VCT's municipalities is affected by this type of land occupation. This trend is likely to continue in the future, a fact which accentuates the need to move toward a polycentric model whose urban sub-centres represent "gravitational forces" that function as "counterweights" against excessive, anarchic growth, based on the suburbanization of peripheral areas.

[20] J. Iracheta, *La Ciudad de México en el fin del Segundo milenio...*, pp. 727.
[21] J. Iracheta, *La Ciudad de México en el fin del Segundo milenio...*, pp. 732.

To allow, let alone promote, urban growth to the northeast of Mexico City to such an extent that it connects with the municipalities of Tizayuca, Zapotlán de Juárez and Pachuca in the state of Hidalgo would be disastrous in terms of environmental sustainability. Instead, the city's growth needs to be channelled in such a way that the resources that would be necessary for creating continuous urban development to the north are used to consolidate the areas in which the greatest amount of urban growth has taken place in the last few decades, thereby curtailing the proliferation of spread out, low-quality housing where there is little access to infrastructure and basic services.

Our "Texcoco" sub-centre coincides to a great degree with two of the axes of urban expansion to be developed as part of the Cuautitlan Valley - Texcoco Regional Metropolitan Plan (PRMVCT for its initials in Spanish) of 1997, known separately as "Texcoco - Ixtapaluca" and "Libramiento – Norte." Similarly, our "Naucalpan – Tlalnepantla" sub-centre coincides partially with the "Naucalpan - Huehuetoca" axis, whose growth is also a priority in the PRMVCT. However, one negative aspect of the strategy to develop this axis is the role that it is given in conjunction with the Tizayuca International Airport in the state of Hidalgo, with its transfer and storage facilities in Coyotepec, which, as we have already explained, would lead to an urban continuum that is undesirable in terms of environmental sustainability.

Also missing in the PRMVCT is our "Santa Fe" sub-centre, which may be due to the fact that its territory is divided almost equally between the Federal District and the State of Mexico, and is therefore not considered an essential part of the strategy of urban development for the Cuautitlán Valley - Texcoco. This is an error, especially, as was mentioned earlier, if one considers the centres of higher education located in Santa Fe that are of such great importance to research, development and providing specialized services. Similarly, to leave out this important urban nucleus is to ignore the fact that a number of important transnational corporations have headquarters located in this same area.

We should point out the more valid strategies proposed in the PRMVCT such as the utilization of vacant lots in urban areas and the regeneration of commercial buildings,[22] underused services and unoccupied industrial plants, strategies that coincide with those put forward in this thesis.

7.2 Urban Policies for a Globalized and Sustainable MCMZ

7.2.1 A General Macroeconomic Framework for Urban Policies

Strictly speaking, the focus of this thesis is not on economic and urban policies, but on the environmental sustainability of the MCMZ. However, it would not be at all complete without observations that –although brief and schematic—take into account the framework of economic policies that should accompany the task of reaching sustainability and facing globalization, in accord with the indicators developed herein.

The city's economic expansion and competitiveness depend as much on strictly local (micro) urban policies as on general macroeconomic conditions. The relationship between these two levels of policy will be crucial to the general performance of the MCMZ. General macroeconomic policies (price levels, fiscal and exchange rate policies, interest rates) affect the city; similarly, the activity of the city (investments, financing, subsidies, etc.) affects economic performance in general. This is why a stable relationship between the two levels of economic policies must be established, without loosing sight of the basic priorities in facing the challenges of sustainability and globalization, which are: to increase the MCMZ's international economic competitiveness, to alleviate urban exclusion and poverty and to assume the responsibility of reversing environmental deterioration. Thus, macroeconomic policy must establish conditions that allow markets to operate efficiently, while public policy should correct their shortcomings through incentives for investment, productivity and export activities (including tourism). The price of key products should not be distorted and should reflect, as much as possible, their relative scarcity and

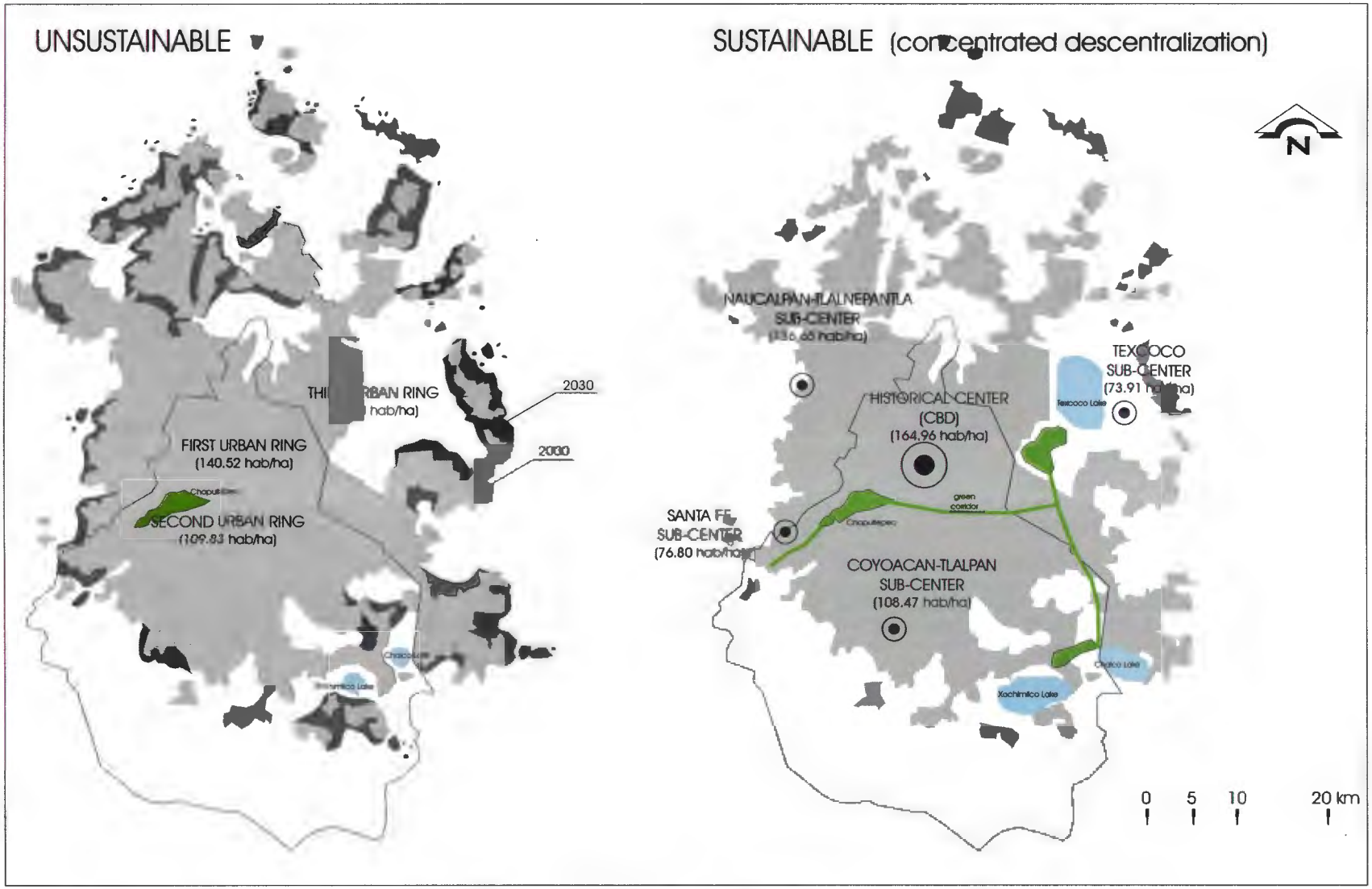
[22] See J. Iracheta, *La Ciudad de México en el fin del segundo milenio...*, p. 733.

environmental value, as with water, energy, greenery and basic public services such as transportation.

The MCMZ has a formidable economic foundation and, despite its problems, is a vital nucleus for the country's economy as a whole; proof of this, as we mentioned in section 4.4, is its huge participation in the nation's GDP. In spite of its extensive poor areas, inhabitants of the MCMZ not only have, on average, higher incomes than in the rest of the country, but higher levels of productivity and education and better social conditions. To put it another way, such advantages have been possible due to the economies of scale and agglomeration produced by a great city. However, years of intense population growth (due to migration and natural growth) from the 40s to the early 70s and subsequent years of economic crisis have taken their toll in terms of decapitalization, marginalization and miserable standards of living for many people, a situation that must be addressed and which requires a great deal of additional economical resources. Social investment for sustainability and the change of economic vocation called for by the challenges of globalization should be backed financially, although through a very different economic model that depends more on national and international private investment and less on subsidies and transfers of central public finances, a phenomenon that is actually already happening.

As we mentioned in section 3.8, during the golden years of the urban boom, from the 40s to the early 70s, the economic and industrial policies in place created what is known as "urban bias." As we noted previously, the government focused on large public investments in the city, and, additionally, granted generous subsidies to urban dwellers for transportation, food, energy, water and housing. This generated a huge, unsustainable bias that favoured the city's growth and distorted prices to the detriment of rural areas. An example of one such bias was the gasoline subsidy which made it cheaper to use a car and caused serious environmental problems such as traffic and atmospheric pollution. The correction of these distortions became the central task of macroeconomic policies directed toward the cities.[23]

[23] See World Bank, *Urban Policy and Economic Development: an agenda for the 1990s.* Washington, D.C. 1991.



Map 7.2. Year 2030: Unsustainable and Sustainable Growth of the MCMZ.
Source: Own elaboration.

Although most of the distortions were corrected during the crisis of the 80s, crucial investment in new infrastructure was at this point dropped and already existing infrastructure was badly neglected, which in turn damaged Mexico City's economy. Misguided policies confused healthy decentralization with severe economic deterrents that eliminated jobs and penalised production in the MCMZ.

Now a more stable, balanced macroeconomic policy should be maintained. It was right to correct the urban bias and to put an end to the price regimes that very much favoured the city over the interior; it was also right, although socially painful, to curb the excessive, distorting subsidies given to consumers (although many continue to exist, such as in the case of transportation). This is why social policy should be much more targeted and, when possible, sustained through direct transfers. Recently, the government announced that a public program known as PROGRESA, which combats poverty through education, health and nutrition, would be implemented in cities as well as in rural areas. This was the right thing to do, since the program will now be carried out neutrally in both the city and the interior. However, care must be taken to keep the program free of distorting, unsustainable consumption subsidies (especially for transportation). The correction of price distortions will increase the efficiency and productivity of the entire urban economy. Many public subsidies must be replaced by private savings, and the costs incurred by public agencies must be recuperated based on the "marginal price costing" principle. This is compatible with the city's need to become increasingly self-sufficient and healthy in fiscal terms and to use property taxes as an important instrument of urban policy. However, as we mentioned, in compensation there should be highly focused social policies to fight poverty, although independently from the prices of services.

Another issue is that, in the last few years, public investment has privileged sectors that produce export goods or tradables. This makes sense in terms of facing globalization, but should be balanced in order to avoid the excessive de-stimulation of housing construction, infrastructure and the supply of public goods, including environmental ones.

The MCMZ is a place where high density interactions take place, not only of a social and environmental nature, but of an economic one as well. Its market directly benefits from its access to specialized labour, relatively abundant financing and, increasingly, technology and an important telecommunications node. This has to do with the economies of scale and agglomeration. Thus, while the economies of scale respond to increasingly greater levels of production and make more efficient use of capital, technology and labour, these are almost always found within companies. In turn, the economies of agglomeration occur when a great economic and population concentration lowers the cost per unit of producing, trading and consuming. These are some of the most tangible benefits of urbanization for society as a whole.

This ties in with the environmental or social effects of economic or investment activity. These are said to produce "positive externalities" when the combination of economies of scale and agglomeration do not affect the environment or when their social costs do not outweigh benefits in terms of well being, income or urban "amenities." To the contrary, the "negative externalities" of urban concentration are a result of traffic, pollution of the air, soil and water, and deforestation caused by the expansion of urban sprawl. These and other microeconomic market failures should be corrected by adequate public policies which we describe in each of the indicators in section 6.1. These are precisely the challenges of urban economic policy within the territory of the MCMZ: to maximize economies of scale and the externalities of economies of agglomeration and to simultaneously minimize diseconomies and negative externalities.

All this requires the microeconomic policies outlined in section 6.1, so as to correct the problems of deficient transportation and road infrastructure and the scarcity of housing, to create public goods and environmental services in green areas, and to change policies related to providing consumer goods and energy and water use and availability.

7.2.2 Basic Elements of a Proposed Sustainable Urban Form to 2030

Although we can derive the greater part of our proposals of urban sustainability from the seven indicators of urban sustainability, it becomes necessary to generate more general proposals as an intermediate step between the urban form we have chosen (see sections 7.1 and 7.2) and the details of each indicator and its policy proposals. That is, based on the polycentric model of urban form, with the CBD or Historic Centre and four other sub-centres, at least seven large-scale proposals for the MCMZ are needed to in some way serve as a bridge between the more general vision and the implications of the seven indicators, plus the one related to globalization. In fact, we have four proposals that refer to environmental and geographic topics and two more that have more to do with the proposal related to the construction of a "World City" that meets the challenges of globalization. We can take a look at each of these:

Urban Form Proposals Concerning the Environment

1) Implementation of a new hydraulic model: This point was previously discussed at length, but is being mentioned here due to its great importance and global impact on the basin. This proposal may be the most relevant since its implications are both strategic and far-reaching. In reality, it affects numerous other variables such as reforestation, soil conservation, the sinking of the city centre, weather, air quality, and, in general, the standard of living of the inhabitants of the MCMZ. Essentially, it requires ambitious policies that gradually achieve hydraulic independence for the Mexico Basin. In terms of consumption, the use of water and waste per inhabitant –currently at unsustainable levels—should be reduced. There has to be greater reuse, treatment, separation and recycling of water. The importation of water from outside the basin should be put to an end by re-stimulating the recharge of the local aquifer.

2) Lake Restoration: As we saw previously in section 4.7.1, the recuperation --although partial—of Lake Texcoco is fundamental to our proposal on sustainable urban form. It would also tie in organically with the reconfiguration project of the existing airport (AICM,

for its initials in Spanish) and would serve as the intersection of the green corridors that would run from west to east and from south to north, as we will see below, in point 4. The restoration of Lake Texcoco, the reconfiguration of the existing airport and the green corridors are projects that would, for the first time in the history of the city, represent an urban and environmental boost to the perpetually poor east side of the city. But furthermore, an attempt is being made to restore Lake Zumpango on the northern side of the basin (and to complement this with wetlands and the recreation areas of Tepotzotlán). Similarly, part of Lake Chalco would be restored to the direct benefit of the inhabitants of this impoverished part of the city. The project includes a corridor of green areas and wetlands that begins at Xochimilco Lake, crosses Tláhuac (where wetlands will be established), passes through Chalco Lake and heads north, forming a green corridor that meets up with the Chimalhuacán[24] section and the intersection between the west-east (Chapultepec) and south-north corridors that we just described (see map 7.3) Although we indicated in previous pages the urbanistic, scenic, climatic and environmental advantages of restoring these lakes, it is worth emphasizing that this is something of great importance. The presence of bodies of water would be highly valuable and provide a better standard of living to the eastern side of the metropolis, which has always been the MCMZ's poorest area.

[24] This involves a project for a lake, just outside Chimalhuacán, called Lake Gerardo Cruickshank.

3) A Low Environmental Impact Perimeter: This proposal involves the creation, more or less around the perimeter of the entire Mexico Basin, of a wide environmental belt or zone that we have called the "low environmental impact perimeter." Visualized from south to north, this perimeter would be in the shape of a horseshoe. It would be much wider and defined in the south, encompassing the Ajusco and Chichinautzin sierras, where the MCMZ's densest, most abundant forests of pine, oyamel and oak trees are located, along with porous soil capable of recharging the basin's aquifers. The peripheral belt would continue to the west and the east, at this point becoming somewhat more narrow. On the east side of the basin, it would cross through the foothills of the Sierra Nevada and Tláhuac, areas that are still home to abundant forests and where the imposing, snowcapped volcanoes, the sentinels of the city, Popocatépetl and Iztaccihuátl, are found. In this eastern section, the belt would go as far as the sub-basin of Texcoco, which, despite having fewer forests, is close to the Texcoco Lake area and would join green areas with the lake restoration zone. The belt would also lie within the perimeter of a project to build a park and large botanical gardens in Tetzcotzingo in honor of King Nezahualcóyotl of Texcoco, who in the 15th century established the first botanical gardens of the Americas. On the west side, the peripheral belt would meet up with the Ajusco sierra and go as far as the Sierra de las Cruces. Despite being lower and less imposing than the eastern zone, this area is also of great environmental interest: the Los Dinamos park and the old national parks of the Desierto de los Leones are found here, and they join up with other forested zones such as the Valle de las Monjas and La Marquesa, as well as with green areas in Cuajimalpa, to the west of the Federal District. Joining all these green areas together would serve to create a green buffer in the zone of imminent conurbation between the city of Toluca and Mexico City. This area is home to numerous streams, unfortunately highly disturbed by squatters, as we saw previously in section 3.8.2. This part of the belt would gradually dissolve to the northeast in the low Monte Alto sierra. To the north the peripheral belt would close very loosely in the Zumpango area, where there are plans to restore a portion of Zumpango Lake and some wetlands. An essential part of the project is to connect this peripheral belt with

the proposed green corridors, which would bring trees and wildlife from the peripheral zones into the city core.

The low environmental impact perimeter, unlike traditional green belts, would allow for a mixture of economic activities that would, nonetheless, be subject to all low environmental impact restrictions.[25] Basically, it is an area of great reforestation, aquifer recharge and conservation of the landscape. But activities such as ecotourism, camping, trekking, and even research centres would, of course, be allowed. Agriculture in the zone would be very limited; encouragement would be given to so-called "permaculture," that is, to traditional, low-impact crops such as cactus paddles and flowers, among others. It would in no way be a grazing area or a place to raise invasive crops such as oats, which have contributed to the felling of trees. Such things as the capturing of carbon, the conservation of the soil and forests and aquifer recharge are all environmental services that society should pay for, thereby de-stimulating the squatting that is so devastating to the ecosystems on the urban periphery. With this peripheral belt, the MCMZ will save a great, continuous, uninterrupted space of green areas for environmentally-friendly activities. With this broad outlying green zone of very low environmental impact, we would be increasing the per-capita green area coefficient, as the corresponding indicator requires (see section 6.1.2).

4) Green Corridors and Urban Afforestation (Urban Greenery): The purpose of the two green corridors proposed here is to connect some green areas with others. The first of these, which we have called "Chapultepec," runs from west to east and would connect, in the thinnest part of the dense urban weave, the green zones of the peripheral, low environmental impact belt in Cuajimalpa with Chapultepec, thereby establishing access from Chapultepec Park in the most central part of the city to the Texcoco Lake zone in the east, which would in turn hook up with Aragón Park. From here, the corridor would once again connect with the low impact belt, close to the city of Texcoco. The second corridor would run from south to north, connecting Xochimilco and Chalco lakes by way of the wetlands of Tláhuac, and, from there, would continue northward to Texcoco Lake in the

[25] Fairlie, Simon 1996, "Low Impact Development", JC Publishers, Bristol

Chimalhuacán area.[26] The two corridors would, of course, intersect, at a point south of Texcoco Lake (see maps 7.2, 7.3 and 7.5). One requirement of the corridors is that they be practically continuous, so as to allow for the passage of wildlife and to take full advantage of the environmental and aesthetic benefits of linkage.[27] Additional corridors could conceivably be built, but the ones mentioned here are very strategic and of great importance.

[26] For further details, see footnotes 22 and 23 in this chapter, in section 6.1.2.
[27] See Bennet, Andrew F. 1999 "Linkages in the landscape: The role of corridors and connectivity in wildlife conservation", UICN, Victoria, Australia

TABLE 7.6

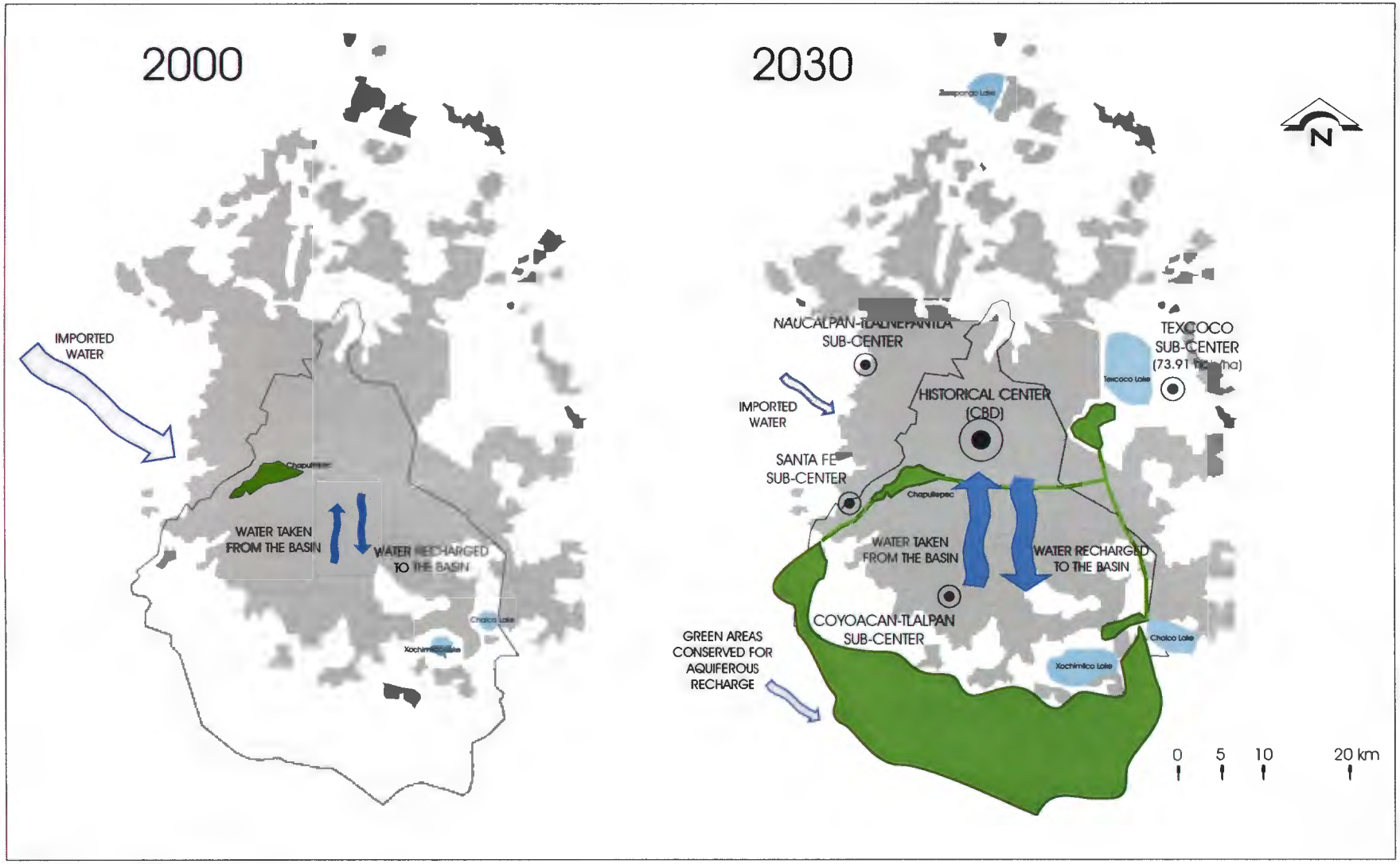
Mexico City: Basic Elements of a New, Sustainable Urban Form

BASIC ELEMENTS OF NEW URBAN FORM	OBJECTIVES
1.- Basic infrastructure needed for the "World City" of globalization: • Airport and "hub" of communications • Ring roads and radial trains • Technopoles • Massive connection of optical fibres, access to and availability of broadband telecommunications	• Economic Globalization • Air Quality • Urban Mobility
2.- Low environmental impact perimeter to allow for reforestation and the recharge of groundwater resources; green corridors which connect up with the low environmental impact zone and "cross" the city in strategic, densely built areas[28]	• Water Balance • Air Quality • Increase of green areas per capita
3.- New hydraulic model (greater reuse rates, surface water utilization, and recharge of groundwater resources), including restoration of lakes[29]	• Water Balance • Air Quality • Increase of green areas per capita
4.- Urban regeneration of the Central Delegations, and consolidation of the urban sub-centres of Santa Fé, Naucalpan – Tlalnepantla, Coyoacán – Tlalpan and Texcoco	• To curb extensive urban expansion • Reduction of demand for metropolitan trips • To optimise the existing infrastructure • To optimise the use of urban land

SOURCE: by author

[28]The first green corridor called "Chapultepec" runs from west to east and connects up with the old airport, which would now have be turned into a large green zone and integrated into Aragon Park. The second corridor goes from Xochimilco and the Tláhuac-Chalco wetlands to the north, reaching Chimalhuacán's southern Lake Gerardo Cruickshank (see green areas indicator and next point). For more information, see project by Cassio Luiselli (et. al) "Chapultepec Green Corridor," ITESM, Mexico, 1999.

[29] The most important would be the Zumpango, Texcoco- South and Chalco lakes, which would connect with Xochimilco and the wetlands of Tláhuac.



Map 7.3. MCMZ: New Hydraulic Model.
Source: Own elaboration

5) World City Infrastructure: As we discussed throughout Chapter 5 (especially in sections 5.1 to 5.3 and 6.1.9), the MCMZ should, in the face of the imperatives of globalization, prepare to become a node on the globalization network. As we demonstrated, Mexico City has what is needed to become a "World City," but it sorely lacks a cluster of infrastructure and information technologies (IT) to provide the capabilities to engage in globalization advantageously. Basically, four elements are needed:

1) A New International Airport: The existing Mexico City airport is now saturated and cannot accommodate its rapidly expanding air traffic. It is indispensable for the MCMZ to have a world-class international airport that becomes the central node of communications in Mexico, as well as an international hub that further penetrates Mexico and North America's already significant, growing internal market and that competes for the crucial routes of Latin America and the Asia-Pacific region. The proposed location of this airport north of Texcoco Lake is ideal both for urbanistic reasons as well as for its proximity to future railroad lines and ring highways, which are also being proposed. The new airport would provide service to the crown of cities that surrounds the MCMZ, whose population, as a whole, is now nearing 30 million.

2) Ring Roads: These ring roads around the MCMZ would service intermediate crown cities such as Puebla, Tlaxcala, Pachuca, Querétaro, Toluca and Cuernavaca. In fact, a great deal of progress has already been made on this highway system and the north-eastern and southern sections are all that is needed for its completion. It is complemented by another ring road that lies closer to Mexico City, which, to be finished, only needs a stretch between the exit to Toluca in the east and the exit to Cuernavaca in the south. Evidently, this ring system would service the new airport and make Mexico City much more accessible.

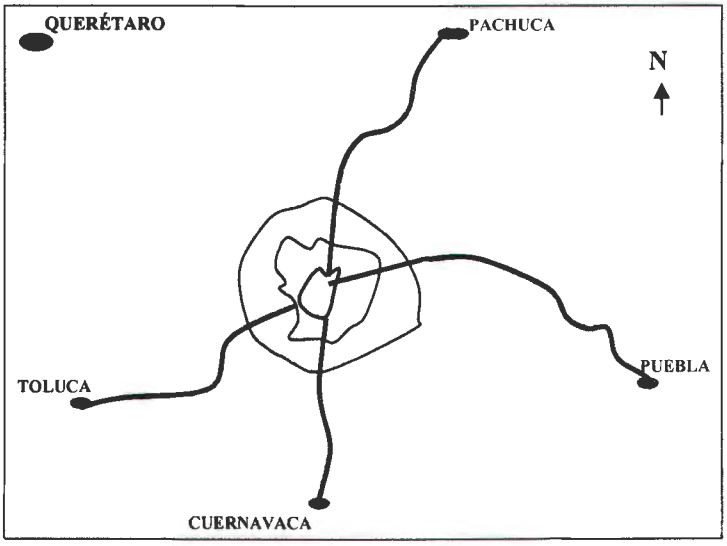
3) Technopoles: As we saw in sections 5.1 and 5.2, this concept refers to establishing true clusters of scientific and technological creation, which is indispensable to any world city. The MCMA is home to a considerable number of high-quality public and private

universities, and is the site of the oldest university in the Americas, the National Autonomous University of Mexico (UNAM), which produces a large number of graduates every year and grants master's and doctorate degrees. Numerous large multinational corporations are headquartered or locate their Latin American subsidiaries in Mexico City. Thus, the city has the potential to develop research clusters centred around its universities and numerous industries. Of particular interest are the information and digital technology industries located to the east and south of the city, and the bio-tech, food and agricultural industry that could be developed in the east, in the Texcoco area, since the zone is the cradle of the "green revolution," and home to the International Centre for Corn and Wheat (CIMMYT for its initials in Spanish) and other centres and universities that focus on agricultural studies.

4) Information Technology (IT) Infrastructure: In Chapter 5, we established the strategic importance of sufficient per-capita investment in information technology, not only in the internet, but in the development of massive computational capacity, among other tasks. The MCMZ needs to invest in two areas: the massive installation of fibre optic cable and much wider bandwidth. These are key ingredients for competing as a world city and Mexico City is lagging behind. Seoul, Korea, for example is the most wired city in the world in terms of fibre optic cable, which is why it can boast that it is one of the fastest, most internet-connected centres in the world. The MCMZ must match such efforts if it truly wants to be competitive in the global and digital era.

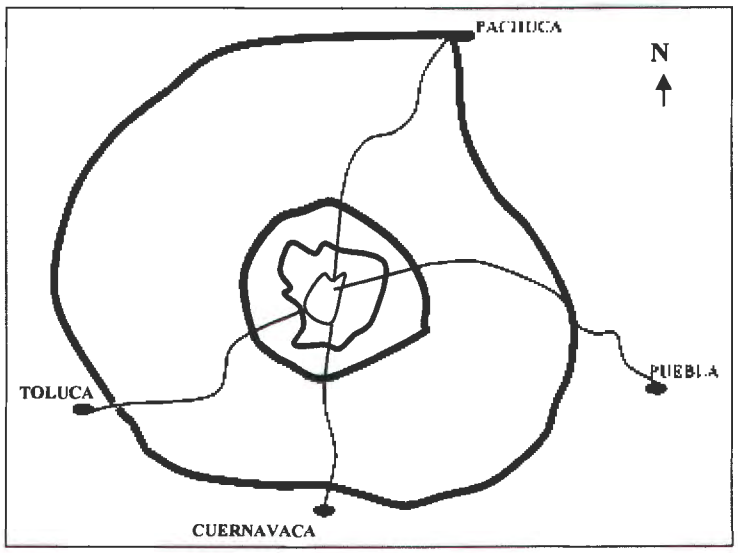
FIGURE 7.2
Road System in the MCMZ: Alternative Models

A) RADIAL MODEL

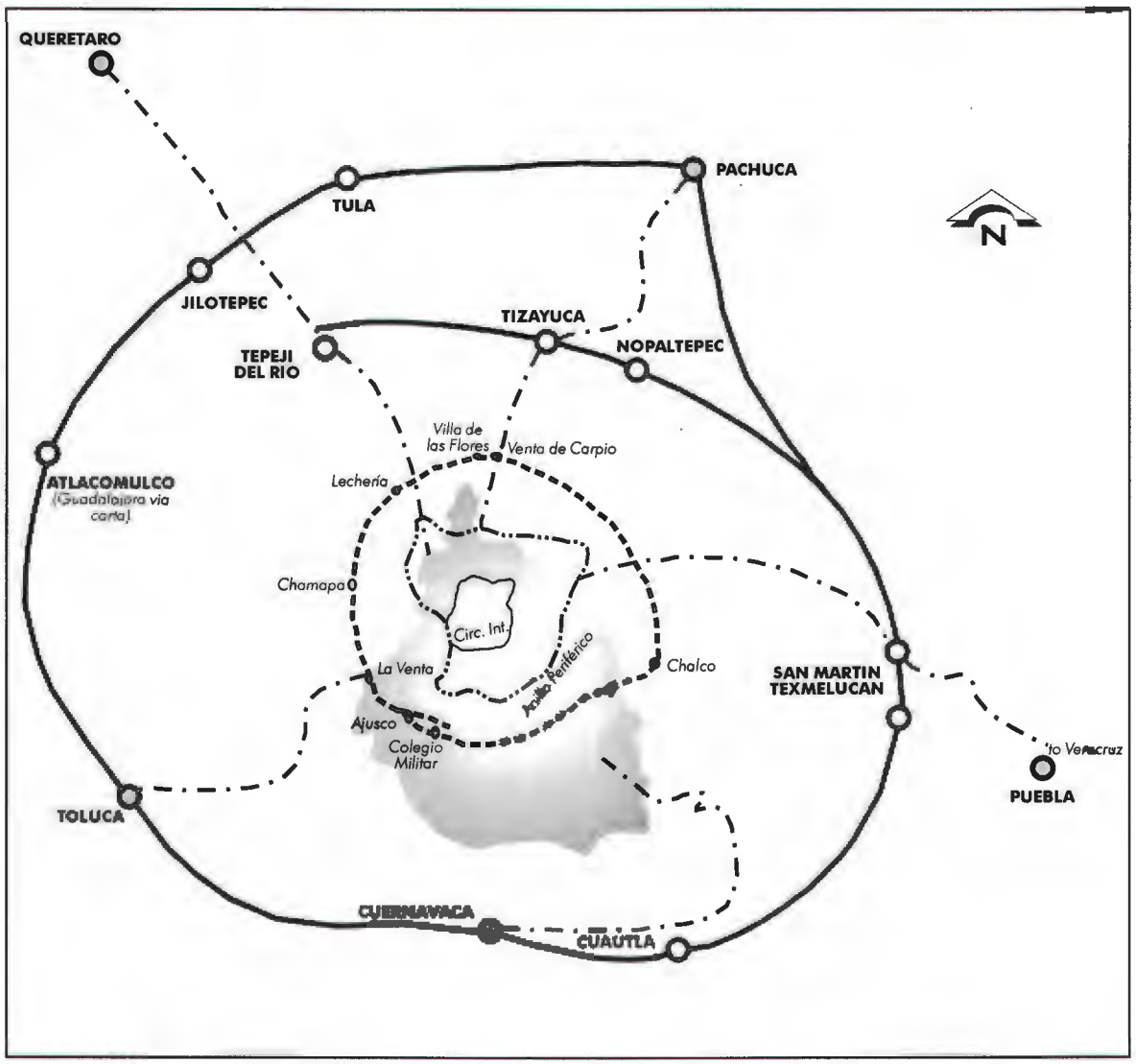


SOURCE: By author, based on COMETRAVI, 1999 and SEMARNAT, 2001.

B) RING MODEL



SOURCE: By author, based on COMETRAVI (1999).



Map 7.4. Road System: Objective Image
Source: Own elaboration based on COMETRAVI, 1999.

6) Urban Renewal Schemes and densification of the CBD and consolidation of the four designated sub-centres

As it clearly follows from the Ring Analysis of the sections 4.2 to 4.4 and from the historic section 3.8, the Central Business Districts (CBD) of Mexico City, known as "Historic Centre", has suffered a fate of the majority of the CBD of the cities of America: A progressive deterioration, first economic and then demographic, that have made them lose population towards the suburbs and to decay to a degree that their role in the life of the large cities, is seen very compromised.

It is therefore necessary that the strategy of sustainability include the massive recovery of the CBD of Mexico City through mechanisms of re-densification and of economic investments for the recovery of the zone. It should include the creation of business opportunities and real estate and property investment. As we saw in the historic chapter (3), the long decline of the CBD, was due to the migration of population, and to certain public institutions that were there since colonial times, such as those of government and superior education. Nevertheless, it is perfectly possible to encourage them to invest back in the CBD. After all this area has always been the centre of government and political life of the nation, sine Aztec times.

As far as the other sub-centres are concerned they already are important and dense places, but they need to be supported further and many investments are needed there. Each one of them has a peculiar vocation that has to be reasserted and fully encouraged. Of course, this should not mean to loose the overall sustainability strategy for the city as a whole.

The first of the designated sub-centre, Santa Fe, to the east, should keep its momentum ongoing. This is a very vibrant and modern business centre with many headquarters of large Mexican and foreign multinationals. It has to be supplied with high teach facilities (such as fibre optics and ample bandwidth). The forests next to it must remain intact with no further urban development allowed to encroach into it.

The second sub-centre, Coyoacán- Tlalpan, to the South – west is very traditional and extremely rich environmentally. It has the largest urban forests and aquifer recharge potential of the MCMZ. This is the area where most of the "Low environmental impact perimeter" is located. But those important green areas are seriously threatened by invasion of squatters (see sections 3.7 and 3.8 above). It is imperative to stop them other wise the richness of the area will be irreversibly lost. But Coyoacán – Tlalpan is also a superb educational and historical site. That too, has to be encouraged and supported. That will be the centre where tradition and higher education meet.

The third sub-centre, Naucalpan – Tlanepantla is by far, the industrial core of the MCMZ. It has to keep that role, but it has to modernize, too. It most relocate outside of the basin the most pollutant industries (chemical and petrochemical) and keep encouraging cleaner and more technological industries as It has done for the past twenty year. This centre sorely lacks green areas and urban amenities. They can be developed further to the north in the Tepotzotlán – Zumpango lake axis.

Finally the fourth one, Texcoco the most strategic place. It is somewhat far away from the centre of the MZMC but it holds great opportunities for urban renewal and for sustainability projects. If the lake of Texcoco is restored and the new International Airport built there, the whole area will be transformed toward sustainability and massive job creation. Besides, in the eastern fringes of the Texcoco sub-basin we proposed very ambitious forestry projects, including the King Netzahualcóyotl Botanical Gardens. Texcoco also has world class agricultural research institutions and can consolidate a Technopole of agricultural and biotechnological sciences. One key feature of this sub-centre is its location near the poorest areas of the MCMZ, such as Chimalhuacán and even Chalco. Thus these areas can benefit very much environmentally and economically if the Texcoco sub-centre develops in the way we are proposing here.

7.2.3 Integrating Urban Indicators into the Main Policies

Once the polycentric urban form was defined for 2030, along with the desired new hydraulic model, the low environmental impact "green perimeter" the technopoles, the airport and the road system model. It becomes necessary to integrate them all with the other variables of sustainability. This is so because it would be impossible to speak of a given urban model without taking into account the quantitative indicator which before the real threshold of sustainability. (See Chapter 6)

Thus, it can be concluded that our proposed image for the MCMZ must guide the environmental restoration of the entire Basin of Mexico for the next decades (Table 7.6 resumes the quantitative objectives, also expressed in Chapter 6). The only work left to be done would be to combine them with our polycentric model, considering a gradual path to sustainability (see table 7.7 and map 7.5). This will convey a simplified but integrated and powerful model of a sustainable Mexico City for 2030.

TABLE 7.7

Towards a Sustainable MCMZ 2030 (Gradual Attainment of Indicators Objectives)

FUNDAMENTAL OBJECTIVE	FINAL OBJECTIVE	INDICATOR	GOAL, 2015	GOAL, 2030
Water Balance	Water Balance with environmental sustainability criteria	Existing deficit between demand and supply of water	Reduce the deficit by 100%	Maintain water balance
Air Quality	Minimization of emissions into the environment	Tons of pollutants in the base year versus tons of pollutants in the year of analysis	Reduce the deficit by 50%	Reduce the deficit by 100%
Green Areas	Attain or surpass the international standard (of 9 sq. metres per capita)	Existing deficit between the international standard for green areas per capita and the actual indicator	Reduce the existing deficit by 25%	Reduce the existing deficit by 50%
Energy	Lessen intensive use of non-renewable sources of energy and the diffusion of clean technologies	Energy use intensity for economic activity: deficit between the actual situation and the international standard; Mixture between different sources of energy: deficit between current situation and a desirable mix	Reduce the deficit by 50%	Reduce the deficit by 100%

(continues....)

TABLE 7.7
Towards a Sustainable MCMZ 2030 (Gradual Attainment of Indicators Objectives) (continued)

FUNDAMENTAL VARIABLE	FINAL OBJECTIVE	INDICATOR	GOAL, 2015	GOAL, 2030
Solid Waste	Balance between the generation and the infrastructure for final disposal (landfills or controlled dumps)	Existent deficit between the generation of solid wastes and the necessary infrastructure for their adequate handling	Reduce the deficit by 50%	Reduce the deficit by 100%
Transport and Road System	Administration of demand (change the modal mix to use more intensive modes of transport of greater capacity)	Existing deficit between the compound index that measures desired modal mix and the compound index that measures the actual modal mix	Reduce the deficit by 50%	Reduce the deficit by 100%
Housing	Address the housing shortage through formal markets and by providing a larger index of environmentally friendly housing	Housing deficit	Reduce deficit by 50%	Reduce deficit by 100%

MAP 7.5
Proposed Image of the Sustainable Basin of Mexico, 2030

SOURCE: By author.

7.3 Summary and Conclusions: A holistic view of Mexico City (MZMC) in 2030

The core topics of this thesis have to do with the recuperation of the past and the search for a better future. Both concerns are crucial not only to the city, but to Mexico as a whole. This tends to be the case since the city has always played an integral, pivotal role in national affairs. Its historic, cultural and economic importance is simply decisive for Mexico's territorial and cultural life and integrity. Its location in the centre of the country, in the area that divides the high plateau and the tropical lowlands of Mexico, is crucial since it is also at the division between the primarily mestizo Mexico of the centre and north of the country and the primarily indigenous Mexico of the south.

The future of Mexico City no longer has to go against its environmental or urban history. There should therefore be no doubt about the conditions and possibilities of its environment, its natural resources and its architectural past, elements to be harmonized with its dynamic future and the challenges of a world in which the unstoppable, onward march of globalization takes on, above all, the form of a dense urban network. But the government and the citizens of Mexico City no longer have time to lose. If one thing is clear from the indicators developed throughout this thesis, it is that, without correction, the tendencies toward unsustainability lead to an increasingly profound environmental and social crisis of an eventually irreversible nature. If Mexico City does not find its place among its equals, the "World Cities," it runs the risk of stagnating and being passed up by other cities of North and Latin America.

The city has numerous strengths, and these greatly outweigh weaknesses such as social inequality, persistent poverty, crime and relative technological backwardness. Its advantages include a large population with a greater income and a much higher educational level than the rest of the country; this represents an internal market and a productive capacity that gives the city a substantial lead, not only over the rest of Mexico, but over the majority of the cities of the world. If it were a separate country, Mexico City's economy would be among the top twenty or twenty-five out of almost 200. Another strength is its

location. Beyond the difficulties of its urban sprawl, the city has an extraordinarily temperate climate and a natural landscape that is extremely rich and diverse. It is close to the largest markets and not far from the Atlantic and the Pacific. But, above all, it is relatively near the largest economy in the world: the United States.

The population is growing at a much slower rate and the economy has transformed, more or less spontaneously, in a direction that is in accord with globalization. That is, there has been a shift toward services and high-tech and environmentally friendly industries.

Here we offer a general vision of what could be a path toward sustainability and a city capable of becoming a global player. But this is just an outline and such a vision should be constructed collectively. Up until the 20th century, Mexico City grew at the expense of its environment, it destroyed its own urban and architectural patrimony and fomented social exclusion and inequality among its inhabitants.

Yet, it is entirely possible to envision a Mexico City where water is conserved to a greater degree, where cleaning and recycling makes it possible to use water originating entirely from the basin, and where abundant rainwater is utilized to recharge the enormous aquifer, thereby halting the sinking of the city centre. There is nothing to prevent the extension and conservation of the existing lake in Xochimilco, or the recuperation, although partial, of three of the basin's five original lakes, Zumpango, Texcoco and Chalco. It is perfectly feasible to carry out the regeneration of rich wetlands around these same lakes, which would produce environmental services and tourism and other amenities that local inhabitants could take advantage of. Fresh water streams can be brought back and be surrounded by greenery; with "green corridors," trees, cool temperatures and wildlife can be brought well into the urban sprawl. All this will make it easier to recuperate soil and to foment the reforestation, in a spacious perimeter, of the majestic sierras and volcanoes that mark the borders of the basin; this can be done especially to the south of the city, where numerous forests remain and could grow much larger. Similarly, energy can be taken from

non-fossil sources and be much cleaner. Solid waste can be reduced by recycling, or buried in such a way as to avoid further damage to the air and public health. All these factors will improve the climate and trap the suspended particles that account for much of the city's pollution. Little by little, the automobile will emit fewer polluting gasses, but traffic will have to be eliminated by restricting the use of cars in the central areas of the city, by making the five proposed sub-centres more self-sufficient, by providing superior, better connected urban highways, and, above all, by making available to the city's inhabitants better, more numerous public transport options, especially the Metro. The urban regeneration of the CBD or "Centro Histórico" is beginning to move in the right direction; similar efforts should be carried out in other areas in the first or second ring of the metropolis. Housing construction can contribute to the re-densification and recuperation of the city centre, limit urban sprawl and better the quality of life of the city's inhabitants in cleaner, greener neighbourhoods. It is still possible, although the task will not, of course, be easy.

But the city can also move toward promoting more high-tech services and establishing technologically intensive industries. This is why it is necessary to create a high technology Technopolis, taking advantage of the city's numerous universities and research centres. This should be complemented by infrastructure, in transport with the indispensable airport hub, and with the attainment of massive bandwidth and fibre optic penetration to facilitate the advent of the digital and information revolution. Achieving all this is wholly possible. In fact, it is happening in many parts of the world, and even in the MCMZ itself, although to an insufficient extent and without a clear, strategic focus.

All these elements form part of the indicators that we have developed in this thesis; based on the polynuclear urban form that we have proposed, progress can be made with this vision of Mexico City for the 21st century. Nothing presented here is either impossible or unrealisable. To the contrary, we can say that it is indispensable to recuperate the city's vitality in this new century. But making this vision a reality should be the task and responsibility of all its citizens. Although embattled Mexico City may deserve it, this is not a blueprint for utopia. It is, basically, a holistic vision for a far better, yet entirely possible

future in which one of the world's great cities ever could look forward to living in harmony with its immensely rich natural and historical heritage.

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