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RESOURCE FLLOWS IN THE URBAN ECOSYSTEM: FUEL, WATER, AND FOOD IN MEXICO CITY

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FUEL, WATER, AND FOOD IN MEXICO CITY

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RESOURCE FLOWS IN THE URBAN ECOSYSTEM:
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I. INTRODUCTION

A great deal has been said about the slowing of national economic growth due to the rising costs of petroleum (e.g., IERD, 1980). But less attention has been given to the role of fossil fuels in Third world metropolitan areas. Meier et al. (1978) argued that a combination of population and income growth in these cities could by the turn of the century result in 400- to 600-percent increases over recent levels of urban energy demand. McGranahan and Taylor (1977) and Cecelski et al. (1979) have begun to explore some of the components of this demand, concurring on the observation that urban residents tend to have better access to, and make increasing use of, higher-quality fuels. The Global 2000 report (CEQ, 1979) and Tinker (1980) widen this perspective to remind us that food and water, among other critical resources in cities, are intimately tied to imported energy.

The prospects for increased energy demand reinforce the feeling that metropolises in the Third World are somehow bloated, unbalanced, and inefficient. But does continued growth inevitably mean a worsening picture for the largest cities? Is their appetite for energy unquenchable? Is it unrealistic to expect that large cities will follow some process of growth that differs from their cousins in the postindustrial world? The evidence

gathered in this brief study of Mexico City suggests that, at least for this city, these questions may be answered with a qualified ``no.'' An argument, along with supporting data, are presented to suggest that a growth in knowledge management and learning has taken place quite rapidly in Mexico City and that new organizations and technologies are continually being found to accelerate this urban learning process. The net results are structural changes in Mexico City's economy which are hidden from standard sectoral descriptions. Moreover, these changes lead to increasing energy efficiency.

This is not to deny the severe resource problems facing the city. Even though it is the capital of an energy-exporting country, Mexico City does face resource constraints, especially water, as we shall see below. In addition, Mexican planners cannot escape the dilemmas and tradeoffs inherent in the allocation of Mexico's fossil fuel wealth. The complexity of these problems will become more apparent as the international price of oil rises on the one hand, while on the other, the growth of Mexico City (fueled to an important degree by cheap energy and water) leads to a worsening of environmental pollution and congestion. The present study attempts a systematic examination of resource flows in the city. The aims of this study are to:

- ⊕ estimate the flows of energy, food, and water and the interactions of these resources in Mexico City;
- ⊕ examine the degree to which the city meets basic (food and water) needs of its residents;

- explore aspects of ``efficiency'' of urban growth in terms of resources consumed, especially energy; and
- propose and examine an ecosystems frame of reference so that Mexico City may be compared with other metropolitan centers in the developing world.

The paper tenders and examines the proposition that information-processing capacity in the city has a somewhat unconscious and largely unexplored positive effects on the efficiency of resource consumption. First, what I call the "informational infrastructure" of Mexico City -- that is, the organizations, knowledge, control systems, and message-transmitting capacity between and among organizations -- affords actors in the city opportunities to cut back on, or get more out of, the resources they consume. This notion flows from an ecosystems concept of cities (see Campbell, 1980, and Meier, 1974), but also builds on long-lost insights such as Alonso's reference to knowledge as a factor in the high productivity of large cities (Alonso, 1968). A second efficiency effect is that increased knowledge and information go hand in hand with the transition to a services economy which diminish the need for energy.

To briefly summarize the findings of the present study, Mexico City consumes about thirty percent more energy per capita as the national average (about as much energy per capita as Hong Kong and twice the amount of Seoul and Manila). Nevertheless, Mexico City is two to many times more energy-efficient -- measured in terms of total energy consumed in relation to total output -- than any other region in Mexico. In addition to the customary explanations for efficiency such as superior investments, technology, and infrastructure, I suggest that this efficiency may be related

to the superior organizational and communications attributes of the city, direct outgrowths of the city's evolution to a services economy. The city has a high per-capita density of organizations (an order of magnitude greater than in Manila) and a rapidly improving telephone network. Data processing capabilities and telephone have more than doubled since 1973. This energy efficiency and the novel explanation for it represent a dilemma facing planners in Mexico who must cope with a national mandate to halt growth in Mexico City and stimulate it in other cities where efficiency up til now has been lower but, perhaps, opportunities more abundant for improving efficiency. In any case, organizational attributes and opportunities for energy conservation in Mexico City appear to be greater than is usually thought.

Several other findings are worthy of mention. The Mexico City ecosystem imports a great majority of food and relies on an energy-intensive food production system. Despite energy subsidies, this makes adequate diets more difficult to obtain for a quarter to a half of the population, even though proven alternatives are available which could produce perishables locally and save water. Increasingly, water is imported as well. Over the next several decades, the energy required for pumping water could exceed by a large amount projected electricity use in the domestic sector. In transport, two to three times more energy of the total ecosystem budget in Mexico City goes to transport than is consumed in comparable sectors of Seoul, Manila, and Hong Kong. Two-thirds of the transport energy is consumed in private automobiles carrying only one-fifth of the passenger trips, while the Metro carries seventy-five percent of the passenger trips and consumes only a fifth of the total energy.

The structure and arguments of the paper are organized in six main sections. Following this introductory section, I shall lay out the conceptual approach to the study of Mexico City and in the third section, describe the physical structure of the EVOM. The fourth section will examine a number of specific ways key resources are used, examining by turns the energy sector; the provision of a minimum adequate standard of living, particularly for the urban poor; the productive sector; transportation; and management of information. Each of these uses is viewed as a point of reference by which performance of the urban ecosystem may be assessed and compared with other ecosystems. The fifth section looks to the future, projecting in a simple way the resource needs for Mexico City towards the turn of the century as it is envisioned by contemporary planners. Finally, the sixth section reviews the arguments and draws some conclusions about the ecosystems view in general and the EVOM in particular.

II. CONCEPTUAL APPROACH AND THEORY OF THE ECOSYSTEM

The urban ecosystem approach employed in this paper sees cities as the loci of living populations interacting with each other and with the built and natural environments. These interactions take place within a boundary permeable to inputs and outputs. Transactions in the city, that is, interactions between and among individuals and organizations, require energy and other resources with varying degrees of order (knowledge and organization). These resources and particularly energy are supplied in the form of food and fuel and indirectly in the form of material inputs. Though most resources are scarce, many can be and are changed by actors in the urban ecosystem to improve their situation or to enhance their chances of survival.

The roots of the urban ecosystems approach reach back to the early works of Park and others at the Chicago school of social ecology (see Berry and Kasarda, 1977 for a historical review). The loose biological analogy they used has gradually been expanded (for example, Hawley 1937; Duncan, 1961; Odum, 1971; Meier, 1974).

The principal value of the enlargement on the biological systems analogy is that it offers a number of intriguing suggestions as to how cities may be viewed, with the difficulty that it often cannot specify beyond a certain point what ought to be taken into account and why. Thus, we know that cities have a semipenmeable boundary populated by animate and nonanimate actors, and we know that key resources are needed to maintain life and to structure the system. The critical world-wide energy situation provides a special reason to examine energy flows which are both of central importance to the theory as well as for developing policy. But in other areas, such as governance and control systems, the analogy with living systems becomes less compelling with the result that ecosystems theory is not sufficiently well advanced to determine what should be studied, and does not increase the capacity to predict the behavior of a system under given conditions.

But the ecosystems approach also points to new, unexplored terrain. The view has embedded in it the idea that organizational aspects of living systems offset the natural tendency (described in the Second Law of Thermodynamics) to decay. This view provides the theoretical backdrop for exploring the relationship between energy efficiency and organization (and the supporting informational infrastructure) in cities. In a wider sense, the ecosystems approach is oriented to survival, not in life-or-death terms

necessarily, but in terms of meeting minimum caloric, protein, and water requirements. In addition, cities of the world compete with each other for goods, resources, and markets, and occasionally have to face natural and human-made disasters which may threaten the viability of the ecosystem. Therefore the potential for increasing efficiency and for reduction of risk of injury or collapse are important considerations.

The present analysis focuses on the way resources are changed in cities and on the contributions of information and knowledge in these changes. Resources are defined as anything in the urban environment which can be made to have value. In particular we are concerned with three resource groups. The first is energy in the form of electricity, fossil fuels, and, in the case of Mexico City, some minor biomass forms. The second is materials such as building materials, land, and water. The third is knowledge or stored information. Technically, information is anything which reduces uncertainty. Information may come in many forms -- words, pictures, data, etc. We shall consider broadly as knowledge all information worth saving, that is, recorded or stored in some form, including for example material in libraries, journals, books, technical manuals, computer routines, technical know-how, and folk wisdom.

Actors (individuals and organizations) in the urban ecosystem transform these resources in a myriad of ways. Transformation is defined as the change of resources from one form to another, usually more valuable, form. Thus, just as a manufacturing plant transforms inputs to produce outputs, cities change resources into different forms, some to be "consumed," others to be used again as resources. In the ecosystems view this process is cyclical and continual, although for analytical purposes we

shall separate the process first into ``inputs,'' strategic resources such as land, water, energy, and data, and, second, into various transformations of them.

In this study, I shall attempt to point out in qualitative and quantitative ways the interplay between information and energy use. Knowledge, organizations, and transaction capacities together make up what I refer to as an ``informational infrastructure.'' This infrastructure plays a role in making the city more energy efficient by offering employment on the one hand, while on the other, supplying informational services, making it easier for actors to make substitutions, find new innovations, avoid crises, and speed recovery from a catastrophe.

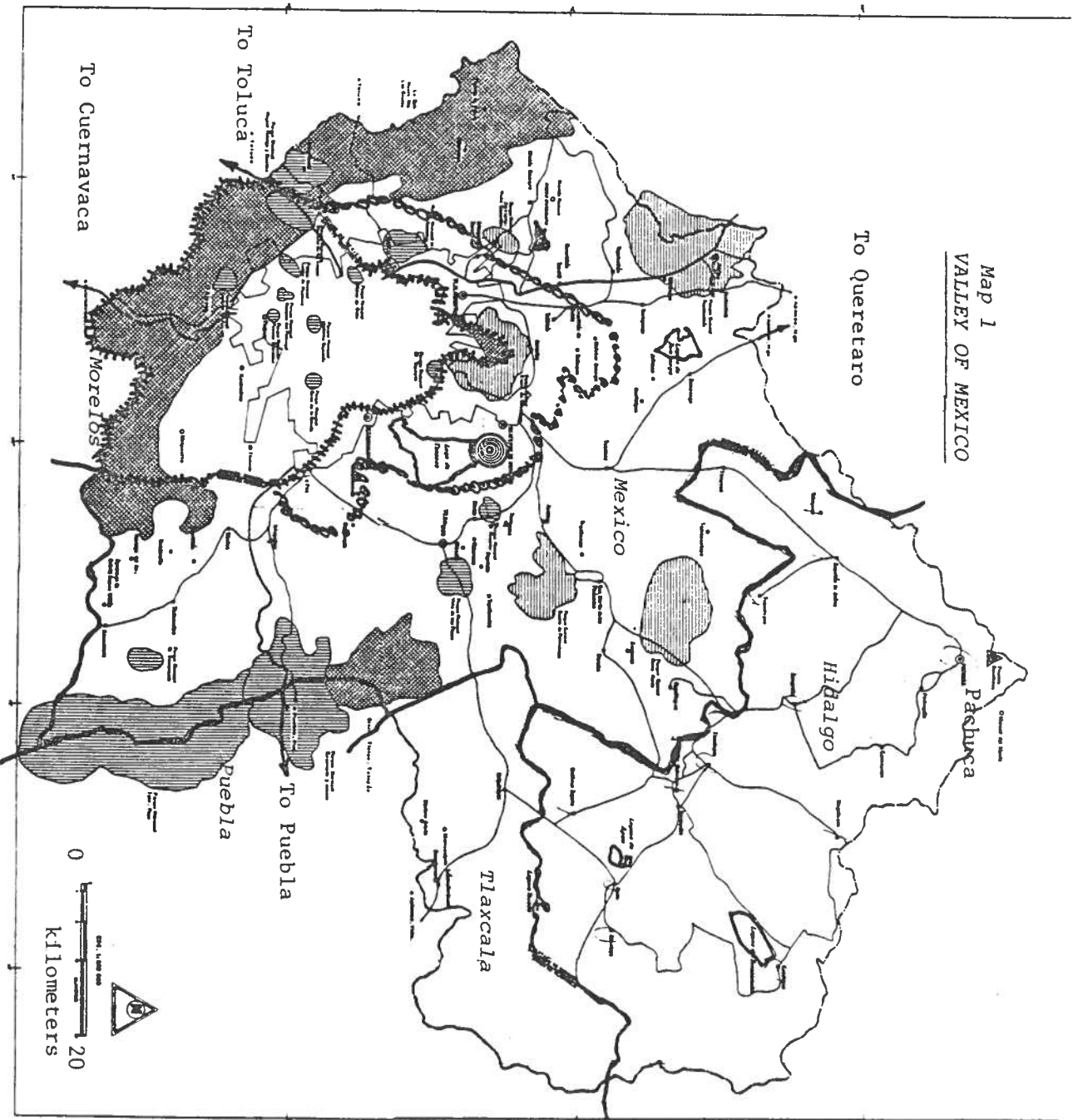
III. PHYSICAL SETTING AND STRUCTURE OF THE EVOM

Before discussing the ecosystem functioning of the EVOM, I shall define its physical components, describe some of the basic resource inputs, and point out some of the more important actors and forms of competition.

A. Setting and Boundaries of the EVOM

The Valley of Mexico is located in the Central Highlands of Southern Mexico and covers some 9,600 square kilometers, at about 2,300 meters above sea level (see Map 1). Besides all of the Federal District, the Valley includes large portions of the States of Mexico and Hidalgo and smaller slices of Morelos, Puebla, and Tlaxcala. Most of the surface features of the Valley are volcanic in origin; all protrusions are formed by individual volcanos or by the superposition of various volcanic eruptions from different geologic eras.

Map 1
VALLEY OF MEXICO



- LEGEND
- National Parks
 - State Parks
 - Projected State Parks
 - States
 - Cities and Towns

- BOUNDARIES
- Valley of Mexico
 - States
 - MAMC
 - Federal District

B. Populations

Two kinds of populations, or actors, will be discussed. Most important are human residents; but organizations are also included because they affect the allocation of, and compete for, resources.

1. Human Residents. According to preliminary figures released after the 1980 census, the Valley of Mexico has slowed to an annual rate of just above 4%, and its 1980 population is on the order of 15 million people (see Table III-1). For purposes of this study, we have put the population of the EVOM at 14.5 million -- 9.5 in the Federal District and the rest in the surrounding states, mostly in the State of Mexico.

The population growth in the EVOM since 1970 has two main components. Growth within the Federal District during the past decade has proceeded at about 3.8 percent per year; in the twelve municipalities in the State of Mexico it has been around seven percent. Larger spurts of growth took place in the previous decade when the municipalities in the State of Mexico were growing on average over seventeen percent per year. Three-quarters of this growth was due to migration (Garza and Schteingart, 1978:69). Even at the comparatively slow rate expected in the future for the Federal District, it could account for as many as nineteen million by the turn of the century. The rest of the EVOM by then could account for another eighteen million. So although the Federal District would double in size, according to some Mexican projections the rest of the MAMC would more than quadruple. As in the past two decades, most of this growth will result from low-income settlements in the northern floor of the Valley surrounding the mushrooming industrial zones.

Table III.1

Population of the Valley of Mexico 1970-2000

(est. millions)

	1970	1980	1990	2000 (approx.)
Federal Districts	6.7	9.3	13.5	18
State of Mexico	2.1	4.2	8.4	17
	—	—	—	—
MAMC	8.8	13.5	21.9	35
Rest of the Valley (Hidalgo, Puebla, Tlaxcala, Morelos)	0.5	1.0	1.5	2
	—	—	—	—
Total EVOM	9.3	14.5	23.4	37

Source: Unikel, 1976 and CCC, 1980

Various planning agencies are aiming for a target of twenty-four million for the entire Valley by the turn of the century, and fourteen million within the Federal District. To meet these targets planners want to increase the density in the Federal District and attract new migrants away to other cities. As we shall see later, there are also environmental limits to continued urban growth in the Valley, mostly because of water scarcity, as well as growing congestion, air pollution, and waste disposal problems.

2. Organizations. An important set of actors frequently overlooked in ecosystems studies, but indispensable in this analysis, is organizations. An "organization" is defined as any entity with a name and address which is capable of sending and receiving messages, and which has members, clients, and networks of relationships, and which therefore connects together different parts of the urban ecosystem. Besides communicating, organizations make choices, compete for resources, and in general react to the environment. Though other disciplines have looked at organizations to trace the processes of change in a political, economic, or social structure, the present analysis makes no attempt to differentiate organizations by power. Rather, we are interested in the macroscopic effect of having many organizations at work in the city.

The sheer numbers of organizations in the urban ecosystem is an indicator of the capacity to generate information and knowledge in the system. Certainly, absolute number itself is by no means an accurate indicator of change. But organizations act as knowledge brokers. In conjunction with the capacity for exchanging messages, they are prerequisites for adaptation and say something about the facility with which new practices, techniques,

technologies, and other information and knowledge may be disseminated throughout the system. I shall discuss this capacity later in connection with the ability to take up resource-conserving measures and to avoid or recover from ``shocks'' or setbacks such as natural catastrophes, war, or the sudden shift in price of key resources.

The minimum number of organizations within the Valley of Mexico is on the order of a half a million.* This number of organizations compares favorably with, say, Hong Kong and Seoul, but is much higher on a per-capita basis than Manila (which has an estimated minimum of about 35,000). These may be broken down by the various types, such as schools, commercial establishments, services, and industry, as shown in Table III-2.

The informational infrastructure associated with human and corporate actors is also outlined in Table III-3. The number of telephones has nearly doubled since 1973 and contracts have recently been awarded to modernize and expand voice and data transmission via telephone. Even more impressive is the growth in electronic computing capacity, which has more than doubled since 1973. On a per-capita basis, Mexico City dominates the country's computer and telephone equipment as well as the facilities for international communication.

C. Resource Inputs

Although a wide variety of qualities and things may be considered resources in the urban ecosystem, I shall focus on a handful that are most

*Excluding informal-sector businesses and voluntary organizations not having telephones or legal status sufficient to qualify for counting by government authorities.

Table III.2

Organizations in the EVOM
1980

Organization Type	Number
Schools ^a	5,900
Services ^b	118,000
Commerce ^b	250,000
Industry ^c	56,000
Government Units ^d	64,000 - 83,000

Sources: ^a Anuario Estadístico, 1973-74, projection based on constant proportions of schools to population.

^b Based on 1970 Census of Commerce and Services, respectively, and reports in Banco de Comercio (1978).

^c Based on Garza and Schteingart, 1978.

^d Based on average of 7-9 workers per organizational unit (after Meier), Garza and Schteingart (1978:67) estimate 500,000 public-sector employees resided in Mexico City in 1975. This figure has grown at 3%/year to 1980.

Table III.3

Information Infrastructure:
Message Transmission Capability

	EVOM, 1973	EVOM, 1980	Country, 1980
Radio Stations		68	728
TV Stations		6	29
Telephones	1,300,000	2,000,000	4,000,000
Computers	36	84	

Source: Anuario Estadístico, 1973-74; 1977-78. Projections based on trends.

important either because they are limiting factors, such as water and land, or because they are common denominators and pervasive, such as energy and data.

1. Land. Most of the surface area in the EVOM is either under agricultural production of one form or another, mainly in corn and alfalfa, or in forests and national parks (see Table III-4). Because much has been written recently on the incursion of urbanized areas into surrounding agricultural land, it is surprising to note that the amount of land under cultivation in the Valley has actually increased slightly over the past decade.

The urbanized area covers less than 10% of the total surface area in the Valley. There are many definitions referring to ``urban areas'' in use in Mexico. Four will be used here. First is the Federal District (DF), the smallest and most restricted definition.* Recent growth has spilled over the arbitrary boundaries originally set in the last century to demarcate the seat of government. Second is the Metropolitan Area of Mexico City (MAMC) which includes the DF plus twelve municipalities of relatively rapid recent growth in the State of Mexico. Third is the Valley of Mexico, defined by watersheds and including portions of the states mentioned above. Finally, the ``Conurbated Center'' extends outside the Valley to include intermediate cities such as Toluca and Cuernavaca, which are in the economic and social sphere of the MAMC.

*The term 'Mexico City' among Mexican planners refers only to the urbanized area of the Federal District.

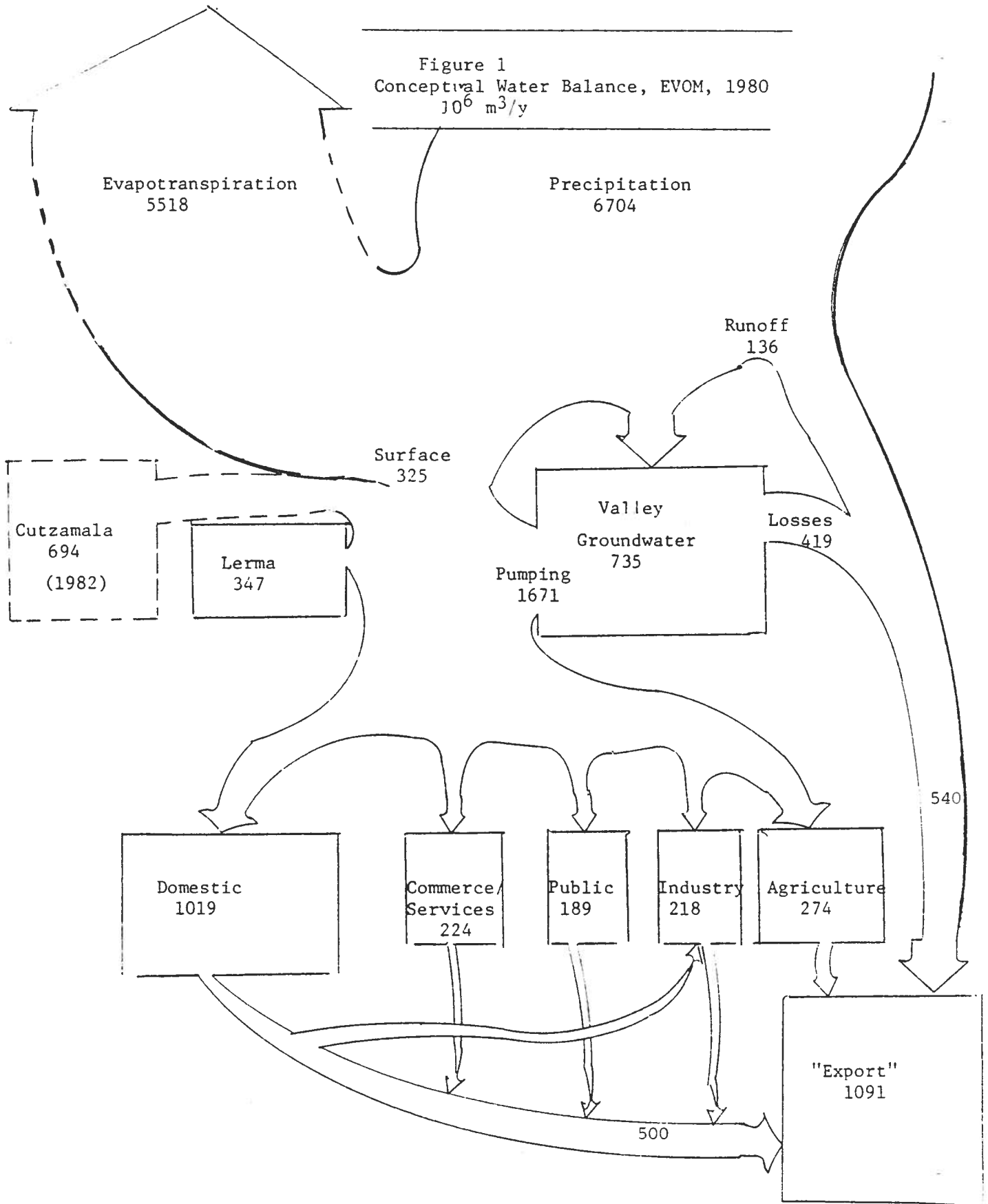
Unikel et al. (1976) have argued persuasively that the urban system in the Valley actually extends beyond the Valley borders via corridors to Toluca, Pachuca, Queretaro, Puebla and Cuernavaca (thus approximating the definition of the Conurbated Center). Although this definition is valid in terms of some linkages -- commerce, trade, transit patterns and the like -- the surrounding urban places are smaller and in many ways distinct. Including them in an ecological perspective complicates analysis of energy and water use. Our analysis is confined to the the Valley as defined by watersheds. Frequently, however, due to data deficiencies, we shall refer to the metropolitan area and sometimes even only the Federal District, although every effort will be made to treat the Valley as a whole as our main unit of analysis.

Though densities generally are comparatively low in the MAMC (14.3 thousand/km² in the DF, the densest area) circulation space is at a premium because the automobile population has grown so quickly over the past ten years. The most important inner-city spaces are subject to fierce competition. (See Appendix 1 for a table on comparative densities.)

2. Water. Since human settlements were first established in the Valley of Mexico water has been an especially important resource. Since the 16th century, the once extensive Texcoco lake system disappeared. Surface sources were tapped by 19th century settlers, and gradually as the modern city grew, subsurface sources were tapped and are now being exhausted. Supply began to fall behind demand in 1959 (Moore, 1968).

A conceptual water balance for the Valley of Mexico may be seen in Figure 1. One of the principal features of this water balance is the strong dependence on groundwater. The mining of groundwater may be seen in

Figure 1
Conceptual Water Balance, EVOM, 1980
 $10^6 \text{ m}^3/\text{y}$



the difference between the amounts drawn by pumping (1671 million cubic meters per year)* for use in the various sectors arrayed along the bottom of the figure, as opposed to the 735 mmy which enters the groundwater in the natural recharge process. This mining has now reached its limits, and the importation of water will become more important over the next several decades. A significant quantity is already imported from Lerma, a well field located some 50 km. from the EVOM (just west of Toluca: see Map 1). The rapid rates of population growth and demand for water have led to the creation of several large water projects, to be discussed later.

Nearly 460 liters per capita per day* are consumed in the MAMC daily, thirty percent more than in Hong Kong. Among household users the range is from 50-450 lcd, high in comparison with other Third World cities. Industrial and agricultural uses in the aggregate are small by comparison. Given the large losses and amounts of unrecovered waste water in the system, the competition for water in food production, hydroelectric power, and domestic use deserves further investigation, but that is outside the scope of this paper.

3. Energy. Because it is a common denominator and used extensively in transforming other resources, I shall go into some detail on energy, referring here to all extrasomatic (non-biological) forms -- fossil fuels, thermo- and hydroelectricity, and biomass -- consumed in the EVOM.

I have estimated that over 850×10^{15} Joules** were consumed in 1980

*Abbreviated hereafter as mmy.

*Abbreviated hereafter as lcd; lcs for liters per capita per second will also be used.

**Abbreviated hereafter as J; the Joule equals 10^3 BTU hydro and 1.15×10^3 BTU thermal.

in the MAMC. Of this total, over seventy-two percent was consumed in the form of fossil fuels and the rest in electrical energy, of which over ninety-nine percent is thermally generated for the grid surrounding the metropolitan area (see Table III-5).

Most of the fossil fuels are imported by pipeline from oilfields elsewhere in Mexico for refining in the EVOM. Two refineries supply hydrocarbons to the MAMC, one in the MAMC, the other near Tula, 60 km. away. Also two large storage tanks are located within the MAMC. Though the EVOM is tied into the national electricity grid, electricity supplied to the EVOM at any given time is ninety-nine percent thermally generated. The national grid is about one-third hydroelectric, but except during cases of emergency such as brownouts, this more efficient electricity is not used in the EVOM. I shall discuss the sectoral and fuel allocational details displayed in Table III-5 later in the paper.

4. Data and Information. The raw material needed for producing knowledge growth in urban ecosystems is data or information. Here it is necessary to think very broadly about information. I refer not only to the popular forms of information, e.g., news, to which we ascribe meaning for use on a day-to-day basis, but also the more neutral kind, data, to which some transformation (e.g., testing for verification, interpretation, and storage) must be effected before it can be useful knowledge. It is helpful to think of cities as generators and collectors of data. Later, I shall discuss a few important ways data are transformed into knowledge.

We may get some idea about minimum amounts of data found in the EVOM by referring to messages (transmissions of data) flowing via formal channels of communication. Though we have no published figures on the number

Table III.5

Energy Demand in MAMC
(1980, est.)

Energy Type	Percent of Total
Industrial Fuels	31.9
Liquid Gas	9.4
Electricity	11.1
Diesel	14.3
Gasoline	25.5
Aviation Fuel	4.9
Kerosene	2.9
Biomass	(neg.)

Source: IMP, 1977 (Table A.8),
projections for 1980.

of phone calls placed in the city, Table III-6 shows that Mexico City accounts for seventy percent of the cable traffic in the country, a small fraction of it originating overseas. Table III-6 also shows that the six metropolitan area TV stations broadcast in 1977 some 27,000 hours of programming, over forty percent of which had some "news content" (as defined by Mexican agencies to mean programs of education, theater, roundtables, documentaries, etc.). Finally, the city accounts for well over half the total pieces of mail in circulation in the country in 1976. Authorities have recently announced an attempt to standardize letter sizes for easier mechanized processing, and for the introduction of new cable TV service (available in border towns for some time and now available in the capital).

5. Other Resources. Naturally, many other resources should be included in this inventory. I have selected a few strategic ones which are likely soon too become growth constraints. The airshed, for instance, cannot be ignored. Air pollution has become one of the most noticeable problems in the EVOM. More than two million tons of contaminants are poured into the Valley's airshed each year. Particulates from the silty soil surrounding the MAMC are also an important source of air pollution. Mention should be made of wastes -- especially waste water and solid waste. From an ecosystems standpoint, wastes should be considered potential resources. We have already seen that liquid wastes amount to more than half the water volume pumped from groundwater sources. Only a tiny fraction of wastewater is recycled. Solid wastes accumulate at the rate of more than 6,500 tons per day, and may be considered to be an important potential resource in land reclamation and food production.

Table III.6

Messages in Circulation
EVOM, 1977

Message Type	DF	Country
Correspondence (1976)* x 10 ⁶	1,043	1,669
Telegrams (1977)* x 10 ⁶	164	743
TV Broadcasting		
Hours "of content" (1977)	11,081	
Total Hours	27,000	

Source: Anuario Estadístico, 1979

*Refers to domestic and international.

IV. THE CITY AS TRANSFORMER -- SURVIVAL AND CHANGE

Now that we have reviewed and defined some key resources inputs into the urban ecosystem, we turn to an analysis of how these resources are transformed. In this analysis, I shall not attempt to discuss all transformations in the EVOM. Rather, our attention will be focused on a limited number of transformations important to the urban ecosystem. Five will be discussed, each of them a reference point by which the system may be assessed and compared with other urban ecosystems. Briefly, these are:

- ⊕ Energy flows and uses within the system;
- ⊕ The provision of a minimum adequate standard of living in the supply of food, water, and waste facilities;
- ⊕ Transportation;
- ⊕ The output or product of the city, and particularly the fraction of output which is exported to earn foreign exchange;
- ⊕ Adaptability to crisis.

We shall look at resource use in each of these transformations in an attempt to assess the overall efficiency in the system. Efficiency is measured in relative terms by comparison to other ecosystems and in absolute terms, ideally by reference to total energy consumed in a given activity. We shall also identify problems, constraints, threats to future growth, and possible opportunities for resource conservation.

A. Energy Transformations.

How is energy used to do (transform) things in the EVOM? Table IV-1 is a rough energy matrix estimated for the EVOM from a variety of sources. The Table gives a sectoral breakdown of energy consumed in the EVOM. Taking each sector by turns, we see that although industry accounts for some forty-five percent of all energy consumed, a large fraction (about half) of industrial output is exported to elsewhere in Mexico or to other countries, and so the total figure is lower by about 250×10^{15} J. (See Section B, below). Transport accounts for two to three times as great a proportion of energy in the EVOM as it does in Seoul, Manila, or Hong Kong. No doubt this is due in part to the cheap cost of gasoline in Mexico. Some of the energy for the services and domestic sectors is distorted. Too much is counted in services because tourism is technically an export. Some food energy consumed outside the EVOM is not counted. After making these adjustments we find that the total energy used by the EVOM remains at about 850×10^{15} J. (See Appendix 2). Finally, it is interesting to note that the pumping of water could conceivably grow to become the second most important single electricity user by 1990, even outstripping domestic (household) consumption by then. Succeeding sections will further elucidate the partitioning of energy, and help account for energy consumed outside the EVOM for needs (e.g., food) within the Valley, and vice versa.

It is worth digressing for a moment to examine the overall energy efficiency in cities. The first column in Table IV-2 shows the per-capita use of energy for four major metropolitan areas, including the MAMC. Viewed in relation to the estimated gross domestic product for each city (given in column two) we have basis for comparison across these cities, though there is some distortion due to differences in exchange rates.* The

*Since subsidies in Mexico are stronger than elsewhere, we can expect higher energy consumption than otherwise. We are not in a position to evaluate to extent to which a higher "shadow" price (reflecting world

Table IV.1

Energy Use in Metropolitan Area of Mexico City
1980 (J x 10¹⁵)

Sector	Electrical	Combustibles	Other	Total	Percent
Industrial ^a	128 ^a	259 ^a		387	45%
Commerce/ Services ^a	17 ^a	50 ^a		67	8%
Transport				253	30%
Private ^b		148 ^b			
Cargo/Public ^a		73 ^a			
Public Metro ^b	3 ^b				
Air ^a		29 ^a			
Domestic ^c	33 ^c	47 ^d	3 ^d	83	10%
Public Utilities and Gov't Services	25 ^e	10 ^f		61	7%
Lighting	9 ^g				
Water	17 ^g				
TOTAL	232 ^h	616 ⁱ	3	851	100%

^aEstimates based on Energeticos, 1975. Electricity use in industry, commerce, and services was grown at 8% for 1976-77 and 12% for 1978-80. Fossil fuel consumption in these sectors and in cargo and air transport was grown at 8% for 1975-80.

^bLegorreta, 1979.

^cThis figure is based on records of the Light and Power Commission of the Center (Comision de Luz y Fuerza del Centro-CLFC) for 1980, which show "domestic" (household) tariff income averaging 16% of total between 1976 and 1979; see CLFC (DeVecchi). Energeticos (1977) puts this figure at 17.6% for 1975 projecting to 17.7% for 1980. McGranahan and Taylor (1977) suggest this figure is as high as 42% (p.24).

^dMcGranahan and Taylor, 1977.

^eTotal monthly bill in June 1980 from CLFC records for public services, including federal government but excluding some Lerma water pumping and lighting.

^fEstimates based on Energeticos, 1975, using 8% growth rates for 1975-80 period.

^gEstimates for water pumping are taken from SAHOP, July 31, 1980 and from Table IV.3.

^hAssumes 99.5% of electricity for EVQM is thermal; SAHOP, 1979.

ⁱTotal combustibles based on SEPAFIN.

Table IV.2
Output and Energy for Selected Cities
1980

City	GDP/cap U.S.\$	Total Energy (J x 10 ⁹) per capita	GDP/Energy (J x 10 ⁻⁸)
Seoul	2,000	29	6.8
Manila	1,200	35	3.4
Hong Kong	2,500	63	3.9
Mexico City	3,500*	59	5.9

Source: Meier, 1980, for Seoul, Manila, and Hong Kong.
Mexico City data are taken from Table IV.1 and Energeticos,
1977:464.

*Assumes conservatively that Mexico City accounts for 40%
of total output (\$120 b. in 1979), grown at 8% for 1980
(AEMM, 1980) after U.S. Embassy and Bank of Mexico
estimates.

table shows that Seoul consumes about two times less energy per dollar of output per capita than Manila and Hong Kong. The MAMC ranks second among these cities, although it ranks far ahead of any other region in the country.

Table IV-3 shows interregional comparisons between the MAMC and the other regions of Mexico, giving total energy for 1975 and energy per dollar output per capita for 1975. Although this table compares an entirely urban region with other regions of varying urban proportions (and uses data which are different from Table IV-2 but internally consistent for all Mexican areas), the MAMC is clearly far below all other areas and the national average in terms of energy required per dollar gross domestic product.

The most frequently cited reasons for this apparent efficiency is that the combination of high density and high per capita investment in public infrastructure enable an urban population to take better advantage of invested capital and therefore to be more productive. (For example, see Garza, 1979.) Federal public investment alone for 1978 in the "central region," (which includes the Federal District and most of Valley of Mexico) accounted for fifty-one percent of all Federal public investments. Federal District and state investment would make this figure even more dramatic.* In other words, nearly four dollars is spent in the Valley of Mexico for every one dollar spent in the other cities in the nation. Garza points out that the combined government investments during the period 1977 to 1982 will be far in excess of the gross domestic product of the transformational industries in the city for the same period (1979, p. 11).

prices) would reduce output.

*CCC, 1980, Section 1: Marco de Referencia.

Another factor is that urban populations have available to them higher proportions of higher quality energy; indeed the total noncommercial energy forms reflected in Table IV-1 are trivial.

Another largely underexplored reason for this energy efficiency has to do with our "efficient cities" hypothesis, which holds that energy efficiency rises with the degree or extent of organization as opposed merely to "services" inside the urban system. So far, I have expressed this organization only in terms of total numbers of organized entities. In a later section I shall identify some of the more important organizations within the group. Up to some point, the volume of data in the system increases the opportunities for creating more efficient ways of doing things. Organizations help discover and diffuse these ideas. To some extent, this degree of organization is proportional with the size of the city. Some evidence for this argument may be seen in the rough correlation between the degree of urbanization in each area, expressed in terms of "Total Energy per Capita" (column three in Table IV-2) and the "GDP per Energy" (column four). We cannot ignore the many difficulties with this hypothesis. For one thing we must recognize the many social and economic inefficiencies (frustrations, lost time) commonly observed in the MAMC. I do not pretend to know at what point the total number of organizations begin to "get in each others' way" and create countervailing effects. I recognize also that I speak of a specific measure of efficiency aggregated at a metropolitan level. The point is, that this efficiency has not been explored and the role of informational services practically ignored in Third World cities.

B. Minimum Adequate Standard of Living

To survive, living populations need a minimum adequate flow of food and water. U.N. agencies have defined per capita minimums in terms of calories (about 2,350 per day), protein (50 grams per day), and water (25-50 liters per capita per day). We are interested in the system costs of meeting these basic needs in the EVOM.

1. Food. Nearly 25,000 tonnes of food are consumed every day in the EVOM, and an overwhelming majority is imported from outside the valley.* Food is hauled on a daily basis from as far away as the United States and in much larger quantities from the states of Jalisco, Sinaloa, Chihuahua, Vera Cruz, and Chiapas as well as from the states surrounding the Valley of Mexico. Thus, as it does in other sectors, the EVOM functions as a major magnet concentrating the food harvest from the Mexican hinterland. Distribution losses, inefficient market organization, inadequate transport facilities, and competitive demands from the United States all push up the price of food making it difficult for low-income families to meet their minimum needs.

A survey of "popular" (lower to lower middle class) households conducted by Batrouni, et al. of the National Nutrition Institute (Instituto Nacional de Nutricion -- INN) in 1979 revealed that malnutrition begins to appear in pre-school aged children in households earning under one minimum salary per month (about \$5,000 Mexican pesos or roughly U.S. \$185) (Batrouni, et al., 1979:21). Nearly half (47.8%) of the households in the Federal District fell below that income level in 1980; the proportion is certainly higher in the rest of the MNC.** The authors note, however, that

*Author's estimate based on sample surveys of per-capita consumption (Batrouni, et al., 1979) and estimates of food processing for export.

** Private communication from BIMSA.

the malnutrition they discovered was due in large part to imbalance in the intake of foods, and to the failure to take advantage of breastfeeding. Malnutrition in lower-income households is a matter of high price.

Certainly it is safe to suppose that the lowest-income segments of the population (say, the lowest twentieth percentile) have difficulty meeting minimum nutrition requirements. In response to the problem of some thirty-five million Mexicans thought to be suffering from dietary deficiency, nineteen million considered in serious condition, the government of Lopez-Portillo has launched an ambitious food program known as the Mexican Food System (Sistema Alimentario Mexicano -- SAM) which seeks to subsidize production of the Mexican farmers (poor as well as rich) and increase Mexico's self-sufficiency in basic foodstuffs. Even if the SAM program is successful in increasing domestic food production, there remains the problem of supplying food to the EVOM at a price the poor can afford. To begin with, although nearly forty-seven percent of the 9,600 square kilometers in the Valley is classified as agricultural land, the agricultural product of the Valley is actually quite small, as is the food production for human consumption. The Federal District and the States of Mexico and Hidalgo together produce insignificant fractions of the total corn and beans consumed in the Valley (See Table IV-4). At the same time, fairly large numbers of livestock, particularly pork and fowl, are raised in the Valley (see Table IV-5). Correlatively, the largest fraction of the irrigated agricultural land (accounting for less than ten percent of the total agricultural area) is used for forage crops, particularly alfalfa. As a consequence much of the food consumed in the EVOM is imported from elsewhere in Mexico and even from the U.S.

Table IV.3

Energy and Output
Mexico, 1975

Area in Mexico	Percent of Total Urban Population 1975	GDP (pesos x 10 ¹²)	Total Energy (J x 10 ¹¹)	GDP/J
North-West	8.9	36.1	51.4	7.0
North	4.9	15.6	44.2	3.5
North-East	11.0	57.4	82.8	6.9
Central-North	3.4	11.3	57.3	2.0
Central-Pacific	12.2	30.6	49.1	6.2
Central-Gulf	6.5	21.0	146.8	1.4
Central	13.0	28.7	82.1	3.5
MAMC	31.5	173.6	32.8	52.9
Pacific-South	5.3	17.6	28.5	6.2
Peninsula	3.3	8.0	72.2	1.1
Average		21.4	53.3	4.0

Notes: These figures (taken from IMP, 1977, Table C-2, p. 464) are not complete as energy figures in Table IV.2 Output figures for 1975 are expressed in constant 1960 pesos.

Table IV.4
Notes on Theoretical Imports
of Selected Foods to EVOM, 1980

Foods	Average Consumption (kg/year)	Total Consumption (tonnes/year) x 10 ³	Total Local Production (tonnes/year) x 10 ³	Imports (Exports*) (Theoretic) (tonnes/year) x 10 ³
Beans	15.7	228	30	198
Rice	13.5	196	3	193
Corn (tortillas)	81.8	1,186	1,454	+268
Fruits	26.9	391	24	297
Lemon, Mango Orange, Banana				
Vegetables	10.2	148	149	nil
Tomato, Onion, Potato, Chili, Carrots, Peas				
Meat	1.0	143	-	-
Beef, Pork, Fowl				
Milk	106.6	1,545	-	1,500
Liquid Powder				

*Plus sign indicates exports.

Source: Anuario Estadístico, 1980; Econotecnica Agrícola, 1977; Anuario Estadístico de la Producción Agrícola, 1977.

Strong competition for calories has been created by large animal populations and by exports to the United States. In the past ten years a rather dramatic transformation in agricultural production has been taking place in which the largest land holders are switching over from staple grains to forage crops such as soy and sorghum produced for dairy and beef cattle, and chicken feed. The beef cattle are then exported to the United States and dairy and poultry are maintained in the Valley to satisfy the high demand for animal protein in the city. A surprisingly high proportion of animal protein is found in the diets of households studied by Batrouni, et al. The average daily per-capita consumption of meat and eggs was 70 and 53 grams, respectively, much higher than in rural areas, whereas direct consumption of cereals is about half the rural amount (1979:18).

Besides exports, another reason for the high cost of food is transport bottlenecks that have plagued Mexico in the recent years. Many staples, including beans and rice, as well as most of the milk and eggs, must be imported; some of it -- such as the case of La Laguna milk -- comes from as far away as Torreon, some 1000 kilometers to the north. Newspapers report stockpiled food and other goods unable to reach their destinations because of clogged ports, unavailability of rolling stock, and trucking companies operating at capacity.

The system of marketing food suggests a pattern of energy-intensiveness and centralization, as represented by supermarkets. Table IV-6 shows that while a large fraction of the population buys from market stalls, as incomes rise, households tend to shift to centralized and energy-intensive food marketing, as may be seen in Table IV-7. Because a minimum income for the MAMC would fall about midway between levels A and B

Table IV.5

Animal Population in the EVOM, 1980 (est.)

Area	Livestock (000s)	Fowl (000s)
Federal District	694	3,960
Rest of Valley		
Mexico	748	3,993
Hidalgo	424	1,741
Tlaxcala	32	77
Puebla	372	372
Total 1978	2,279	10,128
Estimate 1980	2,400	10,600

Source: Anuario Estadístico, 1980.

Table IV.6

The Use of Food Outlets
Federal District, 1976

Facility	Population Using (%)	Number of Establishments
Small Shops	9.8	5,865
Market Stalls	43.3	32,015
Ambulatory Sales	11.8	1,704
Supermarkets	15.7	66
Commercial Centers	13.8	33
Government Stores	5.7	167

Source: Plan del Distrito Federal, 1980, p. 449.

Table IV.7

The Use of Food Outlets in the Federal District
by Income Level, 1978

Level of Income (\$)	Small Stores	Markets	Road Markets	Super Markets	Commer. Centers	Gov't Stores	Others	Total
A. Up to 3,600	11.9%	51.3%	11.3%	6.83%	8.3%	5.43%	4.94%	100.0%
B. 3,601 - 5,760	9.0%	42.7%	10.15%	17.15%	15.1%	5.9%	-	100.0%
C. 5,761 - 9,360 and more	7.3%	33.8%	14.1%	24.9%	14.4%	5.8%	-	100.0%

Source: Plan del Distrito Federal, 1980:446.

in Table IV-7, it may be seen that some seventy percent of the low-income population buys from the open-air market such as La Merced (a giant whole-sale and retail complex for perishables and dry goods) and the rest from "ambulatory" markets, commercial centers, and supermarkets. Over fifty percent of the highest-income populations purchase from supermarkets and commercial centers. The dominance of open-air markets may be expected to be even more accentuated for the more than 4.5 million people living in mostly lower-income households outside the Federal District. Thus, as incomes rise, Mexican food consumers show a pattern observed also in Hong Kong. Centralized and energy intensive foods requiring packaging, advertising, and refrigeration are preferred.

Resource Requirements for Food Supply. As regards the energy required to grow, process, and transport this food, half the energy is expended upon agricultural activities and half is process energy. We may estimate that the caloric value of food losses and animal feed comes to about 100×10^{15} J.* To this may be added perhaps another 250×10^{15} J for transport of food into the EVOM from elsewhere in the nation.** On a per-capita basis, considering only extrasomatic energy, food is delivered to the EVOM at a subsidized energy cost of about 17×10^9 J per annum.

Although production pressures such as the scarcity of water and land will remain in effect and push food prices up (as shall be discussed in more detail shortly), Mexico's abundant fossil fuel endowment and

* Based on caloric value of food plus estimates of at least ten percent of the total for losses and thirty percent of the total on animal feed.

**This figure is based on McGranahan and Taylor, who estimated extrasomatic energy to be 87×10^{15} J (1977:34) (exclusive of transport), as well as upon Government of Mexico (1978:Annex 3.1).

subsidized energy prices could conceivably be used to offset some of these pressures. But a policy of artificial energy prices in the case of food underscores the precarious situation of low-income households on the edge of malnutrition. A decision to remove price subsidies for gasoline, for instance, could dramatically increase the cost of key products such as milk and eggs imported by truck.

But the drought and poor production year of 1979 cannot be readily offset by manipulations of energy resources in the short term. Water is a principal factor in agricultural production in Mexico. During most of the 1970s, over half of Mexico's exports were agricultural and livestock products, and over two-thirds of these come from areas irrigated by government projects (Sanders, 1974:14). But for the Valley of Mexico and increasingly for its surrounding area, water is becoming subject to conflicting demands. As is so often pointed out, MAMC, with twenty percent of Mexico's population, has less than 0.1 percent of its water (Sanders, 1974:2). Mining and importation of water for domestic and industrial use inside the Valley conflict with the needs of farmers for irrigation. A single authority, the Ministry of Agriculture (Secretaria de Agricultura y Recursos Hidraulicos -- SARH), is responsible for reconciling such conflicts. Agriculturalists in the vicinity of the Valley claim they cannot compete with the urban water demand.

2. Water. As with other key resources in the EVOM, we are interested in the extent to which water reaches everyone who needs it. Mexico set a goal in 1975 of connecting at least eighty percent of all urban households by 1980. This goal appears to be already attained for the Federal District, but it has come at a high cost. Table IV-8 shows the distribution

of use for the total water supply of about 458 liters per capita per day. This compares with 325 lcd of fresh water potentially available to the residents of Hong Kong (Aston, 1977).^{*} For purposes of comparison, it is interesting to note the conceptual water balance for Hong Kong and the distributional differences shown in Figure 2 and Table IV-8, respectively. Using Hong Kong as a frame of reference, water consumption in the EVOM is heaviest in the domestic sector and, to a much lesser extent, in public green spaces such as parks. Higher densities and a lower likelihood of leaks reduce total demand. The agricultural sector is much more important in Hong Kong, where food is produced more intensively. This contrasts with the preference to import food in the Valley of Mexico, as we saw earlier.

The rates of consumption across income groups vary widely. For instance, a CAVM demand study (CAVM, 1979) showed higher-income and low-density consumers, such as the well-off residential areas of Lomas de Chapultepec, consumed over 450 lcd, whereas the residents of low-income, high-density areas, such as Ciudad Netzahuacoyotl, consumed an average of 50 lcd. CAVM records show that nearly eighty percent of the users in the EVOM have "access to water." Presumably the remainder must make private arrangements with neighbors or water carriers.

The shortfall of water supply relative to demand in 1980 will amount to nearly 284 mmcy. In addition to the inconvenience of intermittent supply, several million low-income residents still have no water connection at all. According to the Federal District Plan (1980), over 1.2 million

^{*}I have omitted salt water in these comparisons, even though in 1976 nearly half of Hong Kong's total water balance was represented by salt water, used mainly for cooling thermal electric generating plants. Fresh water is more relevant for comparison, as it is the scarce resource.

Figure 2
Conceptual Water Balance of Hong Kong
1977 (mcm/y)

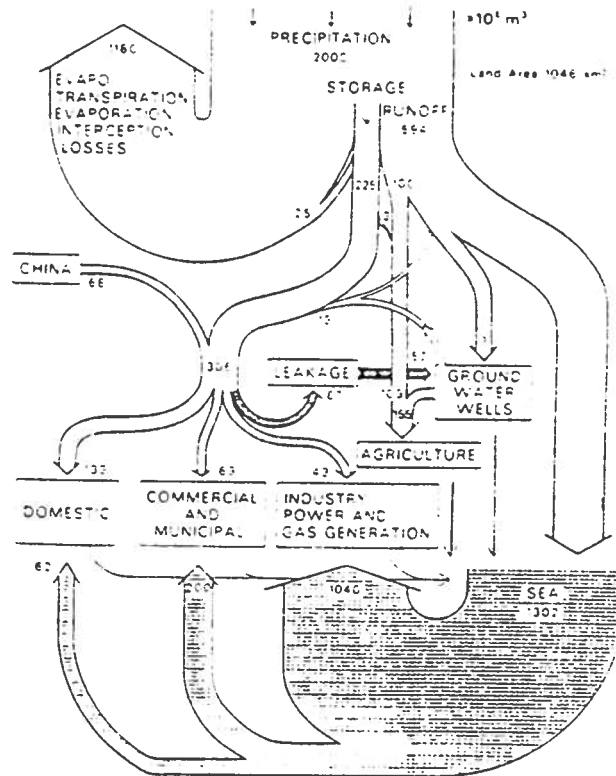


Table IV.8
Water Usage in EVOM and Hong Kong
(m³/cap/year)

Sector	Mexico (1978)	Percent	Hong Kong (1976)	Percent
Domestic	88.7	53.0	25.3	32.4
Commerce/Services	19.4	11.6	8.6	11.0
Industry	18.9	11.3	9.0	11.5
Agriculture ^a	23.9	14.3	31.5	40.3
Public	16.4	9.8	3.8	4.8
TOTAL ^b	167.3		78.2	

Sources: EVOM: National Water Plan, CCC and CAVM.

Hong Kong: derived from Aston, 1977, pp. 338-341.

^a Approximately 34,000 hectares, or 3.5% of the total land area, in the EVOM is under irrigation (assuming the proportion of irrigated land in the State of Mexico that lies inside the valley--22%--is the same as for the state as a whole).

^b Losses of about 18% in Mexico are distributed proportionally across each sector. Losses in Hong Kong ("leakages" in Figure 2) are about 23%, 4% of total water flow when counting salt water.

people in the Federal District alone were without household water connections in 1978. But because of the wide variation in per capita consumption, and the uncertainty as to the number of households actually receiving water (that is metered but not connected, or with access to standpipes), difficulties in water supply affect a much larger fraction of the population than are reflected in the official statistics used in the plans of the Federal District or the Commission for the Conurbated Center (CCC, 1979, Section Two, Diagnostico).

There can be no doubt that the population experiencing the most stress as far as water supply is concerned is in the low-income settlements of the State of Mexico where water service is generally least dependable, and where the fastest growth in the Valley is presently taking place. Based on the number of the unconnected houses as well as the low per capita consumption, the population in need may be estimated to be as high as twenty to thirty percent. Only by carrying out very large water supply projects such as Cutzamala and Tecolutla (which together will increase the present supply by sixty percent over the next ten years) can these deficits and the deprived population be held to a minimum.

These plans include a gradual reduction (by 63 mm/y) of water pumped from Valley groundwater over the next ten years. This is because the mining of water (that is, taking water at a rate greater than that of natural recharge) in the Valley has begun to reach levels at which the water is bearing heavy metals and boron, which pose health hazards. The reduction in mining is also aimed at reducing subsidence in the Valley floor. Subsidence has become a significant economic consideration. Parts of the city near the Zocalo have sunk as much as eight meters over the past seven

decades. The sinking not only damages buildings, but also has created a countergradient in the drainage system for water and sewage, requiring pumping, reconstruction, and repair. Though planners now aim gradually to reduce mining, as we shall see below, the monetary and energy costs of bringing water to the EVOM from external sources will be significant.

It should be noted that large amounts of waste water are generated in the EVOM. Of the large volume of waste water shown in Figure 1, only a small fraction is captured for recycling in industrial uses and irrigation of public parks and spaces, and irrigation of food crops inside and outside the Valley. At present, just over four percent of domestic and industrial wastes are recycled for agricultural uses. The recycled water is used for the growing of forage crops for dairy cattle and (elsewhere in the State of Mexico) perishables for consumption in the Valley. The balance of the waste water and surface runoff is conveyed out of the Valley by means of an expensive system of deep canals and drainage works that criss-cross the metropolitan area and carry the water north into the State of Hidalgo. Plans are being laid for the construction of treatment plants which by 1990 will make available as much as 315 mmy, an amount nearly equal to the total pumped into the Valley from Lerma. However, by 1990, this recycled water will still only amount to three-quarters of the amount (435 mmy) of water currently lost in the system.

The Water Commission for the Valley of Mexico (Comision de Agua del Valle de Mexico -- CAVM) will be undertaking heroic efforts to increase the supply of water in the decades of the 1980s and '90s. The first phase of this effort, the Cutzamala Project, is scheduled to deliver 694 mmy -- over twice the amount presently pumped from Lerma (see Figure 1) -- from

distances which are greater and elevations lower than the Lerma well field. This huge project is expected to meet (or fall slightly short of) the demand for water until 1986. At that time, one or another of the even larger projects -- Amacuza or Tecolutla -- will be brought on line to pump water from catchment areas even further distant and lower in elevation than the Cutzamala Project. By the turn of the century, those projects will increase the water supply by about two-thirds and will necessitate an increase in present pumping by a factor of five or six.

These solutions are heavily oriented towards the supply side. The monetary costs to the future users of this water will probably continue to be subsidized in the form of cheap fuels for pumping, if not also in the form of cross-subsidies in the tariffs. Water plans are based on the assumption that the per capita consumption of water in the MAMC will not increase. This assumption is made despite evidence that per-capita demand rose from 400 to 416 lcd during the 1960s (Moore, 1968, p.46). Finally, these projects call for a vast network of infrastructure to deliver water to the tens of millions of users in the Valley, as well as for an administrative system that will be able to deliver water to everyone who needs it at a cost they can afford.

Resource Requirements for Water Supply. The high altitude and arid climate of Mexico City make pumping for the supply of fresh water a significant issue. We estimate that the pumping requirements for water in 1980 amount to approximately six percent of the total electrical energy consumed in the Valley. This is one-third the quantity consumed by public lighting, and much more important than the electricity required for the Metro system (see Table IV-1). However, the philosophy of meeting the demand for water

in the Valley means that the present electrical consumption for pumping will be more than doubled over the next six years, and then doubled again by 1990, as shown in Table IV-9.

This sharp increase in projected electricity requirements is the result of pumping from roughly 1,000 m below and 100 km distant from the Valley in the case of Cutzamala and 2,000 m below and 200 km distant in the case of Tecolutla. By 1990, electricity for pumping water could easily surpass the amount consumed in the domestic sector, putting it in second place behind industry as the heaviest user of electricity in the Valley.

Electricity is not the only issue concerning the supply of fresh water. As was indicated earlier, competition for water in the production of food is also significant. The intense demand for water in the metropolitan area has alarmed outlying towns such as Pachuca in the State of Hidalgo (also in the Valley) and has lead to the very real possibility that a third major water project, the Amacuzac, may be scrapped because the competing demand for future irrigation in that valley would make the project infeasible.*

C. Productive Sector

Survival in this paper refers not only to basic physical needs for a minimum adequate standard of living. The definition also refers to the resources the city needs to earn its living. Thus, from an ecosystem standpoint we are interested in the resource flows which feed the productive sector (and to discount those resources which get bound up into the

*Interview with the Ejecutivo Vocal, CAVM, Mexico City, August, 1980.

Table IV.9

Energy for Water Pumping in EVQM
1980-1990

		<u>kWh x 10⁶</u>		<u>J x 10¹⁵**</u>	
	<u>m³/s</u>	<u>Project</u> <u>Additions</u>	<u>Cumulative</u> <u>Total</u>	<u>Project</u> <u>Additions</u>	<u>Cumulative</u> <u>Total</u>
<u>1980</u>					
CAVM	15	380			
DDF	34	618*			
State of Mexico	9	398			
Total			1,396		17
<u>1982-86</u>					
CAVM					
Cutzamala	22	1,652		20.0	
Total			4,048		37
<u>1980-86</u>					
<u>1986-90</u>					
CAVM					
Tecolutla	25	3,000		36.4	73
TOTAL	105		6,048		73
<u>1980-90</u>					

*The amounts for the CAVM and the State of Mexico are known and account for 24 of the 60m³ MGMS/s consumed in 1980. The figure for the DDF represents 262 known consumption of power supplied by the CLFC and an estimated amount (356) based on average pumping requirements in the state to account for the 11m³ MGMS/s pumped from Lerma but not included in the CLFC billing records. If electricity consumption were to grow to 8-10% (say, to 500 or 600 x 10¹⁵ J) by 1990, water pumping would account for 12% to 14% of city total. Domestic electricity consumption, growing at, say 8%, would be only about 71 x 10¹⁵ J by 1990.

**Assumes 99.5% if electrical energy is thermal.

``exports'' in which the city specializes).

Mexico City's economic structure is dominated by public-sector service which accounts for two-thirds of its gross domestic product (see Table IV-10). Garza and Schteingart (1978) calculate that nearly forty percent of the country's public-sector employees resided in Mexico City in 1975. Another 300,000 (sixty percent) may be added to cover those who work for various decentralized public agencies and state governments. (1979:67). Though important resource use may be associated with the service sector -- such as the use of energy, water, and land needed to support government offices in Mexico City -- these uses are small (e.g., eight percent of total energy) by comparison to the consumption of resources in the industrial sector, as we shall see below.

Tourism, both domestic and international, represents a large fraction of the gross domestic product for the city. Income from the sale of temporary lodging, and the preparation and sales of foods and drinks including beverages, accounted for nearly twenty percent of all the service income for 1970. Though commercial activity accounts for twenty-five percent greater product than services, a much smaller fraction of commercial activity is exported.

Industry accounts for nearly thirty percent of the GDP for the EVOM and contributes to a sizeable fraction of exports. Nearly one quarter of all Mexico's exports to foreign countries is produced by the EVOM, and much of this is in industrial goods. Garza (1979) reports that in 1970, 33,000 industries in the EVOM produced nearly fifty-six percent of the industrial output for the country. The largest share was represented by chemical products including colorants, pigments, insecticides, pharmaceuticals, etc.

This was followed by automobile production and radio, TV and other electronic apparatus. Given the real growth of the economy in the past year (about eight percent), the creation of new plant and equipment for automotive firms in the Valley of Mexico, the acceleration in petroleum output, and a particularly strong showing of sales for electronic apparatus, we may expect that the industrial structure has changed little over the past decade (Table IV-11).*

What fraction of the energy consumed in productive activities is "exported" to earn foreign exchange? This question is of interest because the energy embodied in exports should not be considered as consumed in the city. Also, knowing the energy needed enables us to gauge the resiliency of the ecosystem to perturbations in energy flow. Because the EVOM exports about fifty-six percent** of its products, we can expect approximately that fraction of industrial energy use to be exported. For manufactured exports this means total energy would come to about 217×10^{15} J, some twenty-five percent of the total energy consumed in the EVOM (calculations from Table IV-1).

Another fraction is consumed in supporting tourism and thus is devoted to earning "foreign" exchange. Between 200-300,000 foreign tourists visit Mexico City a month (higher during the U.S. winter) accounting for another 27×10^{15} J. Thus, together with manufactured exports, we may estimate total energy assignable to export is $240-250 \times 10^{15}$ J, or some twenty-eight to twenty-nine percent of the total, an amount about equal to

*This view is corroborated by the Colegio de Mexico, BIMSA, and the American Chamber of Commerce.

**Both the BIMSA and the American Chamber of Commerce concur on this figure.

Table IV.11

Top Ten Industries in MAMC, 1970

Industry	Percent of Total Establishments in Nation	Percent of Total National Value Added (Industry)
Chemical Products	5.9	19.9%
Radio and Television	1.5	6.3%
Automotive	0.9	5.3%
Editing and Publishing	8.1	4.7%
Textiles	1.5	4.6%
Metal Products (not machinery and equipment)	3.5	3.8%
Production and Repair of Rubber Products	3.0	3.7%
Clothing Fabrication	12.6	3.3%
Basic Iron and Steel	0.3	2.8%
Food Products	16.4	2.6%
TOTAL Output		57.0%

Source: Garza, 1979, pp. 23-26.

that supporting the system of food distribution into the Valley.

Resources Consumed in the Production Sector. We have already noted that the industrial sector accounts for over forty-five percent of the total energy consumed in the EVQM. The energy intensity is highest in the production of chemical products, automobiles, iron and steel, and crude-petroleum refining. All are among the top ten producers in the industrial structure of the EVQM. This is to be contrasted with the eight percent going to the services sector which generates two-thirds of the area's GDP.

As for water, domestic users are by far the most important consumers of water, other sectors -- commerce, services, and industry -- together account for some eighteen percent of the total. Industrial pollution of water as well as of air in the Valley has already been discussed and must be taken into account in the total resources consumed in Valley economic activity. Finally, although the expansion of industrial plants has been dramatic over the past ten years, agricultural land has actually increased rather than decreased as was reported earlier.

D. Transportation Sector.

We see a contrast between Mexico City and other cases studied in the proportion to which intra-city transportation represents of the total fuel consumption. The fuel consumed for transport in Mexico City (estimated at 253×10^{15} J/year) represents as much as thirty percent of the city total. Transport accounts for between nine and twelve percent in Seoul, Hong Kong, and Manila. The subsidized cost of gasoline (1980 price at around 45 cents per U.S. gallon) makes private automobile use attractive, even though only a minor fraction of the population can afford to own and operate passenger

cars in the MAMC. About 1.5 million automobiles are currently in circulation in Mexico City, with approximately another half million busses and cargo trucks. It is interesting to note (Table IV-12) that automobiles, which account for only sixteen percent of the passenger trips in Mexico City, consume sixty-six percent of the energy in passenger transportation (excluding taxis and motorcycles), while mass transport, which accounts for over seventy-five percent of the passenger trips, consumes less than twenty-two percent of the transport energy used (Legorreta, 1979). Mexico is not in the situation of the other cities studied due to its fossil fuel endowment. On the other hand, the automobile population has been increasing by eleven percent per year, and planners in Mexico City must now worry about severe congestion and atmospheric pollution associated with private automobile circulation.

Resource Requirements in Transportation. Aside from the heavy fossil fuel consumption, the sheer numbers of vehicles and their generally bad operating condition place heavy demands on air quality and space.

The two million vehicles generate tons of pollutants every day which combine with sunlight and silt to produce a serious health hazard in photochemical smog and particulates. One public-health official has stated that a large majority of clinical visits in Mexico City relate to eye, nose, and throat maladies due to bad air quality. Despite these problems, the Mayor has taken bold steps to expand the capacity for vehicular circulation and to control it better. Peripheral highways, crosstown highways, and dedicated bus lanes have recently been inaugurated. But traffic criss-crossing the downtown center shows no sign of easing up. Congestion is severe four times a day (due to long mid-day lunchbreaks), despite staggered hours.

Table IV.12

Energy in Passenger Transportation
MAMC, 1975-1985
(J x 10¹⁵)

Mode	1975	1980	1985
Automobiles	71.7	96.9	111.4
Mass Transport			
Busses	24.3	29.4	34.6
Metro	.9	2.0	3.0
Other	.4	.7	1.4
Other	7.3	17.6	19.0

Source: Legoretta, 1979.

E. Information Transforms and Knowledge

The final reference point I have selected for assessing the functioning of the city is its adaptability. By adaptability I refer to more than the ability to respond to change. We should also take into account the ability to operate efficiently as a system, to integrate innovations, to avoid or recover from crisis, and to plan a future. I referred earlier to the number of organizations as being an indicator of a city's adaptability because it is this data category more than any other that grows as knowledge production grows. For example, business, industry, and government must count on easy access to current prices, inventories of spare parts, alternative sources of supply, availability of credit, and the like in order to survive and flourish. Up-to-date data on these matters are supplied by specialized units within companies or by their trade associations. A market for such information is dependent upon large city size. Small cities cannot support such services. As these subsectors (information services) of the local economy expand, businesses are easier to start and maintain. Thus, new growth in a system will be manifest as organizations, some of them specialized in information services.

Though I have already spoken of the total number of organizations in the EVOM, it is worth identifying a few of the most important ones. Institutions of higher learning and research are of course obvious, but not the most important. Private-sector confederations and associations such as chambers of commerce, of building, of trades, etc., play an important role. So do firms dealing in information as a commodity--radio and TV broadcasters, data-processing and market-research firms, and the like. Estimated numbers of these organizations and their growth over the recent years are

given in Table IV-13. I have not included some voluntary associations and more loosely tied ``informal'' organizations such as those in low-income housing areas, because no data are published on them. But associations of these kinds, of squatters for instance, are important: not so much for influencing the larger urban system directly, although this is sometimes the case, but for the survival of the individual householder. Such associations, including kinship networks, do the same kind of data-gathering, filtering, and information distribution (although more of it is spoken) as the more ``formal'' organizations. (See Campbell, 1980, for a discussion of informational aspects of resources among squatters in Rio de Janeiro, Brazil.)

With a vigorous data-transforming sector, efficiency in the urban system is increased at two levels. First, at the level of the individual enterprise, availability of knowledge helps to reduce false starts, errors, and misallocated resources. Individual activities -- householders, firms, other organizations -- run more efficiently. At the level of the entire urban system, the output or GDP becomes less dependent on material resources. A growing fraction of workers are employed in informational services. A different kind of efficiency is thus introduced. As the productive structure evolves in a city, the amount of raw energy it requires to support itself declines. This is probably the explanation for the low energy use per unit of output in the EVOM, referred to earlier. As a system, the EVOM is more efficient than other regions in Mexico, and compared to other metropolises. The half million organizations in the EVOM is an order of magnitude larger per capita than in Manila. We may speculate that Mexico City's organizational growth -- its ability to generate and transform data and to exchange information -- is at a more advanced stage

Table IV.10

Mexico City and the Nation:

Gross Domestic Product

1970 (in 1950 pesos)

Sectors	Nation	MAMC	Percent Total
Agriculture	17,643	54	0.1
Industry*	52,009	16,086	28.4
Transportation	4,778	2,775	4.9
Services	77,330	37,816	66.6
Total	151,760	56,731	100.0

Source: Garza, 1979.

*Industry includes construction (37.4%).

of development than in Manila.

Earlier I referred to other ways in which adaptability may be assessed. The growth of data-transforming organizations enhance the adaptive character of cities by speeding the adoption of foreign technologies, making it easier to cope with emergencies, and by facilitating planning. As for adopting innovation, Meier refers to the receptivity to innovations by an urban ecosystem from outside (particularly from abroad) suggesting that "an openness" to organizational capacity and information flow are directly related to the ability to remain competitive with other cities (Meier, 1974).^{*} This openness to outside innovation may be witnessed in virtually every field of economic activity in Mexico -- the use of Hughes drill bits in the petroleum sector, software technologies from America in computers, German electrical and telephone systems, integrated traffic signaling systems from Singapore, and French technology in the underground Metro system.

One test of the ability to communicate and make use of knowledge from various parts of the system is during citywide emergencies. One such case was the electrical "brownouts" in June and July of 1980. Due to a combination of factors which included abnormally low rainfall, and allegedly bad maintenance on German boilers in thermoelectric generating plants, brownouts began rather suddenly in the third week of June and were experienced all over the city and many parts of the country for seven weeks. For a number of days, outages in the city occurred during peak hours. Industrialists were upset because the outages interrupted their production

^{*}A much more fundamental argument was advanced in Meier's Communications Theory of Urban Growth (1962).

schedules unexpectedly, so the losses were serious. Talks were quickly organized by the Federal Electricity Commission (Comision Federal de Electricidad -- CFE) and various representatives of industry and commerce.

No doubt the close ties between the PRI (Partido Revolucionario Institucional -- Party of Institutionalized Revolution) and the productive sector (see Schlagheck, et al., 1980) expedited a decision to rotate the outages by area. With this scheme in place, production could be programmed and losses minimized. Still, estimates are that industrial production was 15% below its programmed level for that period. Were it not for the ability in the private and public sectors to rapidly mobilize and coordinate their response, losses resulting from this miniature ``shock'' to the system could have been much greater. As it was, they were sustained most heavily by the chief energy users -- steel, petrochemical, and automotive industries.

Another way in which knowledge creation is important has to do with the ante hoc management of difficulties through planning and cooperation between the public and private sectors. The organizational matrix in Mexico City -- encompassing the federal, state, regional, and municipal entities -- provides an illustration of this need. Both presidents Echeverria and Lopez Portillo have given high priority to the human settlements sector. A national human settlements act was passed during Echeverria's regime; national, regional, and local urban development plans have been prepared during Lopez Portillo's administration. In a surprisingly short period of time, urban development plans have been developed and published for the nation as well as in some twenty states, the Valley of Mexico, the conurbated center, the Federal District, and scores of smaller towns around

the country.

The most important advances in this planning endeavor were the creation of institutions to marshal information, coordinate with a myriad of federal entities, and translate general policies and legal provisions into urban development plans. In the Federal District, for example, with the active support of the mayor, planners were assembled and able to draw up a document articulating a strategy for nodal growth within the Federal District all within a period of eight months. In another example, the Ministry of Human Settlements (Secretaria de Asentamientos Humanos y Obras Publicas -- SAHOP) with a staff of under one hundred, in less than two years produced twenty state plans and a number of municipal plans emphasizing environmental and ecological aspects of development. One of these plans was produced for the Valley of Mexico.

A third group, the Commission for the Conurbated Center (CCC) was constituted to plan for the conurbated area. The CCC operates under an executive committee made up of federal authorities, governors of the five states, representatives of the Federal District, and of the over 130 municipalities in the area.

The point illustrated in these instances of innovation, crisis management, and planning is that the urban system in the Valley of Mexico can adapt surprisingly quickly on a large scale and in a coordinated fashion. I suggest that the growth of knowledge and of interacting organizations play an important role in this adaptive ability. Though it may sometimes appear to us subjectively that the city is disorganized, inefficient, even chaotic, I suggest we need to look more closely at different forms of order and at knowledge production. We must take into account the possibility

that extremely rapid growth of the city may jade our view or obscure the ordering effects which are nonetheless achieved by a wide variety of actors. Further, to call the city's economic structure a services economy is to understate the importance of information and knowledge management. Indications are that this function will be growing more important, and the efficiency of the city increasing.

Resource Requirements of Informational Infrastructure. Unlike other transformations discussed earlier, the building up of the informational infrastructure requires few sacrifices of material resources and appears not to be as subject to negative feedback effects as, say, industrial activity or transport. Though education and modern telephone and telecommunications equipment require capital investments, beneficial effects are felt broadly.

In sum, we have looked at five ways in the which the urban ecosystem of the Valley of Mexico transforms key resources to fill the needs of its citizens and to keep the system viable and growing. Large segments of the population are vulnerable to water shortages, not just from the standpoint of having fresh drinking water, but also from the standpoint of suffering from production losses due to importance of hydropower in the national grid. To lesser extents, food and energy can be problematical because of the largely unbridled growth of population in the Valley. The resulting growth in demand for food, electricity, water and other resources requires a doubling of resource flows in as few as seven years. Though the productive and organizational talents in the city show signs of rising to this challenge, it remains to be seen whether the quality of life in the EVOM can be maintained even at the present unbalanced level.

V. GROWTH TRAJECTORY AND PROSPECTS FOR A STEADY STATE

Authorities in Mexico have announced their intention to limit the population of Mexico City to about 24 million by the turn of the century. We turn our attention now to the resource demands implied by this optimistic target and to measures which may help to achieve a steady state in the EVOM.

The prospects for growth in the Valley of Mexico are conditioned upon a number of powerful forces which are not easy to influence. Foremost among these is the historical rate of growth. Only fifty to sixty percent of the population growth in the EVOM is due to natural increase; the remainder results from immigration. The reduction from the historical trend from 31 to 24 million within the next twenty years requires bringing net immigration to a complete halt during that time or achieving an abrupt reduction in fertility. Data from the 1980 census show that the birthrate in the EVOM is in fact falling. But it is still far from a steady state or replacement rate.

In addition, there is a large backlog to be made up in the built environment, and the drive to meet these demands is the second difficult force to divert: the psychology of growth which assumes demand to be paramount and requires that resources such as water, energy, food, etc., be supplied at all costs. This growth philosophy is rooted deep in the history and psyche of Mexico. Moreover, stopping the growth of Mexico City now may be more difficult than ever because growing oil revenues will at least make it financially feasible to accommodate larger populations.

Setting aside questions of philosophy and political will, what are the

implications for resource supply and demand, and what are the prospects for meeting the basic needs of the future city population? We may obtain some idea of future resource needs by using recent historical growth trends to project the need for key resources. These projections are shown in Table V-1.

Supplying water appears to be the most difficult task. Based on current rates of natural population increase and water use, another 500 mmy will be needed; this is over and above projected supplies from Cutzamala, Tecolutla, and 200 mmy possibly available from recycling for industrial use (SAHCP, 1978). Because additional natural supply sources (aside from Amacuzac) are not at present in view, efforts to conserve water are already being contemplated.

Besides recycling for industrial uses, officials are preparing tariff changes required in accordance with the loan agreement from the Inter-American Development Bank (IDB) to build the Cutzamala Project. Little water is metered at the point of consumption at present, and collection of fees from the user by the municipality and, in turn, from the municipality by the Water Commission (CAVM) has not been very successful. With the IDB loan the Water Commission, the Federal District, and the municipalities in the State of Mexico will be obliged to charge prices that could rise to five or six times their present level. Only one price increase in water has been successfully levied during the past ten years in Mexico City.

A complementary possibility and logical outgrowth of the urban ecosystems approach is to adopt domestic water recycling schemes coupled with intensive production of perishable foods (drip irrigation). Such schemes

Table V.1

Key Resource Flows
in EVQM, 2000

Resource	Projected Flow	Difficulties or Shortfall
Water	$4015 \times 10^6 \text{ m}^3/\text{yr.}$	approx. $600 \times 10^6 \text{ m}^3/\text{yr}$
Food	38,000 tonnes/day	production marketing transportation
Energy		
Total	$1,297 \times 10^{15} \text{ J}$	opportunity costs
Electricity	$355 \times 10^{15} \text{ J}$	water
Waste		
Solid	9,144 tonnes/day	none
Liquid	$2,228 \times 10^6 \text{ m}^3/\text{yr}$	new infrastructure
Clean Air	static	pollution
Circulation Space	4×10^6 vehicles	congestion

are being explored with some success in arid climates (Israel). We are aware of experimentation in such schemes only on a minor scale in Mexico (SAHOP, 1979). Such an approach would appear to have the advantage of addressing problems of food production and distribution, waste disposal, and land reclamation.

At current rates of consumption, waste water could well be in the neighborhood of 2,000 m³/day, although increased water tariffs would certainly reduce this flow. From an ecological perspective, this flow together with solid wastes and land needed for solid waste disposal (at 9,000 tonnes/day by the year 2000) may be viewed as resources capable of supporting food production and land reclamation inside the Valley. Further investigation would be required however to ascertain the extent to which saline soils in the Valley floor may be reclaimed and the extent to which production of perishable foods in the Valley would relieve production, marketing, and distribution difficulties attendant to the projected needs of between 35-40,000 tonnes of food per day by the turn of the century.

Given the fossil fuel reserves in Mexico there would be no problem in supplying the $400-500 \times 10^{15}$ J ($100-150 \times 10^{15}$ in electrical energy) needed by the turn of the century. But continued cheap energy will continue to attract industry, residents, and automobiles. A Federal statute calls for a gradual increase (by 1.5% per month -- less than the inflation rate in 1980) in the price of electricity sold by the CFE. The statute has been in effect for the past two years and was recently extended until June of 1981. But at this rate, the cost of electricity would not come into line with 1980 global prices of fossil fuels until 1986.*

*Assuming the cost of thermoelectric power at present is about ten cents

Measures will also be necessary to improve air quality and traffic circulation. The number of vehicles could rise to four million by the turn of the century. Besides possible price increases, strategic use of communications devices and slow-ways as described in Meier et al. (1978) are two resource-conserving measures which may hold promise for the EVOM.

Resources needed in the EVOM depend also on the outcome of decentralization plans by the Mexican government aimed at spreading the wealth in Mexico and braking the growth of Mexico City. Though subsidies and fiscal incentives may have some effect in attracting new plants away from the EVOM (a current thirty-percent subsidy on petroleum feedstocks could be attractive to any export-oriented chemical firm in Mexico City contemplating new capital plants and equipment), there is as yet no evidence that the explosive growth around some of the petroleum export cities such as Vera Cruz and Coatzacoalcas has attracted migrants who otherwise would have headed for Mexico City. At the same time, accumulated public investment in the EVOM referred to earlier is a powerful incentive for continued growth there.

Planners in the Federal District propose to decentralize the congested center of Mexico City and to establish ten "nodes" connected by high speed arterials, dedicated bus lanes, and the Metro system. This plan may help to shift the share of transit ridership onto fewer, more efficient vehicles. The Federal District plan also calls for the creation of new urban markets which would facilitate the distribution of food to the urban populations, although there is no evidence to indicate that this will

per kwh.

result in a reduction of food prices. Certainly the improvements in transportation could unclog some of the bottlenecks which have contributed to food spoilage and therefore at least add to quality.

VI. SUMMARY AND CONCLUSIONS

The ecosystems approach has proved to be useful in several ways. It helps to tie together mentally a variety of different aspects of urbanism normally treated sectorally. The fuel/water/food triad is one example. Another, more novel connection has been to view organizational aspects in relation to energetic ones. This connection leads directly to the energy-efficiency ideas stated earlier. Also, the ecosystems view stresses the cyclical transformation of resources rather than merely linear production and consumption. It thus captures more accurately than sectoral approaches the many important nonmonetary aspects of production, such as the role of information and the value of "wastes." Another advantage to the ecosystems theory is that it stresses survival and balance. Thus we have been concerned with meeting the basic needs of residents on the one hand, and on the other, with the overall growth and competitive position of the EVOM. Further research along these lines might include an analysis of the vulnerability and resilience of the ecosystem to, say, drought, a removal of energy subsidies, or earthquake.

The ecosystems view also stresses energy flows, a timely as well as theoretically important subject. In formulating energy policy for cities, it is useful to have information on patterns of energy use, as well as how well or efficiently energy is used. Further work might attempt to establish the energy cost of a wide variety of reference points in the urban

ecosystem -- including, for instance, the energy devoted to maintaining, replacing, and adding to the built environment. Comparative data on several cities might allow us to construct a typology of cities and to better gauge expectations regarding developmental objectives.

I have put forward the hypothesis that the informational component of the services sector in Mexico City plays an important role in facilitating the survival of the city, so that with this informational infrastructure it is easier to adopt innovations, make and carry out plans, and recover from catastrophe. Further, I have presented evidence that Mexico City is at least two times more efficient in the use of energy than other region in the country. I have suggested a number of ways that organizations offering informational services contribute to this efficiency. These ideas of efficiency and organizations run counter to the drift of popular and intellectual thought on the evils of "gigantism" of cities and counter to prevailing wisdom in policy circles concerning the necessity of decentralization (see, e.g., Rondinelli, 1980). What are the elements of knowledge production and management in cities; how can they be better, more broadly measured; and how can resulting efficiencies be transmitted elsewhere? Much more work needs to be done on these questions. These findings and conclusions are direct outgrowths of an urban ecosystems approach aimed at analyzing large cities in the aggregate and discovering ways to achieve resource-conserving urbanism.

As for the low-income populations, the critical problems really have to do with water and food supply. The largest fraction of infant mortality is still due to gastrointestinal diseases. Though malnutrition is a serious concern, only a partial solution will be achieved by the SAM program.

Food supply lines are long, and transport is subsidized. Local production of staples would reduce food prices and diminish present vulnerability to transport bottlenecks and changes in energy policy.

Turning to the structure of the urban ecosystem of the Valley of Mexico, one is impressed by the physical plant and the capacities of the control systems of government to marshal and process resources. The water and energy resources available to the city are enormous and growing quickly. By the same token, the developmental philosophy has been to respond readily to whatever demands for these resources are registered by the growing populations, often with substantial subsidies. Losses, particularly of water, are quite high. Partly because of artificial subsidies, the ecosystem has grown to a point where it is far from a long-term steady state. Further, from an ecological standpoint, a number of structural pieces are mismatched, particularly in the water and waste system, meaning that substantial resources are lost to the system because water is not used effectively and because wastes are not exploited. Recycling of water for direct industrial use or for agricultural irrigation, the exploitation of solid and liquid wastes in land reclamation, and intensive food growing may offer advantages in resource conservation.

The habitat or built environment, as local planners recognize, is too thinly used to be efficient. Substantial savings could be effected with higher densities -- as much as twenty percent of all the lots in Mexico City are currently vacant -- and by increasing the building height so settlement would be more compact and all infrastructural facilities more intensively used.

The energy subsidies in the production and transportation sectors have protected and encouraged energy intensity in exports and personal transportation. While these subsidies serve certain social and economic objectives, from an ecological standpoint they have created stresses on the air and watersheds and congestion on streets and highways. Alternative policies which would eventually eliminate energy subsidies would have major ripple effects through the economy.

Finally, the management of growth in the EVOM and elsewhere in the country is the key issue facing planners over the next several decades. Though ambitious plans have been laid to attract growth to cities elsewhere in Mexico, so long as capital investment and subsidies continue, it will be difficult to bring the growth of the EVOM to a halt.

APPENDIX 1

Gross Densities of Selected Metropolises

<u>City</u>	<u>Population</u> <u>(millions)</u>	<u>Area</u> <u>(km²)</u>	<u>Density</u> <u>(1000s/km²)</u>
Hong Kong (1980)	4.8	18	267
Manila (1968)	1.5	35	43
Paris (1974)	2.5	107	25
Tokyo (1973)	8.8	576	15
Mexico City (DF, 1980)	9.4	658	14
Seoul (1980)	8.3	627	13
New York (1970)	7.9	814	8

Source: Thomson, 1978, p. 70, and author's estimates.

APPENDIX 2

Calculations of Tourism

In calculating the energy effects of tourism, I have assumed that each tourist spends about \$30.00 per day and stays about nine to ten days (longer during the winter) (Government of Mexico, 1978b, p. 436). In addition, over 76,000 tourists per month visit the Federal District from within the country, up from 51,000 in 1970. The majority of national tourists come from the Northeast and West (probably meaning Monterrey, Guadalajara, and the Western coast around Acapulco). Table A-2 gives the total for national and international tourists for the years 1970-77 and projections to 1980. Total tourist income will exceed (U.S.) \$200 million in the Federal District alone (fourteen percent of the total income for the services sector). Of the total energy consumed in services 66×10^{15} J (forty percent of the total given in Table III-7), tourism would account for only about 20×10^{15} J. Another large fraction (about 7×10^{15} J) would be consumed for air and ground transportation (assuming a conservative one-to-two-kilometer trip per day per tourist).

Table A-2

Tourists in EVOM, 1980

Visitors per Year

	No. of Visitors (000s)	Average Stay (days)	Average ^a Expenditure (U.S. \$)
<u>National</u>			
1970	618	1.9	10
1977	908	2.8	12
1980 ^b	1,017	3.1	14
<u>International^c</u>			
1976	600	3	24
1978 ^d	1,000	4	28
1980	1,010	5	32
TOTAL Estimated Income for 1980 (000s)			\$205,737

Source: Government of Mexico, 1979, La Poblacion de Mexico.

^aAmounts spent by national (domestic) tourists estimated to be slightly less than the average for foreign travelers arriving by land.

^bAssumes straight-line projections.

^cInternational estimates as per ratio given in Banco de Comercio, 1978.

^dBased on 11 months.

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ABBREVIATIONS AND UNITS

AEMM	American Embassy in Mexico City
CAVM	Comision de Agua del Valle de Mexico (Water Commission for the Valley of Mexico)
CCC	Comision del Centro Conurbado (Commission of the Connurbated Center)
CFE	Comision Federal de Electricidad (Federal Electricity Commission)
CFLC	Comision de Luz y Fuerza del Centro (Power and Light Commission)
DF	Distrito Federal (Federal District)
EVOM	Ecosystem of the Valley of Mexico
IDB	Inter-American Development Bank
IMP	Instituto Mexicano del Petroleo
LAUR	Latin American Urban Research
MAMC	Metropolitan Area of Mexico City
PRI	Partido Revolucionario Institucional (Institutionalized Revolutionary Party)
SAHOP	Secretaria de Asentamientos Humanos y Obras Publicas (Ministry of Human Settlements and Public Works)
SAM	Sistema Mexicano de Alimentacion
SARH	Secretaria de Agricultura y Recursos Hidraulicos (Ministry of Agriculture and Water Resources)
SPP	Secretaria de Programacion y Presupuesto (Ministry of Programming and Budget)
b	Billion
GDP	Gross Domestic Product
J	Joules
kg	Kilograms
lcd(s)	Liters per capita per day (second)
m	Million
mcm/y (d)	Million cubic meters per year (day)