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ENERGY CONSERVATION IN TRANSPORTATION IN PUERTO RICO

A POLICY STUDY

by

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FOREWORD AND SUMMARY

Use and waste of energy in transportation in Puerto Rico is such a massive and complex social event that it is particularly suited for a major exercise in policy research and development for decision making. Such an effort must be collective and should aim at both specific recommendations and time tables, and an improvement of the methodology used to analyze the real systemic nature of important social and resource problems so as to enhance public decision making related to them.

The present study is an initial effort to apply social system analysis to transportation energy conservation, in order to prepare the ground for a team effort of transportation and energy specialists, regional planners, policy analysts and generalists, and government administrators--with additional inputs from commerce, industry and the community at large. The task of this study has been to inventory the principal factors and inputs in the field of transportation energy demand and possible conservation, estimate their magnitudes and relations, and arrange them in a tentative but reasoned pattern--where there were before only so many scattered data, technical studies with a limited focus, sectoral programs and decisions, and vague impressions about the serviceability, the impacts and the social value of the product.

It needs to be also noted that this is a technical study addressed primarily to specialists. This explains the compressed form and style, designed to facilitate rapid scanning and reference. It also explains the extensive use of abbreviations and acronyms. These are listed for reference following this foreword and summary.

The preceding table of contents gives a reasonably detailed idea about the structure of the study and the progression of analysis and application. The data are analyzed in a policy perspective, that is with emphasis on their order of magnitude; their relation to the whole system, and a cost/benefit analysis which expresses the whole energetic, economic and socio-environmental cost of the present transportation system in Puerto Rico, dominated by private motor vehicles used with no concern for energy efficiency.

The principal conclusions are expressed in four policy baselines:

I. Transportation energy consumption is usually expressed only in terms of direct consumption, that is gasoline and oil. Even this account represents upward of 30% of the total energy budget in Puerto Rico in a given year. Great deal of energy is, however, consumed indirectly for transportation purposes: losses in gasoline refinement, distribution, evaporation; manufacture, transport, sale, maintenance, repairs, parking, garaging, administrative and enforcement services to vehicles; construction and maintenance of roads and other infrastructure; and repair of accident damage to persons, vehicles and public property. When the applicable amounts are estimated and totalled, Puerto Rico consumes some additional 20% of indirect transportation energy. As a result, transportation consumes directly or indirectly about one-half of the total yearly energy, that is as much as all the other sectors together: residential and municipal, light and heavy industry, commerce, communications and services. Upward of 80% of the transportation energy is consumed by private automobiles (Figure 3).

II. With adequate maintenance of engines, vehicles and roads, with reduced use and acquisition of convenience power equipment, with reduction of driver demand (short trips, low occupancy, nonessential driving) and with the upgrading of overall driver behavior to the standards of the traffic code and of common sense, all the safe essential mobility of persons in Puerto Rico could be satisfied with as little as 50% of the present total direct transportation energy (Table 1).

III. The private-vehicle transportation system is highly publicly subsidized. That means that the users of automobiles do not pay the full economic cost of gasoline, highway use and parking, and that they are also subsidized on a number of other accounts (section 3.2).

IV. Transportation energy conservation cannot be effectively implemented outside an adequate transportation system management, that is the integration of transportation planning and management with the whole social and resource system. The present lack of such a system management creates adverse impacts on public and environmental health, land use and esthetics that must be assumed to be equal in magnitude to the energy and economic cost of automobile-based transportation.

It is expected that detailed quantification and fine tuning of the underlying model,which this analysis attempts to stimulate and facilitate, will results in some adjustments, but that it will not affect the involved orders of magnitude which determine the longer-term policy options and decisions.

The need for fairly rapid changes in the whole transportation system is imperative. No effective transportation energy conservation is considered possible without them. Technical fixes are not sufficient because the problem of energy conservation is a problem of decisions about energy use. Thus it is primarily a human, social and therefore political problem.

Some directions for more detailed policy research and development are indicated in the last section 4.3, with regard to energy conservation and transportation management, basic guidelines for future policies, near-term energy conservation measures, the possible approaches to the limitation of total energy consumption in transportation, the shift to rail as the dominant mode of essential travel, and a review of the present status and plans for transportation system management in the light of energy, enforcement and future transit requirements. Occasional specific reference is included also in this section to indicate the wealth of information and knowhow available to the decision makers through further policy research and development.

Some defects of the present implementation system are also illustrated (sect. 4.38) with the suggestion that this should be the subject of a whole separate study and analysis. The contemporary revision of the Traffic Code and the forthcoming reorganization of the executive branch represent two opportunities to improve the implementation system.

Education is also mentioned with regard to the study topic, as well as the widespread experience that driver education is ineffective where it is not reinforced by economic and enforcement factors.

ABBREVIATIONS. ACRONYMS. TERMS OF ART

b, bbl	Barrel (42 gallons)
B	Billion
C/B	Cost/benefit [analysis]
CBD	Central business district
Cordonline	Traffic checkpoint at the limit of an area
CPI	Consumer price index
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DTOP	P.R. Department of transportation and public works
EPA	U.S. Environmental Protection Agency
ERDA	U.S. Energy Research and Development Agency (now DOE)
f.e.	Fuel economy
FEA	Federal Energy Agency (now DOE)
FHWA	Federal Highway Administration (part of DOT)
Fleet	Motor vehicle population; total of vehicles which serve a specific purpose
FY	Fiscal year
g, gal.	Gallon
HR	Heavy rail [transit], also referred to as "Metro"
I/M	Inspection/Maintenance
I/O	Input/output [analysis]
K	Thousand
km	Kilometer (.62 mile)
LRT	Light rail transit
M [Mg]	Million [million gallon]
mi.	Mile (1.6 km)
mpg	Miles per gallon
mph	Miles per hour
n.d.	No date
NHTSA	U.S. National Highway Traffic Safety Administration (part of DOT)
O/M	Operation/maintenance [cost]
PDO	Property-damage-only [accident]
Platoon	Group of vehicles travelling together, such as from one traffic light to the next
PMT	Passenger miles travelled
PVTS	Private-vehicle transportation system

<u>Screenline</u>	Traffic checkpoint within an area
<u>SJMA</u>	San Juan Metropolitan Area
<u>TDTE</u>	Total direct transportation energy
<u>TEC</u>	Transportation energy conservation
<u>Transit</u>	Collective transportation of passengers on separate guideways which increase speed, capacity and safety. (So defined, transit does not need any such attributes as "mass" and "rapid").
<u>TSM</u>	Transportation system management
<u>UMTA</u>	U.S. Urban Mass Transit Administration (part of DOT)
<u>VM</u>[<u>T</u>]	Vehicle miles [travelled]

1. INTRODUCTION

1.1 Prefatory remarks

This study was designed and begun in April 1977 as part of the endeavor of the Center for Energy and Environment Research to develop and apply methodologies for the analysis of social factors and interactions related to energy and the environment. The problem of energy conservation in such a massive social event as transportation involves a particularly complex and intensive mix of technical, human and environmental factors and mutual impacts. It is suited as a topic for a policy study on both substantive and methodological grounds. In terms of substance, there is a great need and opportunity to reduce the existing waste of energy in transportation in Puerto Rico. In terms of methodology, any contemporary social policy analysis must ultimately address itself to the presently weakest link in public decision making: the tenuous, undeveloped relation between the real nature of major problems --they are without exception complex systems of resource uses and abuses--and the capacity for applied social system analysis, as a state of mind, as an analytical-technical instrument, and as an operational frame of reference. The topical and highly visible nature of energy uses and abuses in transporation in Puerto Rico provides therefore a concrete and particularly relevant setting for a policy exercise which aims not only at a set of specific recommendations, but also at a contribution to the improvement of policy development and decision making, with reference to priorities and time horizons that correspond to the nature and magnitude of the problems rather than to other, shorter-term considerations.

The working thesis of this study is stated in greater detail in sec. 1.2; the focus and methodology are elaborated in sec. 1.3. Chapters 2 to 4 contain the substance in the following sequence:

Chapter 2 organizes the relevant available data with regard to the structure, operation and energy demand of the present transportation system. The analysis of the aggregate and the disaggregated energy demand is expressed in the first two policy baselines.

Chapter 3 analyzes the system with regard to cost and benefit-- the car owner's, the full economic cost and the full social cost. This C/B analysis yields two additional policy baselines.

Chapter 4 synthesizes and interprets these bases as a starting point for the development of a comprehensive and refined model of transportation energy conservation (TEC) and transportation system management (TSM) and lists some directions, assumptions and recommendations for this task.

The task of gathering and organizing a sufficient empirical data base for policy development was inhibited by the well-known deficiencies in Puerto Rican statistics. Instead of finding all or most of the necessary information in a form suitable for policy analysis, considerable search, comparisons and pocket calculator operations were necessary to develop the data and reconcile them. The general problem was described in a recent report, also in the field of transportation, as follows: "The analytic effort was unnecessarily complicated by the dispersion of the basic data and the incompatibility of the statistical series....considerable but necessary time was spent on the structuring of the problem and the determination of how the compiled data should be [utilized]..." (17, ch.II, IV). But why should the transportation sector have foolproof data on, for example, the number of motor vehicles actually in use, when the health department (with a much longer statistical tradition and experience) was reported to have last counted hospital beds in Puerto Rico in 1952 (146, 3 August 1978)? Or when a federal official provided us with information which sounded dubious, was checked out with a local radio-television station, and turned out to be completely incorrect?

On the other hand , and as distinguished from technical-engineering studies, the importance of data in relation to a social policy study lies less in their serial completeness and decimal-point precision that in providing a sufficient basis for order-of-magnitude estimates and for the detection of trends through longitudinal comparisons. Moreover, some characteristics of the private-vehicle-transportation system in Puerto Rico appears so similar to the PVTS sector in the mailand United States that critical interpolations from there are possible and legitimate. It should not be overlooked,either, that statisticians anywhere will collect and organize information in their way if the users--planners, policy analysts, political and operational decision makers--do not provide them with some other, more appropriate conceptual matrix. Analytical studies should generate the need for new data and for new patterns of organizing them, not merely use the existing information and complain about it.

With the exception of a few references that could be incorporated into the typescript while it was being readied, the general cut-off point for data is May 1978. A spin-off product of this study was an extended policy memorandum on the San Juan Transit: Outline of a policy analysis for decision making, prepared in September and October 1977. Relevant excerpts from this memorandum are incorporated in the present study; the table of contents and a detailed summary can be found in Appendix A.

1.2 Working thesis

If "energy conservation is a national imperative and has become a major factor in transportation decision-making" (U.S. Secretary of Transportation, 17 September 1975), the need and the potential for conservation are even greater in Puerto Rico than in the rest of the United States.

According to a study based on 1972 data, Puerto Rico had one of the highest rates of energy consumption in the world, in terms of both productivity, as measured by gross national product per person, and of intensity, that is the amount of energy used per square mile (55). The development of energy-intensive industries since the 1950s was a partial explanation. But a great deal of energy was wasted due to construction practices, unsuitable designs and standards requiring intensive airconditioning and space lighting, as well as simply wasteful habits of consumers, favored until recently by low basic cost and a regressive rate structure.

Puerto Rico depends on petroleum for over 99% of its energy needs. Internal transportation in Puerto Rico depends almost entirely on gasoline-powered vehicles. They consume directly some 30 per cent of the total energy budget. By contrast, United States relied on petroleum for one-half or less of its energy needs (46 per cent in 1972, the remainder coming from natural gas, coal, hydro- and nuclear power; 134, 9). Transportation used about 25 per cent of the petroleum; this represented in terms of the 1972 data only 11.5% of the total energy, as compared with the 30% direct consumption in Puerto Rico, entirely petroleum-based. According to another calculation (55), the approximately 500 million gallons (Mg) of gasoline used in Puerto Rico in 1972 represented five times the United

States consumption per square mile in the same year. This was approximately the double of the ratio between the Puerto Rican and the United States overall energy consumptions per square mile. In other words, the transportation sector in Puerto Rico used twice as much energy as compared with the overall energy budget than the transportation sector in the United States. This estimate is of the same order of magnitude as that cited above, arrived at from different data and through a different calculation.

Thus there is an ample margin for transportation energy conservation (TEC) in Puerto Rico. In fact, this study concludes that as much as 50 per cent of gasoline can be conserved in transportation in Puerto Rico without any reduction of necessary driving. Apart from the considerable additional benefits this would bring to environmental resources and the human ecosystem as a whole (these are elaborated below, especially in sec. 2.25 and 3.3), there is a clear and urgent energetic and economic need to move rapidly toward effective TEC policies and measures in Puerto Rico. The principal reasons are these:

- The substantial dependence of Puerto Rico on OPEC crude.
- The present situation in transportation energy in the United States--a glut of gasoline at a price which is about one-third of the average in other major Western countries--is partly an accidental aberration (the overproduction in 1977 of home-heating oil, gasoline being in fact a byproduct), and certainly a temporary one. It is also being heavily paid for: the relative decline in the United States economic power and the value of the dollar is ascribed principally to the huge trade deficits which are the result of the imports of OPEC crude--$42 billion (B) in 1977, as compared with $4B in general trade surplus, for a trade deficit of $38B.
- Puerto Rico has no general surplus in its socioeconomic accounts to start with. Yet the 105 million barrels (MBBL) of crude and naphta imported in 1976 cost more than the total amount of the government budget for that year.
- It is generally expected that by the mid-1980s at the latest, the Western world will face again a critical situation in terms of petroleum-derived energy. A less sanguine estimate is that the "oil crunch" is coming "perhaps in 2-3 years" (<u>144</u>, 28 November

1976 and 16 April 1978). A laconic summary of more distant future projections, released in September 1977 by the World Energy Conference, was that "oil supplied will fall short of our needs in 15 to 30 years...if tremendous fields are discovered and unexpectedly double our reserves...that would delay the peak for only perhaps 15 years" (142 [October 1977], 246-50).

- Under these circumstances, the find of petroleum reserves off the north coast of Puerto Rico (the exploration is to start in 1979) would merely postpone difficult fundamental decisions. For a comparison, the Prudhoe Bay field in Alaska, the largest ever discovered in North America, amounts to a 2½-year supply at the present rate of consumption. Even if the drilling in the Atlantic Ocean off the New Jersey coast meets the most optimistic estimates, it will fill total U. S. oil needs for some three months and natural gas demand for five months (148, 1 May 1978).

- Lead times involved in the development and implementation of policies--technical and, especially, social--in a field as complex as transportation energy, are very long. For instance, to make operational a major light rail transit and the supporting transportation management system for metropolitan San Juan would take at least ten years. Of course, another oil embargo, gasoline rationing or rise of the pump price to the real cost level, would do conservation wonders. But it would not by itself produce a substitute energy-efficient transportation system.
- The substantial margin for TEC in Puerto Rico is accompanied by a wide margin for changes and improvements in political decision making related to transportation. The present transportation system is in part the result of cheap energy--gasoline. The range of 70-76¢/gal. in mid-1978 may represent as little as thirty-five per cent of the real cost. The low price results from the inclusion of Puerto Rico in the United States system of averaging the price of domestic and imported crude. But the transportation system primarily reflects a sequence of government policies and non-policies--politically motivated choices, yielding to special interests, eternal studying of alternative transportation modes without taking any effective action, overdependence of local planning on the availability of federal funds, and other factors. Above all, however, past policies in transportation in Puerto

Rico were characterized by the failure to perceive and plan a coherent system as a function of the whole society, economy and environment. It is true that the energy cost and fragility of transportation based on gasoline and other petroleum products could not be noted widely enough before the 1973 price increase to influence public decision making. Even such well-known unfavorable impacts of this kind of transportation as exorbitant fatality risk (using fixed rail as a base = 1, the fatality risk factor for commercial airliners is about 1.5, for private automobiles about 50)* and urban air pollution (up to 80 per cent of CO is generated by motor vehicles) were largely ignored as decisional factors.

- It is assumed that strategic decisions with regard to TEC, as well as their concrete implementation, will be facilitated if the analysis and the resulting recommendations are set in a comprehensive framework of all relevant energy, technological, social, economic, administrative, regulatory and political/decisional data.
- A major obstacle to effective TEC is also the widespread public ignorance about the nature and scope of the energy problem, combined with a consumption-oriented value system. In the United States, the first factor was confirmed by a poll taken one year after President Carter's nationally televised energy message (April 1977): 40 per cent of the sample did not even know that the U.S. depended on foreign oil to help to meet its energy needs (148, 1 May 1978). As to the consumption syndrome, U.S. motorists ignoring official pleas burned in June through August 1977 a record 31.5Bg of gasoline (144, 2 October 1977), almost 3 per cent above the 1976 level--and despite the greater fuel efficiency of the new cars in the fleet. There is no ground for assuming that public awareness in Puerto Rico is higher. Information and education are therefore critical ingredients of any TEC program which does not rely entirely on rationing and taxing. The conception and implementation of such public education can be only enhanced by perceiving the problem in the broad frame of reference outlined above.

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* (37, 27).

1.3 Focus and method

The nature, method and some limitations of a policy study of TEC in Puerto Rico need to be briefly discussed.

First, and by definition, only factors that can influence TEC policy development and decision making in Puerto Rico are analyzed here. Since no automotive research and development, nor production, take place in Puerto Rico, data on the improvement of fuel efficiency through better engine design or the development of alternative power plants (13, 56, etc.), or other technical information of this kind, is of course interesting, but is secondary to other TEC elements and consideration, also in view of the present and the prospective age compositions of the motor vehicle fleet on the island.

Second, the use of the term policy is far from uniform. The meanings range from goal or norm (speed reduction) to an operational or technical improvement (increased vehicle efficiency; 97, 31-2). Even a widely officially used terminology--"science and technology policy"--is at best ambiguous: policy for the enhacement of science and technology? Policy, in the development of which science and technology data represented inputs? The latter meaning would be closer to, although only in part concurrent with, the general technical sense of policy as a discrete, comprehensive analytical base for decision making.

This technical meaning is not of a recent vintage. With specific reference to environment and resources, it served as a focus for the ecomanagement conception (52 [1967], 110-44). The principal methodological characteristics of policy research and development in this context were confirmed in the comparative evaluation of 18 regional environmental system management projects sponsored by the U.S. National Science Foundation (137 [1977], iii-iv)--most of them originally designed along econometric lines, that is as quantification and computer processing exercises.

Policy research and development require both more and less. On the one hand, decision making can not wait for mathematical models. It must take place with the data available: numerical data as far as possible, but also incomplete, uncertain, fuzzy data, interpolated and projected as well as the numbers permit; concepts; values; intuition. In the present state of the art, policy development in any real social situation must proceed predominantly on basis of qualitative rather than quantified information. On the other hand, the essence of policy research and development which is the transformation of all the relevant data into reasoned policy options ("decisional vectors") does not require the precision of electronically processed mathematical models. Social decision making, including the most serious and complex problems on the interface man/ resources, will always be intuitive--short of a community of completely programmed robots. The point is to replace raw political intuition by educated intuitive decision making. Therefore, the need is to put together all essential information on the level of order-of-magnitude data or educated estimates, rather than only some information with a decimal-point precision. The practical goal is to approximate without distorting. Where empirical data are missing, "sound technical judgment" helps to complement them (127).

Third, this kind of policy development differs at first sight from the conventional "policy making." Every decision, public or private, executive, legislative or judicial, implements a policy in the sense that it has some purpose in mind. But this policy making or application does not usually follow the organic path from the facts, through their analysis/synthesis, to the acceptance of the most favorable or justified option. "Policy making" has been often an ex post rationalization of a prior decision arrived at on a less complete and rational basis. At other times, such as in the case of many environmental impact statements, the data were amassed, but not adequately analyzed and transformed into alternative options which would merit the technical designation of policies.

Fourth, proper policy research and development is, at least at this stage, more likely to raise questions than to give answers. Gaps in the data may be pointed out to the information generators. Competent policy analysts are likely to be generalists, synthesizers, or at least look across disciplinary lines from the vantage point of their own different background. They may question the way in which information was put together--or even stacked up--by the technical planners. They may suggest other ways of looking toward a solution. They are likely to become "spoilers," especially when planning has gone forward on less than all the important considerations-- particularly social and environmental benefits and costs--long enough to have created its own momentum. This is why the policy dimension should be an integral part of project design from the beginning. Otherwise it is likely that the technical positions and political opinions derived from them will harden before they can be evaluated in a comprehensive policy perspective, with a possibility that better technoeconomic concepts may be developed. (For the exemplary case of the San Juan "Metro" see Appendix A). Even in the exceptional case where the ex post policy analysis prevails, the wastage of time and resources can not be repaired.

Fifth, extensive search in materials produced in North America, in Europe and by international organizations, indicates that the kind of policy research and development outlined above has not been so far applied anywhere in the field of transportation in general or TEC in particular. This study must be therefore judged as a tentative effort which had no existing design to follow. While it makes concrete recommendations where they appear possible, its primary purpose is to establish a first conceptual model which would help the technical analysts and sectoral decision makers in the fields of energy and transportation in Puerto Rico to mutually relate their data and perspectives and to integrate them into a progressively complete and sophisticated operational and predictive model. With such a model available, no separate policy studies will be necessary. The system will function in an environment of direct input from, and communication to and among all the participants--data producers, project designers and planners, policy analysts, decision makers, citizens and users, resource managers, monitoring/feedback systems--facilitated by a common conceptual language and policy principles. System analysis applied to social resource management becomes a state of mind.

2. DATA BASE

2.1 Present transportation system: Structure and operation

2.11 Vehicle population.

In mid-1977, there were 830,373 active motor vehicles of all classes in Puerto Rico. This figure is based on registration licences renewed by 31 June 1977 and on the number of vehicles registered for the first time during FY1977 (fiscal year 1976-77). The Motor Vehicles Bureau makes also other estimates. For instance, vehicle licences which were not renewed are still counted for another FY and renewal notice is sent out. Only when the license is not renewed for two consecutive years, is the vehicle dropped from the "active" computer program. On this basis, there were over 1 M (million) vehicles in Puerto Rico in 1977, of which over 290 K (thousand) were "not renewed." However, this calculation, with the addition of new registrations does not add up to 830,373. Nor does the registered:active vehicle ratio .778, based on a 1971 study (cited in 17, 48) appear correct in 1977. Accepting the figure of 1 M "registered" vehicles, the real ratio would be closer to .825. Similar estimates of vehicle population in the United States appear equally unreliable as compared with a count as of a certain date (132, supp.S3-12), the difference being as much as -12,8% in 1975.

The point is not to dwell on statistical vagaries, but to draw the attention to uncertainty about the rate of scrappage and other factors that are essential if one aims at projections with a tolerable margin of error. In fact, past projections concerning motor vehicle transportation in Puerto Rico have generally not been within this margin--whether they erred on the side of over- or underestimation. It is, however, not impossible to reconcile the figures and methodologies in short term projections. Thus, taking the 1977 figure of 830K, adding the new registrations for the first eight months of FY 1978 and projecting them for the whole year, and utilizing the accepted 8% scrappage rate based on United States data, we arrive at an estimate of 870K active motor vehicles as of 31 June 1978. This is within less than 1% margin of the gross estimate of the Motor Vehicle Bureau that 875K or more registrations will be "renewed", if this is understood--as it must be--as the total number of active vehicles. But if this estimate is based on the total of 950K renewal notices sent out (146, 7 May 1978) and the reasonably probable projection of some 110K new registrations in FY 1977, the cumulative total of all registered cars (as explained above) would amount to 1,060K, not the bureau's figure of 1,005K.

The total motor vehicle population increased from 248K in 1965 to 774K in 1975, that is more than three times. The yearly growth was as much as 70K vehicles (15.2%), in FY 1971. By FY 1976 it was down to 50K vehicles (7.1% increase over previous year). The 1977 figure is less than 2%, but the 1978 estimate above is over 5%. Even considering the uncertainty implicit in this variable (in the San Juan Metropolitan Area, the increase in motor vehicles has varied by as much as a factor of 10 over a five year period 1968-69 to 1972-73, and as much as a factor of 7 from one year to another), it appears unlikely that the projection of the Planning Board and the Department of Transportation and Public Works for a mean vehicle population of 1.1M in 1980 (cited in 17, 48, based on 1970-75 data and U.S. national transportation studies) is correct. See (72, 35).

The person-vehicle rate in Puerto Rico increased from 10 in 1965, to 4 in 1975 and 3.7 in 1977. This was below the U.S. figure of 2. However, the vehicle density in Puerto Rico is much higher. In San Juan, with 40% of households not owning a car, the density was in 1974 about 2335 vehicles/ km^2 (6050 veh./sq.mile), almost 50% more than the highest urban density in the mainland United States. The overall density in Puerto Rico was 6.3 times higher than in the U.S. (30, 103). These figures have increased since then. The absolute figure for San Juan was 401K vehicles in 1977, that is slightly under one-half of all vehicles in Puerto Rico.

Of the 830K motor vehicles, 660K are classified as private cars. But if one adds the other sedans and minibuses (taxis, "públicos," government vehicles) and most of the 92K so-called pick-ups (classified as "camionetas privadas," private minitrucks popular because of the reduced 10% import tax but mostly used for personal transporation), the total of motor vehicles other than commercial trucks, trailers and motorcycles (less than 7 K) is between 750 and 775K. This would amount to 92-94% of vehicles used for personal transportation (the number of buses in Puerto Rico is statistically insignificant) and correllate with earlier data based on a different classification, which indicated that the growth of private automobile in Puerto Rico was much faster than that of commercial vehicles (64). In contrast, in the mainland United States personal vehicles represented only about 80% of the total (116, 9).

2.12 Structure and state of the fleet

In addition to absolute numbers, of particular interest to transportation energy conservation (TEC) is the composition of the personal vehicle fleet by weight and horse-power (HP), and the ratio of imported used cars. These figures are, in fact, interrelated in the sense that most used cars imported in Puerto Rico are heavy.

In 1977, about 55% of personal vehicles were in the "standard" category (3000-4000 lbs); 34% were light (2000-2500 lbs), and 10,5% were heavy. If, however, the heavy category is defined as vehicles 4000 lbs or more, there were more than 225K of such vehicles (31%). The "medium-heavy" category (3500 and 4000 lbs vehicles) comprized over 45% of the total.

About 22.5% of the cars imported in 1977 were used. The great majority were 3500 lbs or more and had engines of 130HP or more. In the 191HP-or-more bracket, 8 new and 182 used cars were imported in the last quarter of 1977. In the 110HP/<2300lbs bracket, 8515 new cars were imported, against only 387 used ones. These new, fuel-efficient cars represented about 10% of the whole fleet at that time.

Another measure of the state of the fleet from the standpoint of TEC are vehicle inspection statistics. The state-level inspection program which consists of an apparently superficial check on mechanical-safety equipment, resulted in 1976 in a reject rate of 30%. A high percentage of vehicles, 13%, were not inspected. It is impossible to estimate how many of these vehicles were in fact active at the time of the inspection which is spread over the twelve months of each year; but it is likely that many of the non-inspected active vehicles would have been rejected. A federally funded I/M (inspection-maintenance) project in Puerto Rico, which also checked emissions--an important indicator of the fuel efficiency of the vehicle--had a reject rate of 90%. And at that rate the project was criticized as using too lax criteria (30, 56).

2.13 Transportation network

Internal transportation in Puerto Rico depends entirely on roads. Railroads were eliminated in the mid-1950s. Transportation on water is de minimis--a commuter-ferry line in San Juan harbor. The development of the road infrastructure responded to numerical growth of vehicles, but also to such factors as the Fomento policy of decentralized industrial development and the advent of containerized cargo shipping, most of which enters Puerto Rico through San Juan. The highway network grew by about 20% from 1965 to 1975, to a total of almost 9,000 km; the surfacing improved from 79% paved in 1965 to 85% in 1975. New construction in 1969-73 cost almost $550M (almost $1,000M in 1978 dollars). Most of these funds were provided by the federal government. The Expresso Las Américas (P.R. 52), paid for largely by bond issues, cost $291M to construct. With financing costs of $396M over thirty years, and undetermined cost of maintenance, it represents a commitment of funds on the order of two-thirds of the contemporary state government budget, for a highway some 91km/60mi long. The expected net revenue in FY 1976 was on the order of $4M. The effects of the structure and state of the highway system on TEC, and the planning perspective will be discussed below.

2.14 Traffic intensity and vehicles.

From the standpoint of policy analysis, absolute numerical data about traffic intensity are of interest only in terms of possible controls on further growth and of measures to enhance the individual and aggregated fuel efficiency. The feasible controls and measures are discussed below. So interconnected are the components of the transportation/energy system that measures which foment fuel-efficient cars also tend to reduce traffic congestion, that is too high traffic intensity. This is so because fuel-efficient cars are generally smaller. Thus they take less highway space; this tends to reduce the severity of congestion--not to speak of the fuel wastage and impact on air quality which traffic jams cause.

The capacity of the highway system in and around metropolitan areas in Puerto Rico to handle the traffic requirements is fair to poor not only in the experience of individual motorists, but also in the judgment of transportation administrators and experts. A scale developed by the Highway Research Board (U.S. National Academy of Science, 1965) rates service on five levels, from A (light, sporadic traffic) to F (bumper-to-bumper traffic with intermittent stoppages). Level C is "normal" traffic, that is the planned flow in terms of numbers and speed. On this scale, "Las Américas" was expected to have in 1977 still only B/C service level in its 8-lane metropolitan segment; instead, it operated generally between C and D and, at some times, even between D and F. Barbosa Avenue, a 6-lane access corridor to the Hato Rey central district, operated during substantial portions of working days on D and F levels. This and other similar experience in Puerto Rico duplicated the experience in the United States a decade earlier: the Long Island Expressway in New York, planned for peak traffic of 80,000 cars/day in 1970, was jammed by 140,000 cars/day in 1966. Similarly in Europe, for example a major exit corridor from Paris, the l'Autoroute de l'Ouest, was so saturated in 1968 that a routine accident on the outskirts of the city could cause a traffic jam extending 10 km into the center. The First Law of Motodynamics--"If left alone, automobiles always multiply faster than highways [and parking lots] can be built"--operated everywhere, including Puerto Rico where it was originally proposed (52, 66, 199, 209).

The rush hour intensity in metropolitan San Juan could be also illustrated by screen-line measurements in the four major boroughs. Of the 24-hour total, 8-9% of traffic moved between 0700 and 0800 h.; 7-8% between 1600 and 1700, the following hour being only slightly lower. Thus almost one-quarter of the 24-hour volume moved in fact in three hours. The same 1976 cordon-line (at the limits of the metropolitan area) and screen-line (at selected points within the city) figures indicated relatively low occupancy rates. In Río Piedras, on a total of 415K vehicles/ week, the private vehicles occupancy was 1.57; all vehicles (including públicos and buses) had occupancy rate of 1.78. For Santurce, the figures were: 400K vehicles, occupancy 1.54/1.56; Bayamón: 184K vehicles, 1.63/ 1.8; Old San Juan: 85K vehicles, 1.62/2.15. The average was 1.63 for all vehicles at all screen-line points. The cordon-line traffic, in- and outbound, averaged 1.73 at the two busiest points, with a total 24-hour flow of 57K private vehicles. The total traffic at these points was 372K, with an occupancy rate 1.94. This reflected probably largely the "público" traffic with often 5-6 passengers per car during the 12 day-hours.

The commuter load factor in the United States, comparable with the cordon-line figures above, was 1.6 in 1975 (134, 37). But it was as little as 1.2 in Nassau County, Long Island (55) and in California (13, 80). By

1978, the Nassau County rate rose to 1.4; a crisis such as gasoline rationing during the second world war raised the California rate only to 1.7.

Occupancy rate of 1.2 means that seven out of ten cars carry only the driver--_if_ two of the ten carry two persons and one three persons. Empirical observation of the 0800 traffic on Barbosa Avenue indicates an even higher proportion of passengerless cars, despite the higher screen-line average for Río Piedras. Such a level of use of cars and highways is not only exorbitant energywise (an average of 150HP or more to move one person at an average speed of under 10mph), but also in terms of land use. To take the two examples above, 17% of land in Nassau County is occupied by highways and parking lots; the figure for Los Angeles is close to 40%. The figure for San Juan is not available but is probably comparable.*

This impact of the present transportation system will be further developed, together with other items, in the section on secondary, indirect transportation energy demand.

2.15 Trip purpose

The cordon- and screen-line figures cited above indicate also that the great majority of private vehicle trips take place in the San Juan Metropolitan Area (SJMA). This share, and the corresponding travel intensity in the SJMA, is substantially higher than that corresponding to the 51.5% of the island's passenger vehicles registered in San Juan. Trips in private cars grew in the SJMA from 64% of the daily total of 1.53M in 1970 (72, Table III-10) to 82% in 1976 (_Id._, ch.III) or 78% in 1977 (146, 4 April 1978). Neither figure was unusual for a metropolitan area with insignificant collective transportation and relatively cheap (in fact, subsidized; see sec. 2.6) private vehicle transportation system (PVTS). To make a geographically distant and culturally different comparison, 87% of all urban trips in Australia were by private vehicle in the early 1970s (93, 261).

* The 1970 figure for street surface in the SJMA, about 8.5% (71, 15) does not provide a base for a reliable estimate. Not only is it out of date, but it does not include parking; moreover, the cordon line encompasses not only SJMA, but a "San Juan Subregion," with 30% undeveloped land. Estimates of street surface in urbanizations within the SJMA range from 25% to 40%. A "guestimate" based on such factors as the 70% growth in street surface between 1964 and 1970, the undeveloped land and the rate of development (almost 20% from 1964 to 1970), the construction or termination of several urban expressways (estimated land use is more than 30 acres of land per 1 km) and 1% for offstreet parking space (including the big new shopping centers), sums up to almost 25%.

An urban PVTS has two characteristics that are important from the standpoint of energy conservation:

a) Urban trips are relatively short. It was estimated that in 1965 auto trips 4 km/2.5mi or shorter represented 60% of all urban trips in terms of fuel consumption. Some ten years later, trips shorter than 8 km /5mi. accounted for 15% of all auto mileage in the United States; they consumed over 30% of all auto fuel (86, 10; 132, S3-33). This was over 50% more fuel than that consumed by all auto trips 60km/40mi or longer. Precise data are again lacking, but empirical observation indicates that the situation in urban areas in Puerto Rico is similar. A particularly dramatic, but apparently not untypical, example is provided by the traffic between the faculty residences and the principal campus of the University of Puerto Rico: many S-shaped trips of more than 1 km are made daily to the overtaxed parking lots inside the campus; direct walking distance, with no parking problems, is one-half as long. This example also illustrates the second characteristic of urban PVTS:

b) High percentage of urban trips are non-essential. Transportation studies typically classify trips in the following categories:

(i) Home to work
(ii) Home to school
(iii) Home to shop/personal business
(iv) Home to social/recreation
(v) Nonhome based trips

The division between essential and nonessential trips is not uniform. It is probably fairly close to reality to draw the line as follows:

Essential are groups (i), (ii), 50% of (iii) and 50% of (v).

Nonessential are group (iv) and 50% of (iii) and (v). The 50% guess for groups (iii) and (v)--nothing better is available in the literature--can be justified, among other, by such data as these:

- Car ownership tends to generate trips and not to consolidate two or more purposes or destinations into one trip. For example, before traffic restraints were instituted in the Singapore CBD in 1975, vehicle-owning households generated 40% more trips/day than households which had to use other mode than private car (60, 179).
- The Los Angeles Regional Transportation Study (1967) identified 22% of trips as other than home-to-work/school/shop (11, 87), with the implication that these were non-essential shopping and driving-around trips.
- "Family business" trips other than shopping and medical/dental visits were estimated at over 14% of all trips in the United States in 1972 (63, 2-23).

- Although the non-home-based group tends to be a catchall, it obviously includes a substantial portion of social/recreational trips.

If the formula for the calculation of nonessential trips, as suggested above, is applied to SJMA data, 35.5% of the 1.9M daily person trips (1970 estimate; 71, 21) and over 40% of the 3M daily person trips projected for 1990 (72, Table III-10) are nonessential. Despite its highly empirical nature, the estimate is probably rather accurate. It certainly compares with the 1972 federal study cited above (63, citing 109) which arrived at the figure of 36.7% nonessential person trips using a somewhat different method and inputs. (Incidentally, the state of the art can be illustrated by the fact that only a 1970 estimate was available for an update study made in 1975; the second study made in 1976, corrected the trip total from the estimated 1.9M to a "real" 1.53M, but then went on to make probably another exaggerated projection for 1990. In this projection the number of "other", mostly nonessential trips, is increased by a factor of almost 3.1 between 1964 and 1990. These uncertainties about the absolute numbers of trips do not affect the estimated percentages of nonessential trips.)

2.16 Collective transportation. As used here, the term collective transportation means transportation of passengers who pay for their seat (buses, "públicos") rather than for the vehicle and the driver (taxi), and who are not moved on a separate guideway which increases speed, capacity and safety. The latter type of collective transportation is currently referred to as transit--and if so defined, does not need any attributes such as "mass" or "rapid."

Under these terms, a system such as the AMA (San Juan metropolitan bus authority) does not qualify as transit. Even where these buses move in separate counterlanes, their average speed is 7mph (1977). According to AMA's own figures (146, 16 Feb. 1978), the mileage/year has remained unchanged since 1973, at 13,5M mi/ 21,7Mkm; the number of passengers decreased from 45M to 34.7M (in 1966, the total was 66M); the average passenger cost was 40¢ in 1973, 63¢ in 1977 (the fare remained constant at 10¢--25¢ in airconditioned buses--on the ground that some 95% of bus users had incomes below $8,000/year/family); consequently, AMA had a deficit of $9.5M in 1973, which grew to $14.2M in 1977. Additional data round out the description of the SJMA bus system:

- The system consisted of 52 routes approximately 850mi/1360km long (1975).

• It had in the same year 390 buses, of which only 290 were in service on a typical day. The rest was immobilized by mechanical defects or absenteeism of personnel.

• The ratio of passenger trips per bus mile, steadily decreasing since 1960, was 3.3 in 1973, and 2.6 in 1977. That means that buses for 50 seated passengers carried on the average only 2.6 persons. (The data for the total mileage/year, 13.5M mi, differ from data provided by the AMA's accounting office to the Office of Energy--11.7M mi for 1977, a steady decrease from the maximum mileage of 13.9M mi in 1974. The lower bus-mile figure still yields a ratio of only 2.95.) Contrary to these figures, based on the simple division of the official figures for bus mileage and number of passengers per year, the P.R. Highway Authority estimated the passenger average at 12 persons/bus in 1972. This figure is 3.5 times higher than the actual ratio for that year (3.45) and the Office of Energy correctly considers it dubious (78b, 2). If the real ratio or load factor were used to calculate the energy consumption per passenger, it would be substantially higher than the estimated 2,792 BTU based on the 12 passenger/4mpg base (78a, 3). *

• The energy efficiency of the buses, which averaged 5.3mpg from 1970 to 1974, suddenly dropped to 3.95mpg in 1975 and averaged 3.98mpg between 1975 and 1977, a drop of 25%. There is no indication in the available sources as to how much of this drop could be assigned to the higher fuel consumption of new airconditioned buses. However, the sudden jump of average cost per passenger from 49¢ in 1976 to 63¢ in 1977 can not be explained in terms of wages or fuel cost. These new buses still operated on the 25¢ fare basis. The loss was 38¢ per passanger trip.

• The velocity of express buses in the "exclusive" counterlane some 13mi/21km long was 12mph in 1974; it dropped to below 10mph in 1977 and, if standard U.S. calculation method was used, the average speed of the whole AMA system was about equal to the speed of the express buses, only 7.2mph. This was, according to AMA technicians, not too different from the average speed in congested U.S. cities; in low-density-traffic cities the average bus speed was 12-14mph.

• The service did not operate on any reliable schedule. The headway between buses (that is the time elapsed between the departure of one bus and the arrival of another on the same route) was as much as 23 minutes

* The load factor of 12, used by the Planning Board in the 1974 National Transportation Study, is so far off probably because it is based on average weekday occupancy (1972), without distinction of the length of the trip. For comparison, U.S. data(1970) were: 10 pass./veh.for urban buses; 2940 BTU per passenger at 4.4mpg (120, 5 [Fraize et al.,1974]).

during working day hours.

Private buses served SJMA principally between Bayamón and Río Piedras, providing the only bus connection between these two major boroughs and the Medical Center; and between Bayamón and Santurce. The ridership, estimated in 1964 at 45K/passengers/year, dropped to some 10K by mid-1970s. Private lines also operated between San Juan and various points on the island. Their share in the total transportation was insignificant. The service could be illustrated by the length of the San Juan-Mayagüez trip--5 hours, compared with 3 hours for a "público" and under 2 hours for private car.

The decrease in bus ridership (omitting the small fractions for private buses) from the 66M peak in 1966 to the 35M in 1977 was 47%--rather comparable to the estimated overall drop in ridership in the U.S. 1955-71, which was 52.5% (123, 125). But if such an obvious variable as the population increase in the SJMA is taken into account--it went from 542K in 1960 to 820K in 1970 (51.5%) and the growth rate in the 1970s was projected at some 20% (72, Tables II-3, II-4)--the real drop in the AMA ridership was perhaps as much as 65%, and continuing. Meanwhile in Nassau County, Long Island, an area comparable physically, if not also socio-economically, the trend was reversed in the early 1970s and the bus ridership grew by 27% (from 55 to 70K/day, for a total of more than 20M/year; 50% revenues came from passenger fare; the 1977 operating deficit was still $9.6M; 55, 17).

"Públicos" represented the relatively most efficient component of the collective transportation in Puerto Rico, in fact, the only one in the rural areas and in much of the SJMA. They totaled almost 10,000, of which about 2,800 were privately owned (PD licence). The rest was owned largely by cooperatives. About 2,000 públicos operated in the SJMA and some 800 operated on routes in and out of the SJMA. Públicos totaled over 150K person trips on an average weekday. Outside of the 0600 to 1800 period, there was little if any service. Despite law and regulation, the system operated on the base of semi-fixed routes, without fixed schedule (except on some long interurban routes by reservation), and on the principle that the vehicle departs only when it is full. However, during the busy hours, the waiting time at terminals or along the route rarely exceeded 10-15 minutes. The system was self-supporting on a fare basis comparable with that of the airconditioned AMA buses in the SJMA. The constant "problems" with the so-called "phantoms" --unlicensed públicos competing with the buses--indicate that at that rate the públicos made a reasonable profit. They also rendered important public services during strikes at the labor-problems-plagued AMA. Contrary to the decrease of AMA ridership, the público ridership increased between 1964 and 1976 by 29% in SJMA, and by 18% on the island as a whole. (The net ridership on the island decreased slightly during this period, from 40K to 38K passengers/day.)

It would not be correct to say that the público system was unique to Puerto Rico. For example, Caracas had a very efficient system of "por puesto" (paying for the seat) taxis already in the 1950s. But as a flexible system of regulated private enterprise--with substantial margins for improvement to make it even more attractive and useful--it was one of the cornerstones of future energy-efficient transportation planning.

If this evaluation implied a contrast to the bureaucratic, tax-supported and inefficient bus system, apparently incapable of reform except by way of a complete overhaul, a supportive comment about public collective transportation was made in connection with the tiniest component, the San Juan-Cataño ferry. Operated by the Ports Authority, it spent $1 to transport one passenger paying 10¢ for the crossing. The daily total was some 6,200 passengers, practically unchanged from 1964 to 1975. Although the U.S. UMTA made a grant to the government of Puerto Rico to upgrade the ferry system, "expectations are that service will continue at about the same level " (72, 57,83). The rate structure of the ferry system, which required an untolerably high subsidy of some 90%, was possibly based on a wrong reading of the AMA statistics. It is true that the drastic reduction in AMA ridership occured since 1969 (64K passengers to 47K in 1972); but during these years, private car ownership rose from 280K vehicles to 340K in the SJMA, without doubt more in response to deliberate government policies than to the fare raise. For the fare rose only to a double (if inflation is taken into account); buses with the original 10¢ fare remained in service; and the increase in vehicle ridership still left some 43% families in the SJMA without car, that is dependent on the public transportation. At 1.5 occupancy rate, the 60K additional private vehicles accounted for 22.5M passenger trips/year, counting working days only. Crash highway building program and reduction in vehicle import and registration fees facilitated this switch from public to private transportation.

To round out the account of collective transportation, mention must be made of the fact that undetermined but substantial number of home to school trips in the SJMA is made by school buses. On the island, estimated 156,000 students were going to be transported every day in 35 municipalities in the school year 1977-78, at a cost of over $9M. No data on total mileage or fuel consumption were available.

2.17 Transportation of freight.

A controlling survey of cargo transportation in Puerto Rico was made in 1976 (17). Although the perspective of this study is regulatory (and in this sense it complements and updates a 1969 study, 29), many data there are relevant to TEC analysis, specifically the proportionate energy consumption of cargo vehicles and the mutual impacts of personal and cargo transportation, with apparent effects also on fuel economy.

From the standpoint of TEC policy analysis, these were the main salient characteristics of the cargo transportation system:

- Of the total cargo which passed through Puerto Rican maritime ports (and that was 99.6% of the grand total, the remaining .4% being air freight), 26MT or 73% consisted of crude and petroleum products, the latter mostly exported. This cargo was moved mostly by pipeline. Of the about 10MT dry cargo, more than 90% entered and left through San Juan, less than 5% through Ponce and about 2.5% through Mayagüez. The San Juan maritime traffic consisted of 439K lift- or roll on/off vans in 1975; the majority were delivered in the SJMA, but a substantial minority went to various points on the whole island.
- If cargo vehicles were classified as light (pick ups, panels, light trucks, all 4-wheel types) and heavy (2-axle-6-wheels truck and multi-axle trucks and combinations), then there were 20.4K heavy trucks (2.6 %) in the 1975 active vehicle population of 775K. For the purpose of traffic intensity calculations, an average (heavy) truck was estimated to take the space of two standard personal vehicles. (The estimate of 20.4K active truck out of 22.9K registered would indicate 11% scrappage rate, as compared with the 8% generally assumed for the fleet as a whole.)
- Of the estimated 1975 total of 7.44BVM (vehicle miles), 820MVM (11%) were assigned to freight. No estimate was available to indicate the ratio between VM traveled within SJMA and those on the island and thus to allow informed speculation about the relative impact of trucks on highway use and the resulting energy account. But, considering the size

of the SJMA relative to that of the island, a major portion of the VM must have been driven outside the SJMA.

• Much more detailed and reliable data would have to be available to afford drawing any inference as to direct fuel consumption based on the information in the preceding item. Data for passenger cars (3500 lbs) and dump-trucks (15-16,000 lbs) indicate that fuel consumption is comparable at constant speeds of 10mph and 50mph (15, 17, Fig. 1). Data for policy development would have to analyze the impact of urban congestion, caused by passenger cars, on truck movement and fuel consumption; and the impact of trucks negotiating gradients at 15-25mph on 50mph-limit two-lane highways, holding up a platoon of passenger vehicles behind them.

• The maximum intensity of truck entry into the SJMA was measured between 0900 and 1000 h.; in Ponce between 0800 and 0900. Of a maximum out-of-city traffic on a four-lane highway between San Juan and Caguas (4238 vehicles in both direction, between 1600 and 1700), 8.1% were heavy trucks.

• Of probable relevance to TEC analysis is the general conclusion of a 1974 study by the regulatory agency, the P.R. Public Service Commission (64) on the low efficiency of terrestrial freight transportation in Puerto Rico. The focus of the study was the rate structure. But conclusions on relative efficiency of light v. heavy trucks and on the high proportion of LTL (less-than-truckload) traffic must be taken into account in any fuel consumption analysis.

2.18 The human element.

It does not need to be particularly stressed that people are an important element of any transportation system. With respect to TEC, the human element looks like the key. The reference is not so much to technological development, but to the assumption that on any level of transportation technology the relative energy account is ultimately determined by the demand for private vehicle transportation as against other practical modes, from walking to transit; by the use of cars (intensity of driving, driver behavior, education and discipline, and diligence/negligence in vehicle maintenance); and by social controls (policy and planning based on the real systemic nature of the transportation/energy complex; political intelligence and will; rules and enforcement).

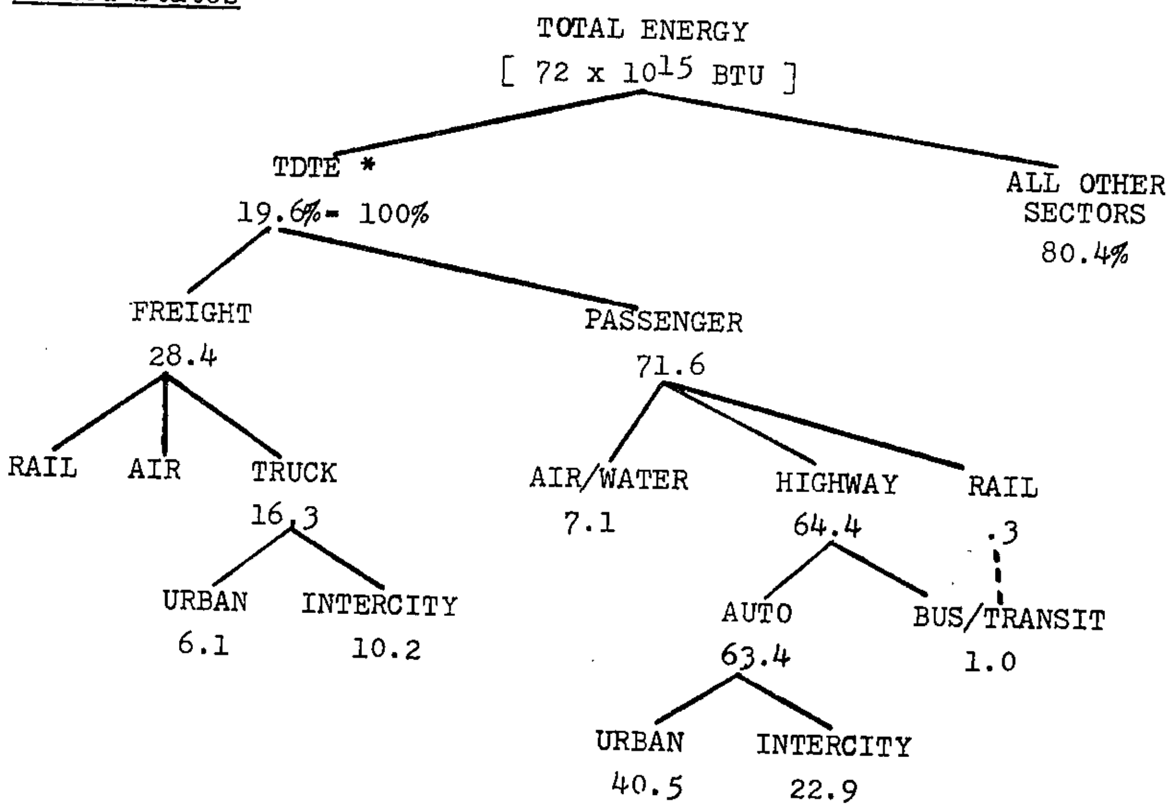
The human element is here listed only for the sake of completeness. More detailed analysis and recommendations are developed farther in the study.

2.2 Energy demand I: Macronalysis

The following Figure 1 shows the disaggregation of total demand and transportation consumption in the United States (105, 14; 112):

Figure 1

United States



Another calculation of the TDTE for the United States is 25.3% (63). This estimate is possibly more realistic, especially because of the steady growth in private auto consumption since 1974. Both numbers represent, however, only the direct portion of the total transportation energy, that is fuel, oil and electricity used for propulsion and lubrication. Transportation requires also a substantial indirect energy input (see 2.22 below). The estimates vary from about 50% to 66.5% (63, 5-6). Again, the latter calculation is considered closer to reality. The total transportation energy use is then: TDTE 19.6/25.3% x 1.5/1.66 = approx. 30/42.5% of

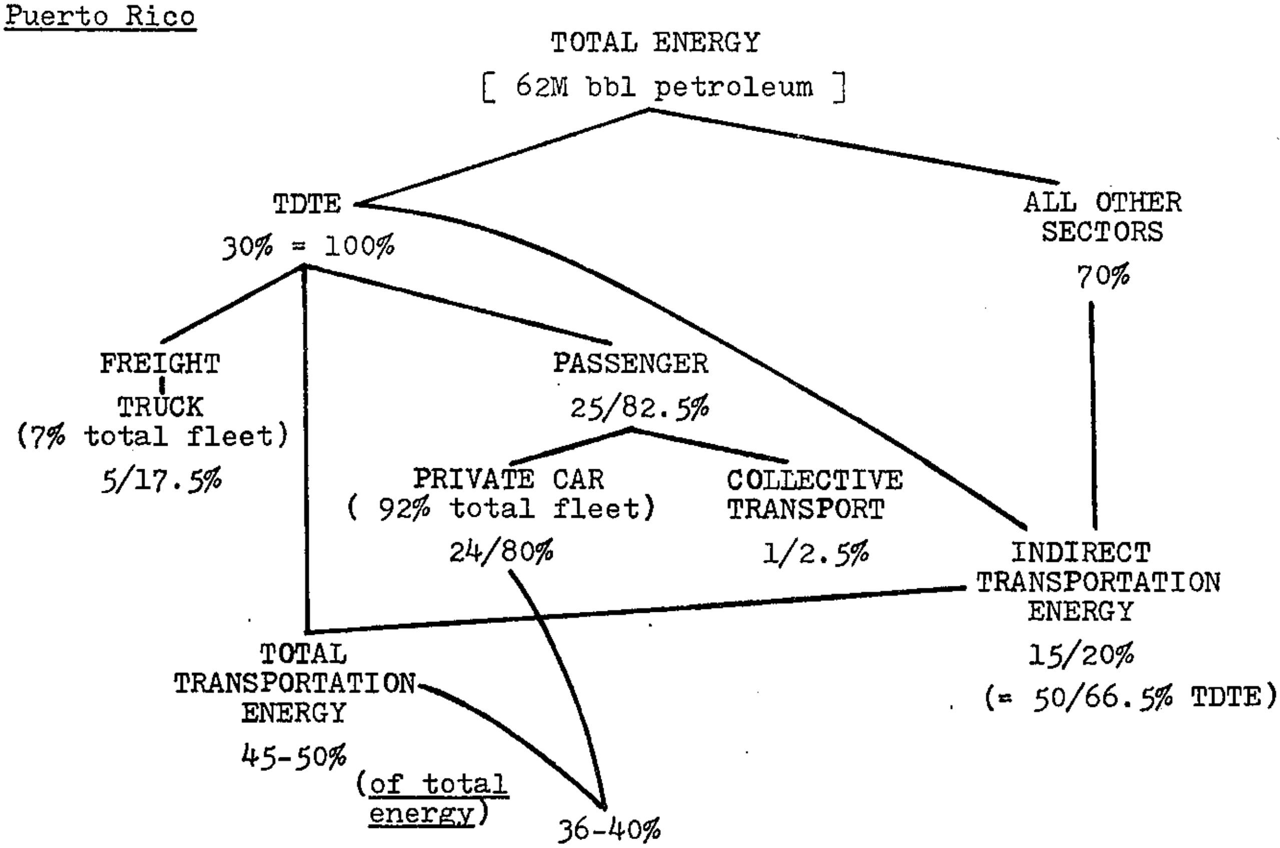
* Total direct transportation energy

total energy consumed. Sweden, which is considered an energy-efficient country, reported TDTE at 17%, indirect transportation energy at 2%--but that includes apparently only manufacture.(43) Both Sweden and a substantial part of the mainland United States have cold weather during 5-7 months; "cold" starts of motor vehicles are known to consume outproportionate amounts of fuel.

Figure 2 shows comparable data for Puerto Rico (79b, 48; updated). Trucks are classified as heavy (see 2.17 above); arbitrary energy consumptions factors are assigned to them as follows: direct consumption equals 2.5 x passenger vehicle; indirect consumption is calculated using a factor of 3.0, largely on account of poor controls on load and the resulting excessive highway wear. Bus TDTE is considered insignificant for separate listing.

Figure 2

Puerto Rico



All the energy accounts are significantly higher in Puerto Rico than in the United States as a whole.

TDTE is 20/34% higher, depending on which base figure is used (see Figure 1 and comment).

Total transportation energy, compared on the same basis, is 15/50% higher in Puerto Rico.

Private car consumption (using the 63:80 ratio for the relative proportions of private automobiles in the whole fleet; see Figures 1 and 2) is about 21% higher in Puerto Rico.

All these data, and especially those related to the PVT (private vehicle transportation) mode, obviously represent significant margins of apparent energy waste. They need to be disaggregated and reassembled in models sufficiently precise to provide a rigorous base for specific TEC projections, goals and policies.

As the previous analysis/synthesis shows, TEC policies based only on direct gasoline consumption--these are the data most prominently, if not exclusively used in governmental and public discourse--seriously understate the energy account of the transportation sector. And the higher the ratio of private vehicles in the system, as it is in Puerto Rico, the more serious the understatement. However, even the addition of the 50 to 66.5% on account of indirect energy does not represent the sum total. What needs to be added is a factor which represents the relative wastefulness of the internal combustion engine. This consideration is especially relevant when one considers not only the TEC potential in a system based overwhelmingly on PVT, but considers the medium- and long-range alternatives of other modes and transportation system mixes.

Energy loss in processing and use is so substantial that not to consider it would greatly distort policy analysis for decision making. The utilization/loss data for Puerto Rico are based on United States data, specifically those for the western states (79b, 48). The effective end use of energy in transportation is 25%, for a loss of 75%. Electrical energy is 35% effective. Although the 65% loss is identified in (79b) as "loss in the generation process", the total figure compares with other estimates which calculate loss in generation and distribution of electricity (for example, U.S. UMTA, information sheet on "Energy efficiency of different urban [transportation] modes," 1976, uses the figure of 59% for generation losses and 8% for distribution losses, a total of 67%).

The 75% loss of energy in the transportation sector partly duplicates items included in the figures for indirect energy consumption (gasoline refining, evaporation in fuel transportation and sale, etc.). There is apparently no basis for useful estimates here, except for the well-known energy efficiency data of internal combustion engines--generally in the 25% range. (Only the 1976 U.S. models were considered "clearly better" that their predecessors, in terms of energy efficiency.)* Although substantial improvements in the energy efficiency of motor vehicles can be expected with the development of new engines , fuels, switch to diesel engines, etc. (representative of the vast literature are 56; the SAE publications in the series exemplified by 47 to 49; 118; 90), electricity-powered transit has already an energy edge now (not to mention other advantages discussed below) and the generation efficiency is also expected to be sensibly improved. Beyond electricity derived from fossil fuel, there is wind and ocean thermal energy. The link-up of these sources with an urban and island-wide rapid rail system must be kept in mind in any future technical and policy analysis.

2.21 Direct energy.

Gasoline consumption. The consumption of diesel oil in transportation in Puerto Rico is insignificant (industrial consumption was at the rate of 7-8% of the gasoline total in 1976; 82). The total gasoline consumed in FY 1977 was 646Mg in transportation (the grand total, including nontransportation consumption, was 664Mg.) This represented more than a double of the 1967 consumption of 318Mg; the number of motor vehicles grew in the same period 2.64 times. The consumption growth since the 1973 oil embargo and price increase was over 20%, compared with a 22% growth in the number of private vehicles (17% if the light trucks are lumped together with passenger vehicles--see the rationale in 2.11 above; and also 17). The latter percentage, probably more realistic, means that gasoline consumption grew faster in recent years than the category of vehicles comprizing some 93% of the whole fleet. The year-to-year increase was 7.9% in 1976, and 4.4% in 1977. The first rate of increase was the highest in the U.S.; the second rate was the fifth highest (146, 5 Apr. 1978). The overall demand for gasoline in the U.S. was increasing at the rate of 6.6% in 1977-78.

* A line must be drawn between engine efficiency and fuel economy, as expressed in mpg. Engine efficiency is a measure of how well the engine converts the energy in the fuel to useful work. The fuel consumption/economy depends also on other variables such as the characteristics of the vehicle, the style of driving, the traffic conditions, etc. (See 126,3)

While the indicator of galons-per-vehicle is about as refined as the per capita income, it affords some comparisons. The 1975 average for the U.S. was 816 g/vehicle. The consumption ranged from Wyoming, 996 g/vehicle, to Hawaii, 518 g/vehicle. Puerto Rico's 772 g/veh. thus put it below the national average, but above California, 765 g/veh. and Florida 720 g/veh. Considering these figures and the relative size of Puerto Rico (48th in terms of area), which means shorter distances, these figures also illustrate the relative traffic density on the island. If other variables are taken into account by comparing the U.S. and Puerto Rico's transportation energy intensity with, for example, Western Germany, the exorbitant consumption is even more dramatic. For a comparable economic and living standard, United States consumes four times more transportation energy per capita (46, s.IV); since Puerto Rico consumed 25% or more of TDTE than U.S. as a whole, its energy intensity per capita is at least five times that of Western Germany, while its economy and standard of life are considerably lower. (Comparisons are difficult because of inflation and changing dollar value, if not also the different components of a good living standard; if, however, the West German per capita income is very conservatively estimated at three times the value/level of Puerto Rico, the factor of transportation energy intensity rises to an incredible 15%). This is not out of line with the general energy inefficiency in Puerto Rico in relation to GNP. See, 136, 189-90; 66.)

In addition to the vehicle's weight and power plant, summarily referred to in 2.12 above, there are other factors related to optional equipment, operations and maintenance, that increase energy consumption far beyond the reasonable minimum needed for safe mobility. Because of their nature, these factors are much more amenable to reduction or elimination through various measures. Thus they constitute the primary target for TEC. They are discussed, with the indicated TEC estimates, below in 2.3.

2.22 Indirect energy. There are four principal groups of transportation-related activities which consume great quantities of energy in addition to TDTE:

a) Refining and distribution of gasoline. In one calculation, a multiplier of 1.26 was arrived at (27, 675, based on E. Hirst; see also 105, 22, Table 6); in other words, refining and distribution of gasoline added 26% to TDTE. Another calculation arrived at 9.5% of the total U.S. energy budget, or 37.5% of TDTE. (63, 5-4). The problem of losses through evaporation in the distribution of gasoline was pointed out already in the mid-1960s as a problem of environmental pollution (52, 41). More recently it was publicized specifically with respect to the high ambient content of benzene--a gasoline additive and a suspect carcinogen--in gasoline pump areas. Since (63) is an input-output analysis, this fuel loss through evaporation is most likely included.

b) Manufacture to services. This group includes particularly:

- Manufacture, transportation and sale of motor vehicles
- Maintenance, repair, parts, tires
- Parking, garaging, toll collection, insurance (energy expenditures only, not costs). This group should also include the energy cost of traffic and parking enforcement--an item that is not expressly mentioned in the various calculations.

The total estimate for group b) is on the order of >4% of the total energy (equal to 17% TDTE); another estimate is of additional 3400 BTU/VM (27, 673). At 136,000 BTU/gallon and the national average of 15mpg at that time, this would add some 37.5% of indirect energy. While these estimates seem to differ by a wide margin, the totals of a) plus b) differ by only 10%: 54-64. This range is confirmed by a third calculation, based on (105, 22). If auto manufacturing figures for 1968 are interpolated into the 1970 series on which the calculation is based (1970 shows a 25% decrease in auto manufacturing energy consumption, probably because of industry recession), the indirect energy sums to 55.6% of TDTE.

c) Highway construction and maintenance. This group should include also the construction and maintenance of rail transit systems, especially the energy-intensive heavy rail. Some estimates address themselves to this account. The parameters of group c) can be inferred from these data:

- A basic estimate for "highway construction" is 1.7% of total energy, or 7% TDTE. This is based on 1967 data and I/O analysis.

- With reference to the controversial planned West Side Highway in New York City, the construction energy for the system (road and transitway, both partly tunelled) was estimated at 74×10^{12} BTU over a period of 10 years, or about one-half of the TDTE for all passenger cars in Manhattan for that period (27, 671).
- Another base for inference is the construction energy cost for BART (San Francisco "Bay Area Rapid Transit"): of the total energy budget of the system over 50 years of operation, construction was estimated at 44%, propulsion at 40%, station operation and system maintenance at 16% (105, 22, Table 5).
- Still another energy cost estimate could be derived from the dollar cost of the upkeep and renovation of the U.S. interstate highway system, put at $329B for the 1978-1990 period (148, 24 July 1978).

The relevance of these figures for transportation policy analysis in Puerto Rico is obvious especially with regard to, on the one hand, the deterioration of the existing system and, on the other hand, the construction and maintenance of toll roads, complex tunelled urban interchanges (for example, the planned connection of the Las Américas and De Diego expressways with the Baldorioty de Castro Avenue in the Minillas Center area), as well as the continued official adherence to the "Metro" concept of conventional heavy rail, in the face of a sensibly more favorable alternative (see 3.12 below).

d) Energy cost of accidents. This category of indirect energy requirements does not appear to be included in the controlling estimates cited above. It is only marginally mentioned in one source (27) with a nontechnical but probable estimate of about 20% of the total auto industry energy being required to repair or replace damaged vehicles. The share of replacement of vehicles would duplicate the particular portion of energy expense in the item production of new vehicles. In addition to the remaining portion of indirect energy on account of

- Repair of accident damaged vehicles,

there are other obvious indirect energy costs caused by accidents:

- Energy costs of funerals, hospitalization and outpatient therapy;
- Repair of damages to public and private property other than vehicles.

Data for Puerto Rico are scattered and incomplete but sufficient to indicate the magnitude of this account and lay out the base for more precise enumeration. (The energy used by ambulances, tow trucks and other emergency vehicles is direct energy and thus part of TDTE.)

The accident statistics show some discrepancies as between such agencies as Department of Transportation's Bureau of Traffic Safety, the Police and the state Commission for Traffic Safety. The difference is as much as 32,469 accidents (over 40%) between two statistics for 1975. One of the safety agencies announced in its yearly report to the Governor that there was a 36% reduction in the number of accidents, when there was in fact an increase of almost 8%. Next year (1976), accidents grew another "natural" 6.5%. According to the apparently most reliable count by the Department of Transportation and Public Works, there were some 360,000 accidents in Puerto Rico from 1973 to 1977, for a yearly average of 90,000. This total shows the following cumulative ratios:

	% (of accid.)
Traffic deaths (including pedestrians)	.75
Heavy injuries (standard category A, requiring transportation of the victim from the scene)	13.0
Total injuries	45.0
PDO (property damage only)	68.0

Important for the energy interpretation of these figures would be at least the following considerations:

One of 9 cars will have a recorded accident in an average year.

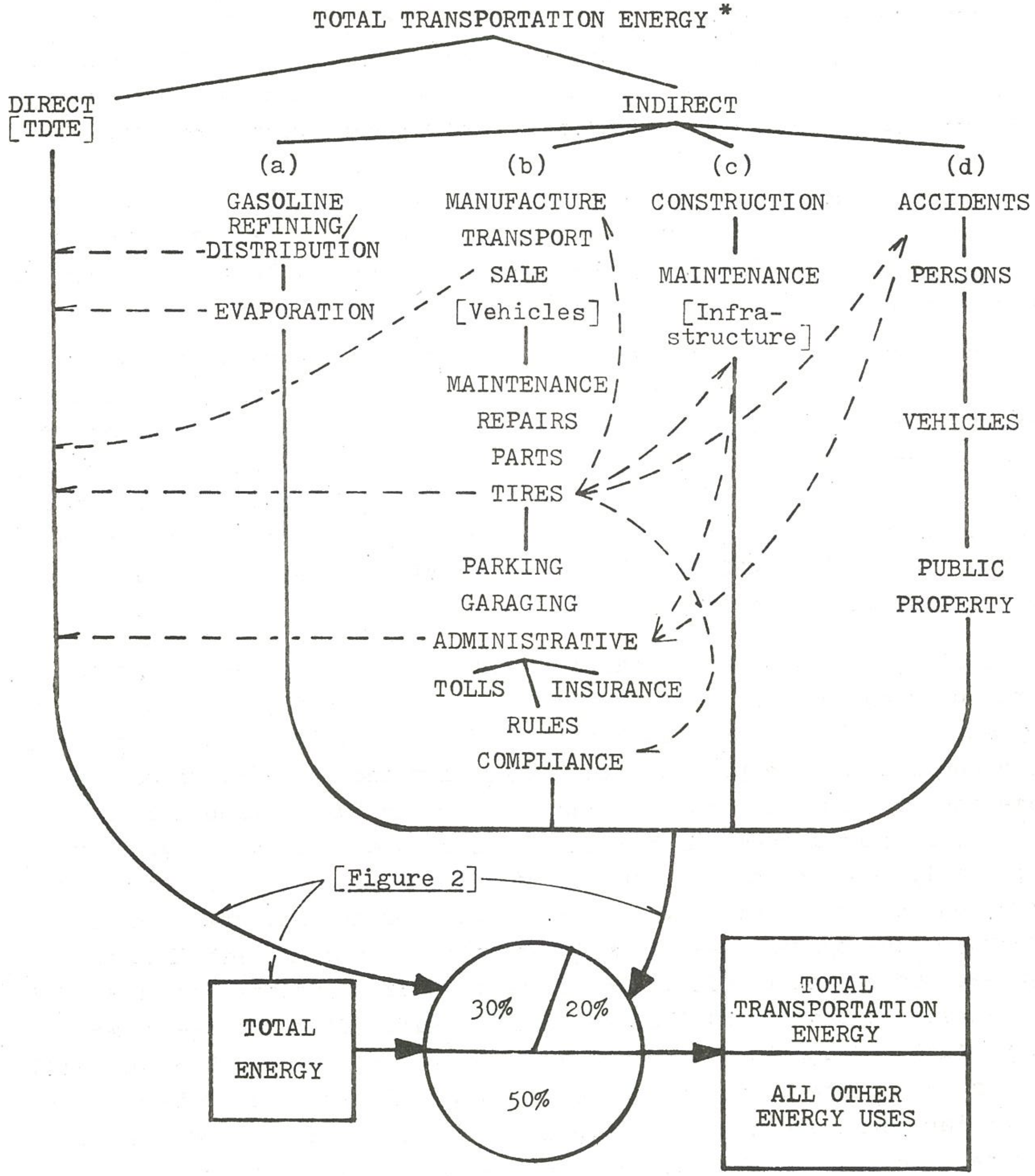
The energy cost (or even dollar cost) of PDO accidents is virtually impossible to calculate at the present. Only accidents worth more than $100 need to be reported to police under the law. Not all are. Nor are all such small damages repaired, as the state of many cars in the active fleet shows. Only a fraction of private vehicles--in fact even públicos, licensed public carriers--have individual private insurance. The obligatory state insurance (ACCA) does not cover property damage. Even if the net cost of repairs could be learned, it would not be disaggregated in categories appropriate for this analysis. Careful sample survey would be necessary.

Almost the same is true about energy estimates of personal death and injury. But the dispersed data on ACCA yearly payments, on the energy budgets of such major emergency facilities as the Centro Médico, and on longer-term hospitalization and followup therapy could yield reasonable input in the overall energy estimate. On the other hand, monetary estimates of the cost of traffic accidents in Puerto Rico--$233M in FY 1976--are based on U.S. mainland values and costs, mechanically transferred and, therefore, having more a shock value than analytical value. For instance, the $100,000 assigned by the U.S. National Safety Council as a loss caused by a traffic death is unrealistic in Puerto Rico where at least one-half of the population lives below the federal poverty line. On the other hand, NSC assigns an average cost per injury of $3900 (1976); the Insurance Institute for Highway Safety found that in 1974 over 5,300 Americans suffered spinal cord injuries in traffic accidents. Of the less than 3000 survivors, 338 recovered and about 2600 became permanent para- or quadriplegics. The initial hospitalization and lifetime care of the survivors cost about $250M; the indirect economic cost (including some energy expense) was estimated at $580, for a total of $830M in 1974 (143, 28 February 1977; 38, 41). The first figure, directly relevant to indirect energy estimates, comes to over $85,000 per case.

Data are also lacking for an estimate of the energy budget with regard to repair of damage to public property caused by traffic accidents. Where the driver can be identified, the police notifies the regional director of Transportation and Public Works. The cost is assessed and the driver is made to pay it, in instalments corresponding to his economic situation. According to the finance division of the department, the bill is often in the $1500-2000 range. But the division keeps no statistics on the total of the damage caused and recovered.

2.23 Overview. The preceding inventory of the elements of total energy consumption related to transportation does not pretend to be either complete or refined. Even this tentative policy-oriented synthesis imposes a conclusion: The present statistics, limited to TDTE, grossly understate the real energy cost of transportation in Puerto Rico. Thus they do not represent a base for realistic energy and social policy. Figure 3 graphically represents the elements of a comprehensive model of transportation energy budget in Puerto Rico. It does not attempt to show how intervowen the system is--a reality which makes the present TDTE data look even more reductionist. For example, tires inflated to only 16 lbs. as against the optimum 24 lbs.--a hardly visible difference--increase direct fuel consumption by reducing mpg (see 2.33 below). The underinflation can also deteriorate the tires at a 50% higher rate. This requires an earlier replacement; if not replaced, defective tires are contributing to more than 10% of all accidents in the U.S. (1.2 - 1.5M/year; 143, 31 January 1977). Either alternative caused additional indirect energy consumption. (To complete the system on the preventive side, one must consider also the social management factors of surveillance to reduce vandalism of the air pumps and regulation to force gasoline retailers to keep them in working order.)

Figure 3. Elements of a model of total energy consumption related to transportation in Puerto Rico



* The broken lines suggest some obvious TDTE resulting from transportation-related activities/events, and the multiple intrasystem effects of a minor factor--the example of underinflated tires in the preceding text.

The stark conclusion to be drawn from the inventory and the known or interpolated numbers in Figure 3 and expressed in the "bottom line" is that Puerto Rico uses about one-half of it total annual energy budget in direct or indirect transportation accounts. At least 80% of this energy (that is, 40% or more of the total energy) are consumed by private vehicles (see Figure 2); these are estimated to make over one-third of non-essential trips (see 2.15 above).

The upper range of the U.S. coefficient, interpolated in the Puerto Rican model as 20% of TDTE, is considered more realistic on several grounds:

a) The study from which it is taken (63) is the most comprehensive and recent in the literature. The interpolation is on the conservative side: the order-of-magnitude value used here ("two-thirds") corresponds to a coefficient of .666; in (63) it is closer to .68. Another estimate of comparable competence (105, 19, based on E. Hirst) is much higher--approximately 100% TDTE or an increase coefficient of 1.0--expressed by saying that indirect energy reduces the mpg of the motor vehicle fleet to one-half, from the then national average of 14mpg to 7mpg. In other words and applied to Puerto Rican figures, the total transportation energy used in FY 1977 would represent the equivalent of some 1.3 Bg--rather than the "official" figure of 646 Mg (of gasoline).

b) The U.S. figures apparently do not include the not negligible indirect energy consumption in column (d) of Figure 3 - Accidents.

c) The only items among the standard components of the indirect transportation energy account, which do not apply to Puerto Rico, are in column (b): manufacture of vehicles, tires and most parts. A more refined quantification would therefore require that the energy estimates corresponding to the new and used vehicles introduced in Puerto Rico in the given year (the recent average has been > 100K), and the imported tires and parts. On the other hand, some parts are produced in Puerto Rico for U.S.-made motor vehicles.

On these considerations it appears unlikely that the fine tuning of the tentative heuristic model in Figure 3 will substantially change the first baseline for policy development and decision making in Puerto Rico in the area of this study: Transportation consumes about as much energy as all the other sectors put together: households and government, light and heavy industries, commerce, communications and services. Compared with the energy-intensive United States as a whole, Puerto Rico's share of transportation energy in the total energy budget may be as much as 10% higher.

2.3 Energy demand II: Microanalysis

As overwhelming as the preceding conclusion on the total direct and indirect transportation energy demand in Puerto Rico may be, its translation into concrete TEC policies and recommendations requires a more specific determination of the energy minima necessary for safe essential mobility, given the insufficient collective transportation and the absence of transit. In other words, what are the various categories of transportation energy consumption that could be reduced or eliminated by various operational measures, changes in driver attitude and behavior, and legal/regulatory measures, incentives and constraints?

The identification of these categories and a first estimate of their individual and cumulative impact on TEC is the purpose of the following "microanalysis" of transportation energy demand in Puerto Rico.

2.31 Age and maintenance of the fleet.

The age structure of the Puerto Rican fleet, especially the over 90% of private vehicles, apparently does not fit the standard of useful life of vehicle used by the U.S. EPA--9 years/100,000 mi [160,000 km] (141, 8[1977]29). Neither does, for example, California where the "volumetric decay rate for automobiles" shows that it takes between 11 and 12 years before one-half of any year's vehicles are retired (11, n.p.[63]; there is, however, a sharp increase in retirement from the 10th year on). From the standpoint of fuel economy (f.e.), the age of an automobile represents two possibly unfavorable factors: higher weight and generally less careful maintenance. The contemporary impact of these factors on f.e. shows in the following figures: the 1977 U.S. model cars tested at an average of 18.7 mpg and effectively operated at ø 17 mpg; but the whole fleet had an average f.e. of only 13.7 mpg (132, S3-29; 148, 11 April 1977).

While the size/weight parameter can be optimized only slowly, as automobiles are replaced by smaller and lighter models over a period of 10 or more years, maintenance can be improved relatively quickly and with a great impact on f.e. One particularly important and telling yardstick of vehicle performance and f.e. is the rate of polluting emissions. Much of the data on f.e. have been collected with primary interest in the control and reduction of emissions. But a car which exceeds pollution standards is a car which burns gasoline inefficiently and therefore uses more fuel than it should with relation to its performance.

The margins for improvement in maintenance can be gleaned from such data as these:

- In a sample of 5600 cars tested in 27 different sites in the U.S., 4 out of five had some maintenance deficiency which had an adverse effect on f.e., exhaust emissions or performance. The U.S. DOT estimated that cars needing a tune-up wasted 375 Kb/petroleum/day (___, 18 July 1977).
- An EPA study, related to a pilot I/M (inspection-maintenance) program in New Jersey, concluded that "improper adjustments and lack of proper maintenance" were the major reasons for the perceived "shortfall in the Federal motor vehicle control program" and that "the latest technology...seems as sensitive as older cars to proper maintenance and adjustment" (127, 24).
- Visible exhaust is one indicator of a badly out-of-tune vehicle, with an f.e. penalty of 25%. This was assumed to be in 1974 one out of every ten vehicles (120, 7). Empirical observation indicates a much higher proportion of such vehicles in the Puerto Rican fleet. This state of engine maintenance was also confirmed by the high reject rate (90%) of a temporary I/M program which tested also emissions, as compared with the standard inspection program in Puerto Rico (since 1969) which records only 30% of rejects (see 2.12 above). For a comparison, a rejection rate of slightly under 20% in Ohio (including emission testing) was considered too high and the EPA went to court against the state of Ohio, although the police issued almost 79,000 citations in the preceding year 1976 (144, 30 January 1977, supplemented by EPA, Region V).

These data indicate the magnitude of the problem and the margin of opportunity for better maintenance and enforcement in Puerto Rico. The age of the fleet as a factor is probably supported by another comparison with California: In a voluntary I/M program in Riverside, 85K motorists were invited, 50K participated and of these 17K (about one-third) failed (144, 24 July 1977). This rate is 50% higher than that recorded in the Cincinatti, Ohio test. The Riverside test took place two years before the Ohio test (1975-1977) which certainly affected the age-efficiency factor; it is also assumed that the Cincinatti fleet is relatively younger.

The major elements of maintenance with regard to f.e. are:

Tune-up. Of the wealth of data--and also sizeable differences in estimates--the following items represent an illustrative sample for the present purpose:

• Following manufacturer's specifications (e.g., with regard to correct ignition setting, not >5 degrees off) makes 3-9% difference in the car's f.e. (120, 7).

• Simple exchange of spark plugs improves f.e. by 3.5% (143, 18 July 1977). One non-functioning spark plug substantially reduces f.e.

• Proper tune-up of the nation's fleet would improve the overall f.e. by some 11.5%, but some automobiles could improve their f.e. by as much as 50%. (Id.) Tuning vehicles every 6K mi, instead of the present average of 12K mi) would represent a saving of 1.5% of the TDTE (63, 2-16).

Idling. A particular aspect of tuning is the proper setting of the idling speed of the engine. In urban stop-and-go or jammed traffic, the low average speed combined with high idling speed can burn fuel at a rate comparable with the vehicle travelling at a sustained speed of 65 mph. If the variable of nonessential driving is added, the same situation affecting f.e. can occur also in exurban traffic. On an April 1978 weekend, traffic between the edge of the SJMA and Luquillo (beach) and Fajardo (boat show) was reported averaging 12 mph for a strech of some 20 miles.

Lubrication. The use of a 10W-40 oil, instead of 30W oil, is reported to have sensible effect on f.e.(1) The applicability to of this datum to the relatively uniform temperature in Puerto Rico ought to be established. A recently developed "uniflow" oil claims an mpg improvement ranging from 9.8 to 22.7 per tankful; this would mean an average mpg improvement of some 4%.

A synthesis of various estimates for f.e. improvements through maintenance, as well as on account of other factors discussed in the following sections, appears in Table 1 (pages 53-54 below).

2.32 Roads and traffic management.

Extensive tests in Pennsylvania showed that it cost an average 41% more "to drive on deteriorated [fair to very poor] pavement because of higher fuel consumption, accelerated tire wear and damage, and greater vehicle wear and damage. The impact on f.e. can be inferred from the fact that fuel accounted for 75% of the total running costs of the test vehicles (101, 7). The state and progressive deterioration of roads in Puerto Rico in the last several years probably increases the f.e. penalty above the Pennsylvania figure, which translates into 5 mpg loss for an average vehicle (1977 - 17 mpg). Even at an average figure of 20% loss of f.e. on account of less than excellent road surface--i.e., 3.5 mpg for the average vehicle--this factor amounts to an astronomic figure.*

Traffic management consists of engineering, laws and regulations, and enforcement. The low state of the art in all these departments in Puerto Rico is notorious. It is subject to policy analysis and recommendations below--from simple techniques to improve urban traffic flow to information and education of drivers. The magnitude of possible TEC is illustrated by the following sample of data:

- The reduction of stops--mostly on account of faulty timing of traffic lights or oversaturated traffic--by 15% during a typical urban trip results in a 3% improvement in f.e. (63, 2-21).
- At an average traffic flow of 25 mph, the fuel saving is 40% as compared with a "normal" stop-and-go city traffic (Id., 2-20)
- In exurban driving, combination of highway design and poor enforcement that results in steady speeds of 70 mph--such as on the Las Américas toll road--represent a fuel loss of some 24% when compared with a steady speed of 50mph, and some 30% in comparison with the most economic steady speed of approximately 40mph (24).

2.33 Tires and proper alignment of wheels.

The relative drag of tires has considerable impact on f.e. The coasting distance from 25 mph to a stop is 334 m for bias-ply tires, 360m for radials, and 482 m for a recently introduced "oval" type. Radials, kept inflated to the maximum recommended by the manufacturer, improve f.e. by some 7% over bias-ply tires; the "oval" model is said to represent additional 3-8% (148, 10 October 1977) or 7-10% (143, Nov. 1977) improvement over radials--approximately .3 mpg on the average car. Using the VMT data for Puerto Rico, this seemingly minute f.e. improvement amounts to some 240 miles more traveled by the average car annually, using the same amount of gasoline.

Proper alignment of wheels is also listed as a perceptible factor in f.e. (1). As many of the other factors, it can also influence indirect energy consumption—by an accelerated wear of tires and contribution to accidents if tires are not replaced in time.

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* Another supportive estimate is 15% fuel penalty at 40mph cruising speed over "badly broken and patched asphalt" (126a, 11).

2.34 Convenience power equipment.

This category includes four principal types of optional equipment that carry fuel penalty, on account of added weight and operation.

a) Automatic transmission. As compared with manual gear shifting, automatic transmission reduces f.e. by about 1% on account of the added weight, and by 10-15% on account of operation consumption, with urban driving the less economic. The fuel efficiency of both the manual and the automatic systems are being improved: manual by going from 3 speeds to 4 or 5; automatic by a similar increase in speeds, by a switch to infinitely (constantly) variable transmission, and by adding locking torque devices to prevent slippage (56, 294; 48, 13; 31, 140; Technol. Rev. III-IV/1977). Among the top 31 cars in the 1977 EPA mpg tests, 30 had manual transmission, one (number 17) automatic (148, 3 October 1977).* Manual transmission appears to have an f.e. edge which even the best improvements in automatic transmissions--80-100% in performance or 15-20% in f.e.--will have a difficulty to erase, because of other diseconomies of the automatic mode when operated by an average driver. Indeed, the engineering efforts probably respond to the fact that the automatic transmission is more energy efficient than the average-to-poor driver, that is the bottom two-thirds of the driving population. With manual transmission, these drivers tend to shift too slowly into higher gears, thereby revving up the engine more than corresponds to the actual speed. However, the same drivers are often equally clumsy with automatic equipment: by not letting off the accelerator, they delay the gear shifting (7). At the same time, they feed the engine more fuel than it can burn. The only way out for the unburned energy is through the tailpipe--an f.e. loss as well as a source of air pollution. The greatest disservice of automatic transmission is probably the fact that many of these energy-wasting drivers would likely not drive at all, or would drive much less, if they had to shift gears manually.

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* In the 1978 tests (1979 models), all the top 10 cars listed in the first press report (UPI, 15 September 1978) had manual transmissions; eight had the standard "European" 4-speed gear shift, two had an improved 5-speed shift.

b) Airconditioning. This option is generally considered the most energy-draining. It increases consumption 1-2% on account of weight, and 9-20% when operating. The high figure corresponds to urban stop-and-go traffic on a hot day.(126) This would seem to be the condition which prevails when automobile airconditioning is used in Puerto Rico.* It was aggravated in the last decade by the systematic desertification of urban areas and highway fringes, depriving them of trees and bushes--the natural air conditioners and purifiers. However, as is explained in the next paragraph, airconditioning is a dubious protection against air pollution in heavily travelled corridors--no doubt the apparent justification in the mind of many drivers, in addition to the safety factor of keeping the car windows closed at all times.

No data are available at this time on how many cars in Puerto Rico have airconditioning. Local industry data indicate that airconditioners are being installed into small new and many used cars at the rate of some 6000 units/year. Paradoxically, these units are of the so-called vacuum type which is much cheaper (ø $365), but more useful as a protection against foul air since they circulate only the air inside the vehicle. The factory-installed airconditioners are of the ventilation type; for an average cost of $900 they not only aircondition, but also force inside the car traffic fumes--unless the vent is opened and shut according to the outside ambiental conditions, which is probably beyond the attention capacity of the average user. Very sensitive measurements of traffic CO were made inside a car with only this ventilation open (14).

A small-scale study of bicycling and air pollution by U.S. DOT (reported in Science 199, 1187 [1978]) also showed that the control group riding in airconditioned cars showed more CO absorbed than the cyclists in hot, polluted Washington air, probably because the latter moved faster through jams. This example takes us back to the f.e. as related to idling and is just one of many illustrations of the systemic interlocking of many of these factors, separated here for the purpose of analysis.

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* Simulated test with a 1972 standard automobile in Puerto Rico arrived at the figure of 17% (30, 72). It is probably low as compared with real operational conditions as summarized in the text above.

c) Power steering, brakes, seats, windows, sunroof.

This equipment adds up to 2% in weight; the amount of energy varies with the frequency of use (steering, brakes, as compared with the occa sional use of the other options).

d) V-8 engine instead of V-6 engine.

The average performance of standard cars without these power options (and high f.e.) was 23 mpg; with the power equipment of all four categ ries it was 16.3 mpg, for a total fuel penalty of 41% (7, 5).

2.35 Nonessential driving.

Nonessential trips were already defined and estimated at 35-40% of the total trips in Puerto Rico (sec. 2.15 above). If the conclusion that the VMT per household per year vary more with annual income that with any other factor, this would mean that higher-income drivers who own on the average bigger, less energy-efficient cars, do more driving in general and therefore also more nonessential driving. This would tend to increase the energy consumption above the overall estimate based on nonessential VMT, putting it somewhere between 40 and 50% of TDTE. Some doubt may have been cast on the correlation income/VMT cited above (132, S3-10) by a mid-1978 survey related to the cost-of-life index in Puerto Rico. It was reported (146, 3 September 1978) that both a typical family close to the poverty line (income of $6000/year) and one at the middle-class level ($16,000/year) spent about $40 a month for gasoline that is over 55 gal. at the prevailing average price of $ .725/g. But the higher-income fami- ly did at least 450 miles/month of nonessential driving (daily roundtrip home for lunch, 10 mi each time; and a 60 mi. roundtrip out of town on the weekends), that is over 56% of the total 800 miles (55 g @ 14.5 mpg). No data were available to calculate the nonessential driving, if any, of the poor family.

Another kind of energy-expensive driving--and often nonessential, too--are short trips. Here the U.S. data probably cannot be applied with- out taking into account the climatic conditions. Trips under 5 miles do not normally allow the engine to reach its best operating condition; on the other hand, warm-weather driving tends to improve f.e. by as much as 8% (130, 6-7). With specific Puerto Rican data interpolated, the basic fact of severe f.e. penalties for short trips is likely to remain un- changed. It was calculated (132, S3-33) that if a car can make 10 trips of 40 mi each, using 25g of gasoline with an f.e. of 16 mpg, the same amount of fuel will be spent on 60 4-mile trips, 90 2-mile trips or 100 1-mile trips. The respective total distances driven are 400, 240, 180 and 100 miles; the shortest trip is four times as energy expensive as the longest.

A special category of nonessential consumption are recreational powerboats. Boat engines and motors are notoriously energy-inefficient. At 6,200 BTU/PM for a recreation boat carrying 4 persons, the energy consumption is four times that of a small car carrying the same number of passengers; it is nine times that needed to transport 1 ton of cargo by water (11, Appendix A; 120, 5). Powerboats are frequently excessively overpowered. The 15-foot-light-weight-flat-bottom "cruiser", equipped with two outboard motors totalling 170 HP, and observed while it was trailed by a sedan with a 250 HP engine, is an exception. But 75 HP motors on runabouts, where 10-25 HP would be ample, are a rule in Puerto Rico. The tendency to abuse this power and thus to consume even more energy is greater on water than on highways, though the sense of safety because of the free space can be illusory. U.S. Coast Guard statistics show that more than 50% of boating accidents involve vessels less than 20 feet in length, powered by motors of more than 75 HP (144, 22 May 1977). The boating Cadillacs have commonly engines of 300 HP or more. Although these are in most cases diesels, the fuel consumption is still extraordinary when considered in the whole framework of energy, recreation needs and social utility.

2.36 Driving habits in general.

Driving style which results in substantial f.e. (not to speak of safety and lower polluting emissions) requires nothing more than to observe the rules of the road, to use common sense and to act with a modicum of courtesy and discipline. This kind of driving is almost becoming an exception. All the transportation and f.e. specialists, since at least the late 1950s (15, 42), agree on these simple rules:

- Be gentle on the accelerator. Do not practice "rabbit" starts. Once the car moves, it takes only 10 HP to keep it moving. By not pressing hard on the accelerator, you allow the engine to use effectively every drop of fuel.
- Maintain as steady speed as possible. Adjust your speed to the density of the traffic.
- Leave some space ahead of you. Anticipate stops. In tight urban

traffic, look two lights ahead. Coast to a red light as soon as you see it. Do not keep on running at the same speed and then break hard. Do not "beat" red lights: you may pass one but still have to stop at the next.

- Do not let your car run when stopped, except at a traffic signal.

Difference of 20% in fuel consumption due to differences in driving style was demonstrated (63, 2-19). On basis of a pilot program of the U.S. DOE, carried out in Nevada, it was concluded that the f.e. of any driver can be improved "up to 15%" by instructing him on the simple rules of acceleration, stopping and steady driving speed (146,6 December 1977). In view of the "up to 15%" for the average driver, the 20% figure cited above may be a conservative optimum. Instant fuel consuption meters may be necessary as a standard equipment. *

To suggest just one more example of the interrelated system nature of these factors and considerations that is vital to an adequate policy development: erratic stop-and-go driving from one traffic light to another is (i) a major source of fuel diseconomy, (ii) leads to longer idling times at the stop lights where (iii) the fuel consumption is a fuction of proper maintenance (correct setting of minimum idling speed) and (iv) is a major cause of high traffic pollution concentrations.

2.37 Speeding.

Driving above posted speed limits or exceeding them for the purpose of passing is so energy costly that it deserves separate listing. At least three factors contribute to speeding:

- Design speed of roads. While, for example, the Las Américas toll road has the federal speed limit of 55 mph, its design speed is 70mph in the northern segment, 60 mph in the central segment (Caguas-Salinas) and 80 mph in the southern segment (Salinas-Ponce). During the National Speed Monitoring Program in 1977 it was found that over 50% of drivers in Puerto Rico exceeded the 55 mph limit; 17.6% exceeded 65 mph; the overall average was 52 mph (the speed limit on most highways in Puerto Rico is 50 mph; some 60mph signs "may have been left by oversight").

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* ERDA began testing similar meters of electricity consumption in households in Washington in 1977 (146, 7 October 1977).

The invitation to speeding and its acceptance was such that a respected columnist could write after the inauguration of the final segment of Las Américas (146, 7 Oct. 1977) that "as almost everybody else" he was not observing the speed limit; and to predict that the short travel time from Ponce to San Juan would bring many people "to get in line" on a new popular movie. Calculating this combination of speeding (ø 65 mi, plus city driving) and nonessential driving induced by the expressway (130 mi round trip) comes out to some 11 gallons (at 14 mpg, with a 20% fuel penalty for the 65 mph average as compared with a 50 mph average).per car --a considerable energy price to see the "Star Wars" perhaps two weeks earlier.

• Publicized industry acceleration standards. These are usually expressed by the time needed to accelerate from 0 to 60 mph. The "macho" appeal is measured in tenths of second . The planned new DeLorean DMC-12 car has a "0 to 60 performance of about seven and one-half seconds, close to the Porsche 911" (144, 18 September 1977). The acceleration capacity goes hand-in-hand with speed performance; so the DMC-12 is also "designed for...survivability at an 80-mile-per-hour-plus head-on collision." The more sedate standards of the big auto makers are in the 11-14 seconds range for the acceleration. Now the industry seems to fear that this propaganda may backfire and make the new GM diesel passenger cars "unacceptable" to the consumer, as they take 15 secs or more to accelerate to 60 mph (145, 16 May 1977).

The related fuel penalties are considerable. If the acceleration performance design were reduced to 17 secs, 2.4 mpg would be added; a car with a 20 secs acceleration time would gain 5 mpg (22, 28).

• Driver attitude. This is, of course, the cardinal factor, since the vehicle does not speed without the driver making it.

The exponential growth of fuel consumption at speeds above the most energy-efficient steady 35-40 mph is extensively documented (e.g., 19, 20, 126a,b). A table in the latter source shows the following "cruising" performance for a "typical domestic automobile":

20 mph	16.5 mpg	50 mph	21.5 mpg
30 "	22.0 "	60 "	19.5 "
40 "	22.5 "	70 "	17.3 "

According to these figures, the f.e. penalty at ø 70 mph is -23% as compared with ø 40 mph; -19.5% as compared with ø 50 mph. Other data indicate stiffer f.e. penalties. EPA's own penalty figures derived from the table are, in fact, higher: -25% for 70 mph as compared with 50 mph. This would mean a penalty of -30% in comparison with the optimum steady speed of 40 mph, calculation confirmed in (24).

The table also offers an argument in favor of a minimum speed limit of 30-35 mph on exurban primary highways; and it allows another calculation of f.e. penalty of urban stop-and-go driving. At ∅ 20 mph in urban traffic, the vehicle delivers only 10 mpg, as compared with 16.5 mpg in 20 mph cruising. The penalty is more than -40%. The average speed in congested urban areas, such as SJMA, is estimated at only 10 mph or less. These figures are in the same range as (63, 2-20), cited in 2.32 above.

A combination of speeding, abuse of the acceleration capacity and erratic driver behavior--such as passing at speeds above the maximum limit--also results in heavy fuel penalty. At 50 mph (the maximum speed on most primary roads in Puerto Rico), one speed change (acceleration) per mile can result in a penalty of -25% (126a, 11).

2.38 Tax-free gasoline. Analysis of consumption of tax-free gasoline (74), used mostly if not exclusively by government vehicles, shows a surprising increase. In FY 1975, the 11 Mg of this gasoline represented 2% of the total transportation gasoline consumption. In FY 1976, it was 3.5% of the total, and in FY 1977, 29 Mg or 4.5%. It is conceivable that the lower cost (the tax is 16¢ per gallon) makes the government users less conscious of the consumption. In addition, government cars have to burn more fuel to travel to separate central pumping stations to fill up.

2.39 Summary. Figure 1 on the following page synthesizes the inventory of physical, human and institutional characteristics of the transportation system in Puerto Rico (with emphasis on the predominant private vehicle sector), that increase the direct energy demand beyond the minimum necessary for safe essential mobility; and the table presents the corresponding fuel penalty estimates. These are weighted approximate median values derived from the indicated sources, taking into account some special circumstances in Puerto Rico.

Thus the table indicates how much transportation energy could be conserved in Puerto Rico without affecting the basic social and economic need for mobility. The sum of the TEC potential represents a second policy baseline: The essential functions of the present (private) transportation system in Puerto Rico could be satisfied with as little as 50% of the current TDTE.

Table 1. Summary of the categories and estimated potential for transportation energy conservation in Puerto Rico.

CAUSE OF ADDITIONAL FUEL CONSUMPTION	DISCUSSED ABOVE IN SECTION:	FUEL PENALTY[a] (General) %	COMMENTS[b]	TEC POTENTIAL (Puerto Rico) %
I. MAINTENANCE				
1. Tune-up	2.31	25	Increase by 5% for P.R. indicated: age of fleet, perceived state of maintenance, a specific experimental datum[c]	30
2. Idling (speed & mixture)	2.31	2	U only	2
3. Lubrication	2.31	2.5		2.5
4. Roads	2.32	20	Progressive deterioration of roads in P.R. recommends higher estimate	22.5
5. Tires: Type. Inflation	2.33	10 (items 5–6)		10
6. Alignment	2.33			
II. POWER EQUIPMENT				
7. Automatic transmission	2.34a	1 15	W UO (CO = 10)	13.5
8. Airconditioner	2.34b	2 20	W U, hot weather	22
9. Power options	2.34c	1.5 1	W O No quantitative estimates for P.R.	1
III. DRIVER				
10. Urban traffic	2.32 2.35 2.36	35	Includes flow (traffic engineering & control) and driver demand (short trips, low occupancy)	35
11. Speeding	2.37			
12. Erratic driving	2.36			
13. Unnecesary weight[f]			1% each 100 lbs.	1

Table 1 - Continued

		%
SUBTOTALS:	Items 1 - 3	34.5
	" 4 - 6	32.5
	" 7 - 9	36.5
	" 10 - 13	36.0
GRAND TOTAL	(rounded)	140.0

EXPERIMENTAL FORMULA FOR THE CALCULATION OF TEC POTENTIAL:

"Essential" fuel consumption 100

"Real" aggregate fuel penalty:

(i) 50% of the grand total[d] = + 70
(ii) 75% of non-essential trips = + 30

100

TDTE 200

TEC POTENTIAL EQUALS THE AGGREGATE FUEL PENALTY, THAT IS 100 = 50% OF TDTE.[e]

Notes

[a]The sources consulted and drawn upon in the manner described at the beginning of this section 2.39, are: 1. 6. 7. 15. 16. 19. 22. 23. 24. 30. 47. 61. 63. 120. 121. 126a,b. 130. 132. 134. Considering the experience with EPA's city/country (55/45) driving formula, abandonned in 1978 as unrealistic, the median estimates are weighted toward the urban driving f.e.

[b]C means country (driving); O means operating (consumption); U means urban; W means weight.

[c]The measured fuel penalty incurred by one 1972 test car, in an out-of-tune condition, was 42% (30, 89). The value of this figure is that it represents a real measurement in Puerto Rico. It does not, however, represent a statistical sample.

[d]Not all cars incur all fuel penalties, nor will all of these be eliminated. The 50% figure is, however, considered realistic especially if it is noted that the estimates in Table 1 refer only to direct energy, and not also to indirect consumption on account of accidents, where there is a wide margin for improvement in Puerto Rico, desirable also for other than energy conservation reasons.

[e]Due to absence of data on fuel consumption of heavy trucks (see 2.11 and 2.2, Fig. 2, above) and on their equipment, no effort is made here to disaggregate TDTE in the private-passenger and the freight sectors. As in Figure 2 above, bus TDTE is insignificant at the level of analysis attempted here.

[f]This reference is not to the weight of the vehicle, but to objects stored and "permanently" carried in it.

3. COST/BENEFIT ANALYSIS

3.1 The auto owner's cost.

The preceding data and analysis show that a) over 90% of transportation in Puerto Rico is by passenger vehicles or their equivalents; b) over 99.5% of these vehicles are privately owned; c) this private vehicle transportation system (PVTS) consumes over 80% of the total direct and indirect transportation energy budget. It is therefore the primary target for TEC. Unless otherwise indicated, the remainder of this study addresses itself to PVTS.

The principal benefits of the owner of an automobile are:

- The satisfaction of the need for essential mobility, in the absence of an alternative (collective) transportation mode.
- Freedom of nonessential mobility.
- Status symbol; opportunity for conspicuous consumption.
- According to studies in such long-distance commuting areas as, for example, Los Angeles, the satisfaction of a psychological need for privacy and own space in an increasingly crowded and noisy environment.

The cost of owning and operating in 1977 in Puerto Rico an automobil acquired in 1973 for $5,000, with an estimated lifetime of 10 years and 100K mi, was calculated at $ .3218 per mile (including the usual financing cost) (68). This is a substantially higher figure than the various data for the mainland United States (e.g., 44). Even in comparison with the highest-cost area--Boston, $ .2363 per mile (144, 18 September 1977)--the figure for Puerto Rico is + 36%. The Boston figure is so high on account of insurance; the Puerto Rico figure is distorted for the same reason . It includes $4,830 insurance cost over 10 years, whereas the great majority of auto owners in Puerto Rico have only the obligatory third party liability insurance which would cost them only $350 over the same period of time. On this base, the operating cost in Puerto Rico would still be more than 10% above Boston. Considering the high cost of living in Puerto Rico, this is probably a realistic estimate.

The cost of car ownership is estimated at more than 20% of personal/family income, as much as 27% in the latest statistic for the U.S. (147, 1 July 1978). These data need to be interpreted for the purpose of TEC analysis. In this perspective, three conclusions are particularly relevant.

First. Despite the cost increase, the ownership and operation of an automobile has become progressively cheaper. Although the 1977 figure of 27% represented an increase of 7% over 1976, the share of personal income dedicated to automobile in 1976 was higher (28.3%). Income has grown much faster than prices (147, 31 October 1977). Especially the principal energy parameter, gasoline, has been getting progressively less expensive. The CPI figures show that between 1940 and 1970, all items increased by a factor of 2.8; gasoline only 2.5 (144, 1 May 1977). In 1975 dollars, gasoline cost in 1960 $ .576/gallon, in 1976 (that is after the post-1973 increase) only $ .558/gallon (135, June 1977).

Second. The present price levels had no appreciable effect on TEC. Both in the U.S. and in Puerto Rico, the transportation sector was the only one in the recent years where energy consumption was increasing. In the absence of an effective I/M system and driver information, the relative price increases of gasoline had probably an inverse effect on f.e.: engine maintenance cost were cut, consumption of fuel as the economically cheaper factor was increased.

Third. The operating cost represent neither the full economic cost (3.2 below), and even less the full social cost (3.3 below). The PVTS is highly publicly subsidized.

3.2 The full economic cost.

The component acquisition has relevance for TEC analysis in the sense that fuel consumption is directly affected by the number of cars and the capabilities to acquire them. Personal/family budgets have shown surprising elasticity in this regard. The facilities for financing, the cost of which are "hidden" or at least so distributed that they can be met, are probably most responsible. This factor was apparently not sufficiently considered by decision makers. During the 1969-1972 period, when everything possible was done in highway development and reduction of auto taxes to facilitate acquisition of automobiles, the widely reported tacit premise was that the private economic capacity will limit the vehicle population to a maximum of 600K. The error in judgment was 240% (1969 = 418K registered vehicles, 1978 = 874K). There are also social implications which will not be further discussed in sec. 3.3. Money spent for an auto, not matter how "inconspicuous," is not available for other family needs. Puerto Rico's rate of private indebtness is substantially higher than that of the world's foremost credit economy, the United States as a whole.

The component operation bears more directly on the question of whether automobile owners in Puerto Rico pay the full economic cost of the PVTS, with implications for TEC suggested below.

The following is a list of the principal cost items of operating an automobile, with comments on the real economic cost.

Gasoline: base price. The price of crude imported in Puerto Rico rose by a factor of almost 4.2 between FY 1972 and 1976. The gasoline price rose by only 1.45. This is principally due to the "equalization" of prices between Puerto Rico and the mainland U.S. But the increase in the U.S. gasoline base price in the 1972 to 1976 period was x 1.9, that is .45 more than in Puerto Rico. While the absolute prices of gasoline are higher in Puerto Rico, they rose about 31% less than in the U.S. during the last five years.

Gasoline tax. No federal gasoline tax (4 ¢ a gallon at this time) is collected in Puerto Rico. The local state tax remained unchanged at $ .11/gal. from 1966 to 1974, despite highway investment which amounted to $520M between 1969 and 1972. A tax increase was then contemplated but not enacted. The tax is at $ .16 since 1974; the CPI has risen over 40 points since then. Just to reflect inflation and the corresponding increases in average income, the gasoline tax would have to be now in 1978 at $ .23/gal. Even at 16 cents it was in 1977 the highest state tax in the U.S.

The U.S. gasoline price and tax policy, which Puerto Rico follows, is very low by world standards (105, 13). Prices in a representative sample of foreign countries, in Europe and the Americas, ranged in April 1977 from $2.13/gal. in Italy to $1.04 in Chile, for an average of $1.38 (147, April 1977). In several countries, they have risen since then. The difference is even more striking when the cost of gasoline is compared with GNP as an approximate indicator of the ability to pay. If the U.S. cost (per litre) is 1.0, Sweden is 2.41, West Germany is 3.0, Italy 7.06 and India 115.3 (12, 29). Even these absolute/relative prices were considered as not expressing the real cost (21b, 41).

The fact that the U.S. (and Puerto Rican) gasoline prices are depressed by government control was emphasized in an official report to the Congress on "automotive fuel economy" (117, 33 [Jan. 1977]).

Highway use. A heuristic calculation based on U.S. (44) and Puerto Rican data indicated that highway users pay in Puerto Rico as much as 25% less than the 8.7% assigned to the average mainland motorist on account of highway use and maintenance (52b, n79). In fact, highway users in Puerto Rico pay nothing directly for road maintenance. All the gasoline tax goes for construction and financing of new highways. Maintenance and repairs depend on general budgetary assignations. These have decreased from $15.8M in FY 1972, assigned for the maintenance of 6530 km, to $13.7M in 1977, for a network of over 7000 km. The maintenance assignation is slated to return to the 1972 level only in 1980, in current, not constant dollars. The accelerated deterioration of the highways and the effects on f.e. were already discussed above in 2.32. By not being assessed an adequate tax for road maintenance, drivers in fact spend more on fuel and vehicle; since maintenance cost come from the general budget, nondrivers or occasional highway users pay along with regular users.

Transportation costs as a function of the consumer price index (CPI). Between 1974 and 1977, the consumer cost of private transportation rose by 30.6%, of public transportation by 41.3% (82, 31 March 1977). When the price of gasoline rose in 1974-75 by 47%, the PVTS/CPI rose only by 20%, the public by 27%. These comparisons are rough because public transportation includes wages and other costs which do not enter the PVTS account, but in absolute terms public transportation became almost one-third more expensive--an incentive/subsidy in favor of the PVTS. The growing deficit of the AMA was, however, covered also from the general budget, that is paid for by the residents of the whole island, not by San Juan residents whose preference for PVTM contributed to AMA's deficits.(29).

Parking subsidies.

a) No-fee parking on government-owned lots.

b) Specific parking space requirements in commercial buildings as a precondition for construction permit.

d) Control of parking prices in privately owned commercial lots, by the DACO (department of consumer affairs). This may seem to be a laudable policy of consumer protection, but it is totally wrong in transportation energy perspective. Urban parking space is a very costly land, the use of which ought to be costed at its real value. The differential between the presently allowed rates and the real cost represents a margin for some price increases for the operators, as well as a parking tax. More important, the tax would be an instrument of traffic management: it would reduce nonessential trips to expensive parking areas and would allow distinctions between commuters and shoppers by making all day parking substantially more expensive per hour than short parking. Similarly, parking during working hours could be easily distinguished from evening or weekend parking which serves noncongested traffic.

Parking violations. The fine of $7 for on-street or sidewalk parking, combined with mediocre ticketing performance and inadequate tow-away facilities (in 1977, there were 6 trucks in the SJMA for this purpose, only 4 of which were normally in service) invite the motorist to take a chance. There is no increase of the fine for repeaters. Automobiles cause damage to the sidewalk pavement, according to the director of public works for SJMA (146, 24 March 1977). Even the fact that it is possible to pay the fine with a delay of as much as 12 months without any interest or surcharge is a form of subsidy.

Miscellaneous. The following--and perhaps still other--items represent an undetermined economic subsidy for the PVTS:

- The yearly cost of licence plates is deductible from income tax.
- The Highway Authority bonds are tax exempt.
- Transportation administration and enforcement cost come from the general budget.
- Cost of repairing damage to public property caused by accidents is only partially recovered.
- The low I/M standards represent an indirect subsidy at the cost of air quality, accidents and other social costs.

In sum, automobile users do not pay the whole economic cost of their transportation. (Nor do, for that matter, the users of collective transportation, since the bus rates are underpriced and the públicos are subsidized on many of the listed accounts along with private vehicles.) As a result, those who drive sparsely, pay also a share of the economic cost for those who drive intensively; those who do not own an automobile --upward of 40% families in SJMA--pay in two ways: first, because general public funds must be used to subsidize the PVTS, instead for services and facilities; second, because PVTS not supplemented by adequate collective transportation or transit discriminates against the poor, the aged and the handicapped for whom public transportation is the only economically feasible means of mobility. Even on much narrower grounds it was concluded that "American highway investment in urban areas results in social costs that far exceed the present taxes and charges and taxes on American driving." The real cost, expressed in terms of a "toll per unit of driving," to be added as tax to the cost of gasoline, was calculated at $ .50/gal.*

The resulting third policy baseline is this: PVTS, the almost exclusive transportation mode in Puerto Rico, is not only an excessive energy consumer, but is also highly publicly subsidized, partly at the cost of those whose mobility depends on public transportation.

3.3 The full social cost.

The total economic cost of motor-vehicle transportation is not the total cost. Although the focus and interest of this study is policy for TEC, it will be argued below that a more energy-effective system, with a planning horizon of several decades, must be an integral part of a comprehensive vision of the whole society, and its energetic and environmental resources and prospects--in other words, Puerto Rico viewed as a human ecosystem (52; 52c, 21f.).

It is therefore convenient at least to list the major interactions between the present transportation system and the human system it serves. In addition to the factors of mobility and energy consumption, the C/B analysis of which has been outlined above, the present PVTS involves a number of other factors and impacts that are not perceived as cost either by those who drive or by the society at large.

- Air quality. This is generally considered to be the most serious problem (e.g., 12, 149; 60, 54; 128, 44; 134, 42). The contaminants are principally CO, NO_x, airborne lead, HC. Direct correlations between these substances and environmentally induced cancer and respiratory diseases have been established. The Netstal (Switzerland) study, carried out over a period of 15 years (1958-72), found a ninefold rate of cancer among residents near a local highway, as compared with those living 500 m or farther

* If this calculation were applied to the tolls charged at the Las Américas expressway, the cost for the whole length should be $2.15 (60 miles @ 14mpg [no fuel penalty for speeding, but averaging the fleet] equals 4.3 gallons @ $ .50/gal. surcharge). It is only $1.35. Recent figures released by the Highway Authority (146, 10 September 1978) illustrates the extent to which the expressway users do not pay for the benefits. It was estimated on basis of (67, updated) that the direct benefits to the users of the Las Américas expressway--fuel, oil, tires, maintenance, depreciation; shorter travel time; decrease of accidents; convenience and comfort--totalled almost $80M in FY 1977. The tolls collected were, however, only $4.1M; they covered O/M amply, but contributed only a fraction to the about $20M of the debt service for that year--which is, in principle, financed from the gasoline tax. The figures were possibly released to assuage the expressway users who protested in 1977 against the raise of the toll from $1.10 to $1.35. But the point is that the $80M worth of user benefits was presented as public benefit.

away. Aromatic HC, measured in tailpipes of passing cars, and in soil and soot around the homes, was identified as the probable cause. The traffic density was measured at 4K to 5K cars/day. It is, according to figures for August 1978, 50K/day on weekdays and 45k/day on weekends on the opened segment of the De Diego expressway in San Juan. The concentrations of contaminants in SJMA were documented in a local study (30). In California they led to emission standards which exceed substantially the federal norms. In New Jersey, which has the highest rate of environment-caused cancer in the U.S., a pilot I/M program consists of stopping motorists, rapidly measuring their emissions, and giving them a short period of time to tune or repair the vehicle, under considerable penalty. SJMA has at this moment only a mathematical simulation model of air contamination from mobile sources (1971). The Highway Authority's office of environmental studies does not include air pollution in impact analyses, relying on dispersion. The Environmental Quality Board has prepared only in 1978 a request for federal funding to establish a monitoring network which would collect real data. The Netstal story was published also in the local press (146, 2 November 1977). The solution of the impact of automobiles on air quality through emission control devices is far away and problematic. Only 18M cars of a fleet of about 107M had emission controls installed in the United Stated in 1977. The effectiveness of the present catalytic converter after 50,000 miles is subject to doubt. The proportion of emission-device-equipped cars in Puerto Rico is smaller. The device can be, in the absence of regular and stiff controls, disconnected or made inoperational by the use of leaded gasoline or of some substitute additives to boost the octane rating--that is the capacity to accelerate and speed.

- Other sources of environmental pollution. One instance of several is the problem of disposal of used lubricating oil. In 1976, there were about 10Mg of it in Puerto Rico, representing a problem of disposal for some 1400 gasoline stations. The seven oil companies which operate gasoline stations were ordered to instal disposal tanks. Five complied completely, one partially, one not at all. This means that a considerable number of gasoline stations in Puerto Rico does not have this means of disposal. Nor is it clear what happens with the used oil when the disposal tank is full.

- Congestion.
  - Time spent in travel. In Caracas, which has a traffic density

somewhat comparable with San Juan, it was estimated that up to one hour may be lost by travellers every day because of traffic jams. The total was (in 1975) some 1.5M man-hours/day, with the implied impacts on productivity, physical and mental state. A study by the transportation workers union estimated that bus, jitney ("por-puesto") and taxi drivers used for the same reason extra US$200,000 worth of gasoline monthly, that is 1 Mg at the prevailing price of US$ .20 or less per gallon (26, 120). The impact on air quality does not have to be belabored.

- Pedestrian delay.

- Noise and vibration, both directly correlated with public and mental health parameters.

- Accidents. This factor was already discussed in 2.22 d) above. In the human ecosystemic perspective, one notable relation is between traffic congestion, accident pattern (both are a function of traffic engineering and enforcement), the mobility of ambulances and the often futile excessive noise they make.

- Land use.
  - Direct use for highways, streets and parking (see also 2.14 above).
  - Disruption of residental and business districts by highway construction.
  - Impact of land use decisions on transportation and vice versa. Urban sprawl, location of big shopping centers, the selection of automobile and transit corridors, interact in a synergistic fashion, making many decisions virtually irreversible. The construction of a new shopping center, such as Plaza Carolina, looks quite differently from the viewpoint of the investors and the developers, and from the viewpoint of traffic density in the approach corridors such as the already saturated 65th Infantry avenue, the Loiza Expressway and P.R. 3.
  - Impact of large paved areas (highways, parking lots) on flooding, run-off, underground water replenishment, miniclimates.
  - Decline of public transportation. Interference with energy-effective modes indicated for short trips, such as walking and bycicling.
  - Lack of mobility of nondrivers.
  - Environmental esthetics. The question is not only one of unfa-

vorable impact ("visual instrusion") but of esthetic opportunities and their relation to broader aspects of environmental management. An example is landscaping, including the maximum of tree planting, on the right-of-ways of new expressways, especially their urban segments. This was specifically proposed for the Muñoz Rivera Expressway, but remains on paper several years later. The relation between such "esthetics" and air quality and conditioning was already referred to (2.34 b/ above).

The preceding is only an illustrative inventory. All the categories could and should be developed into submodelsfor further policy analysis and synthesis which is outside the scope of this study. Much data is available or can be developed when the conceptual model is constructed. Some ten years after the concept of external costs was proposed (Mishan et al., 1962-67), energy and transportation specialists insist on the need to "determine and internalize...the entire...'non-dollar' cost to society...the social cost of urban transportation modes" (134, 42-3). The transportation system in Puerto Rico is in this sense an urban system.

3.4 Summary.

In sum, PVTS in Puerto Rico is not only an excessive energy consumer which does not pay for itself in economic terms, but it generates social and environmental costs not enumerated in the preceding discussion but extensively generally documented. Until they are sufficiently quantified for Puerto Rico, these externalities must be assumed to equal in magnitude the energy and economic costs. The first of several causes of the excessive external costs has been the separation of transportation planning and development from the whole social and resource system.

The consequent fourth policy baseline is twofold:

a) Transportation energy conservation can not be effectively implemented outside an adequate transportation system management (TSM);

b) the development of such a TSM is not possible unless transportation is perceived and planned as part of the whole human ecosystem, and monitored with reference to an equally whole cost/benefit calculus.

4. POLICY DEVELOPMENT: BASES AND SOME RECOMMENDATIONS

4.1 The policy baselines

The discussion of transportation energy demand and the cost/benefit analysis of the full economic and social cost of the present transportation system in Puerto Rico--principally its dominant mode, the PVTS--resulted in the following baselines relevant to the consideration of policies and measures to conserve energy in transportation:

I. Transportation consumes directly and indirectly about as much energy as all the other sectors put together. This share of transportation energy in the total energy budget may be as much as 10% higher than in the United States as a whole.

II. All the safe essential mobility of persons in Puerto Rico could be satisfied with as little as 50% of the current TDTE, with adequate maintenance of engines, vehicles and roads, with reduced use and acquisition of convenience power equipment, with reduction of driver demand (short trips, low occupancy, non-essential driving) and upgrading of overall driver behavior to the standards of the traffic code and of common sense.

III. The PVTS is highly publicly subsidized. That means that the users of automobiles do not pay the full economic cost of gasoline, highway use, parking, and that they are also subsidized on a number of other accounts.

IV. Transportation energy conservation can not be effectively implemented outside an adequate transportation system management, that is the integration of transportation planning and management with the whole social and resource system. This will also reduce the social and environmental cost (that is, adverse impacts on public and environmental health, land use and esthetics) which must be assumed to equal in magnitude the energy and economic cost of automobile-based transportation.

It is concluded that a detailed quantification and fine-tuning of the conceptual and methodological model that underlies these policy baselines may adjust the implied relations and vectors for the purpose of interim or tactical measures, but that it will not affect the orders of magnitude which are the proper base for longer-term policy options and decisions.

4.2 Collective development of a policy model.

The need for a fairly rapid change in the whole transportation system that the numerical and policy data indicate is staggering. No effective TEC is considered possible without such changes.

The lead times necessary to achieve anything but bandaid treatment are long. It takes some 10 years from the threshold decision to a full operation of a metropolitan rail and feeder system of the size San Juan needs.

The complexity of the system of technical data and elements, of their interrelations and tradeoffs; of government processes and financing; of social and economic expectations and vested interests, is mindboggling. The power of the auto-transportation-industry complex to resist even remedial corrections can be gleaned from the fact that in the 1978 Fortune list of the 500 largest industrial corporations (142 , 8 May 1978), there are five gasoline and three auto producers among the ten top U.S. companies; the top nine in the world (by sales) consist of seven refiners and two auto makers (Id., 14 August 1978). According to a leading senator, the three most active lobbies in Puerto Rico in 1977-78 were 1) auto manufacturers and distributors, 2) financing companies, 3) gasoline distributors (146, 7 June 1978).

There is a wide consensus that the no-action alternative--that is, the continuation of past and present policies--would lead to a major crisis. Small, incremental changes such as right-turn-on-red, increased excise tax on the heaviest automobiles, small park-and-ride programs, improvement of traffic light timing at a few intersections--create a feeling that something is being done, while in fact they amount to a no-action, when the system is considered.

No sufficient technical fixes are available because the problem of energy, general or transportation, is ultimately the problem of decisions about how to use energy. Conservation means such a use that the source of energy is not completely exhausted before other sources and ways of using them can be developed. The latter is technology; the former is a human, social and therefore political problem.

It is evident that the useful function of a single policy analyst ends when he has inventoried the principal factors and inputs, estimated their magnitudes and relations, and arranged them in a tentative but reasoned pattern--where there were before only so many scattered data, technical studies with a limited technoeconomic focus, sectoral programs and decisions, and vague impressions about the serviceability, the impacts and the social value of the product.

From this point on, the development of a policy model based on all the available empirical and decisional data and indicating pragmatic decisional options, priorities and tradeoffs, becomes the task of a team of transportation and energy specialists, regional planners, policy analysts and synthesizers, and government administrators--seeking and applying industry, commerce and community input where indicated.

It would be presumptuous, if not impossible, to try to anticipate the specific reasults of such a collective exercise--even though a great deal of Puerto Rican and adaptable external data and analysis are available for this purpose. The scope is partially reflected in the appended working bibliography.

Nevertheless, some directions for further policy research and development for the purpose of decision making follow so clearly from the policy baselines that they are at least briefly outlined below.

4.3 Some directions and recommendations.

4.31 TEC as a function of total transportation policy and management.

FIRST RECOMMENDATION: THE CONSIDERATION AND IMPLEMENTATION OF TEC MEASURES OUGHT TO BE INTEGRATED WITH THE OVERALL TRANSPORTATION PLANNING AND SYSTEM MANAGEMENT.

The basis for this recommendation is the close interrelations between the parameters that affect TEC and TSM. Two examples must suffice:

a) Velocity and fuel economy.

- Speeding and erratic driving is a great fuel waster.
- Enforcement of the highest speed limit (55 mph) cannot be separated from general enforcement of legal speed limits, nor from driver education (both of them TSM measures), because it is a matter of driver attitude and behavior in general. Over 50% of drivers were shown exceeding the maximum 50mph speed on primary roads in Puerto Rico.
- More important consequence of the 55 mph limit on federal highways and in foreign countries than TEC has been a dramatic decrease of serious and fatal accidents.
- One source of TEC is the gradual replacement of heavy automobiles by compact and small models. The proportion is expected to be about 50:50 in 1980. But there is a tradeoff: in a collision with a heavier automobile or truck, the risk of death increases by 75% for the small car passengers, the risk of permanent inju-

ry by 38% (Allstate Insurance Co., Automobile rating program, November 1976; see also 36; 53). The severity of accidents increases proportionately with speed (41).

b) Transit and fuel economy.

- There is a direct but relatively minor f.e. in having an operational transit in addition to other transportation modes.
- The more important f.e. is indirect. It comes from the constraints on PVTS which can be implemented when satisfactory transit is in place.
- Light rapid transit (LRT)--apart from being less energy-intensive in the construction phase and cheaper--is more favorable with regard to restraints on PVTS. Since it runs in principle entirely at grade, it forces TSM to implement restraints on PVTS in the LRT corridors. Heavy rail is constructed around the existing PVTS and has no measurable TEC value.
- A favorable concept of transit also enhances two other concerns of TSM: air quality and the rehabilitation of urban human environment. (Appendix A: 4, 4.9, 4.10)

The second basis for the recommedation discussed in this section is of a decisional nature. Even minor, short-term TEC measures need to be presented to political decision makers in a policy context that makes them appear as orderly and necessary steps in the right direction, rather than only either-or suggestions, the acceptability of which may be determined by considerations extraneous to the real problem.

4.32 A first list of integrated criteria and indicators.

SECOND RECOMMENDATION: SIMPLE BASIC GUIDELINES FOR FUTURE TRANSPORTATION ENERGY AND DEVELOPMENT POLICIES OUGHT TO BE AGREED UPON AND PROMULGATED.

Even a tentative list for further consideration and elaboration is likely to contain the following criteria and indicators:

- Transportation energy prospects and constraints. Convergence of the principal long-term trends--energy, population, food, resources and the related economics--advocates conservative policy thinking based on the assumption that severe constraints will prevail in the future over the "limitless" opportunities which shaped the decisions in the last 25 years in Puerto Rico and in much of the world (52d, 2, 7).
- The need for, and content of, long-term policy decisions rather a series of crisis responses and makeshift "solutions."
- Social criteria for transportation system development, rather then merely engineering parameters and economic cost.
- Policy concern about essential mobility with reasonable margins

for personal freedom of choice at real economic cost.

- The close relation between TEC and the turn to an ecosystemic civilization which conserves not only transportation energy, but also conserves, reuses and recycles other forms of energy, water, materials and other resources.
- Transportation as a function of the urban habitat: physical enhancement, environmental quality, human and esthetic improvement, reversal of urban nonplanning and of land wastage.
- The economics and institutional aspects of TEC (to be specifically mentioned below).

Already the first San Juan "metro" study (1964-67), focused on technical planning, urban land use parameters and financing, concluded that the transportation plan "will require pooling of resources and foresightedness to bring about the greatest concerted effort ever undertaken in Puerto Rico by both private and public sectors and the citizens in general." The social dimension of this planning appeared then to be too narrow (52) but was more than the decision making process could handle. The present gap to be spanned can be inferred from two recent policy documents: the latest Governor's message to the Legislature (February 1978), makes only an incidental reference to transportation with regard to the economics and regulation of the "público" sector; the "energy problem" is dealth with with a similar lack of prominence * and narrow economic focus. The draft "Plan of integral development," prepared by the Planning Board (March 1978) devotes four out of a total of 210 pages to generalities about transportation and energy; the first of six specific transportation objectives is "to develop a vast program of highway construction" to supplement the existing network. Transportation energy conservation is not mentioned or implied.

4.33 Near-term TEC policies and measures.

THIRD RECOMMENDATION: THE SCOPE OF PRESENT AND PROPOSED TEC ACTIVITIES SHOULD BE ENLARGED TO RESPOND TO THE FIRST, SECOND AND THIRD POLICY BASELINES.

The supportive data and analysis are in sec. 2.2, 2.3 and 3.2. These invite further development and refinement. The policies and measures could be conveniently grouped in the following categories:

* 24 of a total of 1026 column/centimeters, i.e. some 2.4% of the total wordage.

- Fiscal/economic
- Technical/mechanical (including vehicle and road maintenance and improvement)
- Planning/management (the bulk of TSM)
- Legal/regulatory
- Enforcement/surveillance
- Driver information/education
- Improvement in data generation/processing

4.34 Setting a limit on energy consumption in transportation.

FOURTH RECOMMENDATION: TEC POLICY OUGHT TO FOCUS AS SOON AS POSSIBLE ON MEASURES THAT WILL DIRECTLY LIMIT ENERGY AVAILABLE TO PVTS.

There are at least four possible approaches:

- Ceiling on petroleum imports. This has been implemented in such countries as France and Brasil; it is implied in the U.S. energy plan. The consideration of this alternative would obviously require a review of the outstanding petroleum import and gasoline export commitments of the Puerto Rican refineries.
- Ceiling on gasoline available on Puerto Rican domestic market. This measure is contingent on the longer-term commitments and/or the possibility of exporting greater quantities of gasoline refined in Puerto Rico.*
- Raising the consumer price of gasoline progressively to its real economic value.
- Establishing a surtax on nonessential gasoline consumption.

The last two approaches were tentatively analyzed in San Juan Transit (Appendix A: 3.2, 3.4, 3.8) along the following lines:

a) Besides scarcity of supply, price is the only variable which can importantly affect gasoline consumption. The elasticity of demand is such that the cost becomes effective only when it reaches the range of \$1.50 to \$2/gal.

b) Allowing the gasoline price to raise to this level would cause substantial hardship, not justified in view of the fact that it was past government "planning" that created the degree of dependence on PVTS for essential mobility.

c) The government has no duty to provide unlimited supply of gasoline.

d) A surtax would in fact created a double price level:

(i) A reasonable allotment of gasoline for essential economic driving;

(ii) free purchase of additional gasoline at current price plus

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* A target could be the 10% excess share of transportation energy estimated in baseline I (sec.4.1 above).

surtax. If the surtax amounted to 100% of the current price in mid-1978, the total price per gallon of the free gasoline would merely equal the contemporary average price in a great part of the world.

There is a similarity between the two-tier gasoline price and the residential electricity rates in Puerto Rico: low consumption is subsidized (as gasoline is subsidized now); consumption above the reasonable minimum of 425Kwh per family is charged at full price.

Additional comments are necessary due to developments in the last twelve months. First, the basic price of gasoline will rise within the next years, largely because of the U.S. commitment at the economic summit in Bonn (July 1978) to raise energy prices to their real level by 1981. Second, the surtax is not the same as the U.S. standby rationing plan. Rationing absolutely limits the amount of gasoline available. But it is somewhat similar to the modified rationing discussed in the spring of 1978, that is the freedom of car owners who do not use their ration to sell it at higher price to others. However, the surtax proposal for Puerto Rico was motivated also by the need to generate funds for transit; the Schlesinger "white market" concept turns nonconsumption into private profit enterprise.

4.35 Positive restraints on PVTS.

FIFTH RECOMMENDATION: ENERGY PRICE AS THE KEY TO TEC MUST BE ACCOMPANIED BY OTHER MEASURES SUCH AS WITHDRAWAL OF "HIDDEN" SUBSIDIES OF PVTS.

Price is the key, but not the only key. Observation of the Tokyo transportation system, subsequent to the preparation of the report on San Juan Transit, established a surprising tenacity of PVTS in the face of:

- One of the most extensive, efficient and reasonably attractive combined urban/exurban rapid rail systems in the world
- Price of gasoline of \$1.68/gal. in 1977 dollars, \$2.28 in mid-1978 dollars
- Uncomfortable traffic density and congestion, despite an elaborate network of urban toll expressways.

The conclusion must be that in addition to gasoline price and the availability of transit, positive steps to restrain PVTS must be undertaken. In Puerto Rico, a substantial restraint would probably result from withdrawing the various subsidies enjoyed by PVTS and putting it progressively on equal footing with other transportation modes. That presupposes the next policy direction. Before going to the next point it should be noted that the preceding concentration on PVTS corresponds to the numerical preponderance and dominance of this sector and to the resulting TEC potential. It does not imply that the collective and freight transportation sectors operate economically and should not be monitored and analyzed for possible TEC gains.

4.36 Shift to rail as the dominant mode of essential travel.

SIXTH RECOMMENDATION: THE PRINCIPAL FACTORS THAT IMPEDED IN THE PAST A FAVORABLE DECISION IN THE MATTER OF RAPID RAIL TRANSPORTATION FOR SAN JUAN AND ISLANDWIDE OUGHT TO BE ANALYZED SO AS TO FACILITATE FUTURE DECISION MAKING.

Reference is made to the relation between rail transit and TEC, touched upon in 4.31 b) above. The concept is to substitute eventually rail transit for PVTS as the dominant mode for essential travel.

The following premises ought to be verified:

- The past "Metro" planning was conventional, misled and requires dramatic conceptual innovations.
- It was not pragmatic enough in terms of cost, equipment, simple adequate technology needed to serve transit needs in the available economic and social framework.
- It was therefore too expensive. "Metro" (heavy rail) is costly economically (the new system for Caracas is budgeted at US$100M per mile; the cars proposed for the San Juan "Metro" were the most expensive Boeing model, costing $560K each in 1975). "Metro" type transit is also costly in construction energy and in environmental impacts during the construction phase.
- LRT is the mode indicated for San Juan as well as islandwise. The preceding points were elaborated more in (52b; see Appendix A: 4.3f).
- Although economic cost was always cited as the principal obstacle, at least three bids by private enterprises to construct rail transit in San Juan and on the island were turned down.
- Bus is not a practical long-term alternative for rail, even if it operates on separate guideways (Appendix A: 4.2).

Rail transit as a substitute mode for commuting and other essential travel is a medium-term project, but the long lead time requires that the threshold decisions and commitments be made early (Appendix A: 6.).

4.37 Adequate TSM

SEVENTH RECOMMENDATION: THE EXISTING TSM PLANS OUGHT TO BE THOROUGHLY REVISED IN THE LIGHT OF ENERGY, ENFORCEMENT AND FUTURE TRANSIT REQUIREMENTS, AND IMPLEMENTED AS SOON AS POSSIBLE.

The existing TSM plan for SJMA (75) needs to be revised and broadened:

- TSM is an essential factor in the effort to conserve transportation energy.
- TSM is not only an engineering enterprise, but depends heavily on enforcement. Traffic lights are meaningless if they are ignored. Traffic jams are caused or aggravated by intersections blocked by drivers who entered the area without having a clear exit in their direction. Most often these drivers enter after green had switched to amber. Traffic engineering would be to clearly advise the driver that unless he has crossed a (yellow?) line before the amber signal came on, he must stop. But this would be a waste of paint without enforcement and sufficient fine for violation.
- Finally, TSM in the sense of the best use of what is available and of graduate improvement, is an absolute precondition for satisfactory functioning of the feeder system of buses, vans, públicos, park-and-ride lots, etc. on which rail transit depends.
- As transit planning, traffic engineering in Puerto Rico has been plagued by tendency to rely on too complicated and costly technologies (e.g., underground sensors to activate traffic lights, which tend to break down after a while), instead of such simple techniques as to advise the driver by means of a small sign at what steady speed he ought to travel to make the next light. This would seem to be cheaper and more adequate than six different computerized programs for various traffic densities--which are out of order most of the time.
- TSM ought to be also coordinated with all the other planning, maintenance, enforcement and public safety factors needed to foster low-energy mobility such as walking and bycicling.

4.38 <u>Law, institutions, information, education.</u>

The best policies for TEC and transportation in general are useless unless reflected in law, institutional implementation and enforcement, information access and utilization, and continuous education of all the actors. This implementation system is a subject for a whole separate study and analysis.

Only some current reference is made here:

- The Traffic Code (Ley de Vehículos y Tránsito), now being revised, does not reflect TEC concerns and has not an adequate philosophy of penalties. It ought to rewritten in this respect.
- The status and personnel of the traffic police (November 1976: 8.7% of all policemen, 7.2% of all police employees, no separate organizational status, as it had in the past) is severely out of line with the size and needs of the transportation system. The philosophy of enforcement is selective so that the police commanders determine in fact which law or laws (also noise, littering, etc.) will be enforced at what time.
- The recent internal reorganization of the DTOP is a step in the right direction. But this is only one agency involved. TEC and TSM

require close integration of policies and programs between DTOP, Office of Energy, Environmental Quality Board, Planning Board, Police Department, Public Service Commission, Department of Consumer Affairs, Public Instruction and perhaps still other agencies. If the forthcoming reorganization of the executive branch is intended to be more than a mere nominal simplification of the government's organogram, it should examine the "deep structure" of major social problems and issues, and shape the institutions accordingly. The transportation energy and management field is a strong candidate for this kind of analysis/synthesis.

- The inadequacy of the information system for policy analysis was mentioned at the outset of this study. There is much more information and know-how in Puerto Rico than has been effectively used in past decision making.
- When education is mentioned in connection with transportation, the meaning is usually limited to the basic knowledge of driving and of the rules of the road. Even in this narrow sense, a great deal remains to be done:
    - The driving practice of a considerable portion of drivers indicates deficient training and testing on both accounts.
    - The authorities do not inform drivers adequately about new rules. For instance, the new law extending the right-turn-on-red privilege (August 1977) was implemented at 80% of intersections a year later; but a substantial portion of drivers either did not know about it, or abused it to turn to left. A "campaign" was planned only in mid-1978.
    - Information about TEC should be included in drivers test; drivers should be periodically retested when their licence expires. Public service time on radio and television stations (some 12% of total broadcasting time) should be effectively used to enhance TEC.
    - Contrary to the belief in the effectiveness of driver education, it has been shown time after time that educational effort which is not reinforced by economic incentives and by police enforcement, is wasted. In a recent California experiment, 95,000 drivers were saturated with leaflets, tips and how-to-do information. Six months later, the rate of traffic violations and accidents in this groups was the same as in an "uneducated" control group (146, 2 April 1978). In a federally sponsored study (132, S3-34), information on energy conservation was found to be the least effective of four approaches. "Exhortation/prompting" was the last-but-one in effectiveness. Economic motivation was the most effective approach.
    - Apart from its continuity, education in the field of transportation in general and TEC in particular is probably most useful when it is not considered as a sector or element, but as a dimension and a transmission belt of applied knowledge, from the top decision makers, through the administrators and technicians, to the individual motor vehicle operators.

APPENDIX A.

SAN JUAN TRANSIT

OUTLINE OF A POLICY ANALYSIS FOR DECISION MAKING

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This memorandum, derived from the broader study, is made available in a preliminary and separate form to provide a specific policy focus on the San Juan Transit plans, in view of decisions on the concept which need to be made in the near future.

The analysis and conclusions reflect the best present judgment of the author on basis of data available to him. They do not express any position of the CEER.

October 1977.

Appendix A-2

AUTHOR'S NOTE

The designation of this paper as merely a working draft is not excessively modest. It was prepared for reasons and under time constraints that are explained in the text. In its _form_ it is a rush job with only rudimemtary random editing.

Hopefully, the concepts and analysis are presented in a clear and helpful fashion.

This rapid mobilization of the _substance_ was possible because the San Juan transit problem is conceived in this analysis as a particular problem of allocation and management of the total resources--human, energy, environmental, economic--in other words,an ecomanagement problem susceptible of being attacked by the particular kind of system analysis/synthesis which is the methodology of ecomanagement.

In this framework, the scattered pieces seem to fall in place enough to make possible the threshold decision. The ball is then back in the technical planners' court.

While the typescript was being readied, the American Public Transit Association met in Atlanta. Statements made there by federal and state officials confirmed the policy premises summarized in Section 2.2 below.

J. M.

Appendix A-3

SUMMARY

This memorandum draws attention to the policy defects of past planning and cost-benefit analysis related to the San Juan Transit (SJT).

It assumes that the next round of competition for federal funds will take place at the beginning of FY 1979. Very early decision in principle is necessary to meet this deadline with a competitive revised proposal. The state funding commitment must be accompanied by other advance steps related to Transportation System Management.

There appears to be a substantial convergence between the most pragmatic concept of the SJT and the present federal funding priorities.

The "Metro" alternatives of 1976 are analyzed under the assumption that the more simple, innovative and dollar-effective the SJT will be, and the more positive social cost-benefit ratio it will achieve, the higher the probability of securing federal funding. The social accounting includes not only capital costs and technical-operational factors such as speed and capacity, but also considerations of energy efficiency, land use economy, air quality, safety and long-range flexibility.

To enhance both the economic feasibility and the social balance of the SJT, an innovative approach to the dominant mode and to its interface with the private vehicle transportation sector, is unavoidable.

The concept which appears best justified in terms of a synthesis of the various policy consideration is proposed for technical and economic reevaluation. It is a modified Poly-Modal Alternative, organized around Light Rail Transit, with predominant at-grade guideway, no subway section(s), and operating in a pedestrian environment along the "Spine" --the Old San Juan to Río Piedras corridor.

Supportive concepts, incentives and disincentives are exemplified.

The available data are considered sufficient to justify an intuitive strategic decision with a time horizon well into the 21st century.

REPEATEDLY USED ABBREVIATIONS

AB Advanced Bus alternative
AMA [San Juan] Metropolitan Bus Authority
B Billion
BC Bayamon Crescent alternative alignment
BTU British Thermal Unit
HR Heavy Rail
IB Improved Bus alternative
LR Light Rail
LRT LR Transit
LRV LR Vehicle
M Million
MPG Miles per gallon
NS North-South alternative alignment
PMA Poly-Modal Alternative
PMS Poly-Modal System
PMT Passenger miles travelled
PVTS Private vehicle transportation system (on sector)
ROW Right-of-way
SJMA San Juan Metropolitan Area
SJT San Juan Transit
TSM Transportation System Management
UMTA [U.S. Department of Transportation] Urban Mass Transportation Administration

The "Spine" is the Old San Juan - Santurce - Río Piedras segment of the BC or the PMA alignments.

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Planning any transportation system is not primarily a techno-economic problem, but a complex, interrelated process of decision making about, and management of, human, social and environmental resources. The policy analysis in this memorandum aims at supplementing the technical submodel of the <u>SJT</u> with considerations derived from a broader social model. The limited function of such an exercise is to raise questions at the technical end, and to stimulate the process toward a timely and justifiable go-ahead decision.

1.1 <u>Basic propositions concerning past and future-oriented transportation planning in Puerto Rico are listed</u>

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2. FEDERAL FUNDING ENVIRONMENT AND TIMETABLE 3

A threshold policy question as to whether exclusive state level funding of <u>SJT</u> could or should be considered is posed, based on some comparative data about allocation of capital funds in the transportation sector; and on the possibility of constraints which federal funding might impose on the most cost-effective procurement of equipment for the <u>SJT</u>. The memorandum is, however, based on the general assumption that federal funding will and should be sought.

2.1 <u>Possible arguments in favor of exclusive state funding are exemplified</u>

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based on some questionable premises and they are not economically feasible as presently conceived. <u>SJT</u> with Light Rail as the dominant mode, operating almost entirely at grade --and in a pedestrian mall environment throughout the length of Ponce de León Avenue, from Old San Juan to Río Piedras--is proposed as a concept which is feasible economically and offers considerable opportunities for simultaneous urban and social enhancement. Other opportunities which such total transit planning affords--such as the transformation of Old San Juan in a pedestrian city, and a waterway from Old San Juan to Carolina North--are suggested. Aspects of a decision in favor of the new SJT concept are discussed.

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The decision about San Juan Transit can not be based on engineering and economic data alone. When the whole transportation and social model is considered within the indicated time frame of several decades, the data base and the policy vectors become so complex that the decision on the principle must be intuitive. The empirical and analytical data available are considered sufficient to make an informed intuitive decision now 39

APPENDIX B.

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