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Pam — So where do we & GOT go from here? What action & who's got it? Jim Beyer 2/22/84

TRANSPORTATION ENERGY USE AND EFFICIENCY

IN TUNISIA

Final Report

A Joint Project of the Government of Tunisia and the
U.S. Agency for International Development

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We also thank our American colleagues Mr. Richard Stevenson, Ms. Pamela Baldwin, Mr. Allan Evans, Mr. James Gibbs, and Ms. Maria-Elena Dubourt for their many contributions and dependable support.

For whatever errors may be present in our analysis, we take responsibility. It is our hope that this study will in some way reflect the diligent efforts of our Tunisian counterparts and serve them as one piece of the foundation they are building for energy policy research.

Foreword

This report constitutes a final report of resesarch by Oak Ridge National Laboratory in collaboration with staff of the Ministry of National Economy, Government of Tunisia toward a complete report of transportation energy use and efficiency in Tunisia. The report includes chapters on highway passenger transportation, marine, and rail transportation which are substantially complete. Additional data on taxis, louages (intercity taxi's) and privately owned large trucks remain to be gathered. Some key tables have been included. Data were not collected for an analysis of the air and pipeline modes.

The major achievement of this report is a detailed analysis of the National Survey of Vehicle Energy Use, an extensive survey of automobiles and light trucks under 3.5 tonnes. Though the data have some significant shortcomings they provide valuable insights into energy use and efficiencies of this most important transport mode. This study by no means exhausts the usefulness of this data base for energy use and conservation analysis. The National Survey will very likely serve as a valuable resource for research studies for years to come.

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I. Summary and Recommendations

Introduction

Energy use in Tunisia's transportation sector grew at an estimated annual rate of over 7 percent from 1975 to 1981 despite steep increases in world petroleum prices, and periods of slow economic growth (Figure I.1, Table I.1). Over 60 percent of this estimated increase is attributable to increased diesel (distillate) fuel consumption and as much as one-third of the total estimated increase may be due to increases in light truck diesel use alone. Only about 10 percent of the increase can be attributed to greater gasoline use.

Total transport sector energy use in 1981 is estimated to have been 683 thousand tonnes equivalent petroleum (TEP). Of this, 378,000 TEP (55 percent), and perhaps a bit more, is diesel fuel (Figure I.2, Table I.2). Gasoline is second in importance at 136,000 TEP (20 percent), followed closely by jet fuel 131,000 TEP (19 percent). Residual fuel is consumed by ships, exclusively, and its apparent consumption fluctuates considerably from one year to the next. This may indicate substantial sales to foreign vessels.

Highway transport is by far the largest energy consuming mode, accounting for an estimated 295,000 TEP of diesel fuel and 136,000 TEP of gasoline in 1981. This represents 63 percent of total transport energy use in that year. Highway consumption may actually be 5-10 percent higher than the estimates reported in Table I.1, since no data were available on privately-owned and operated heavy trucks.

This report concentrates on analysis of energy use and efficiency in highway transportation. In particular, the National Survey of Vehicle

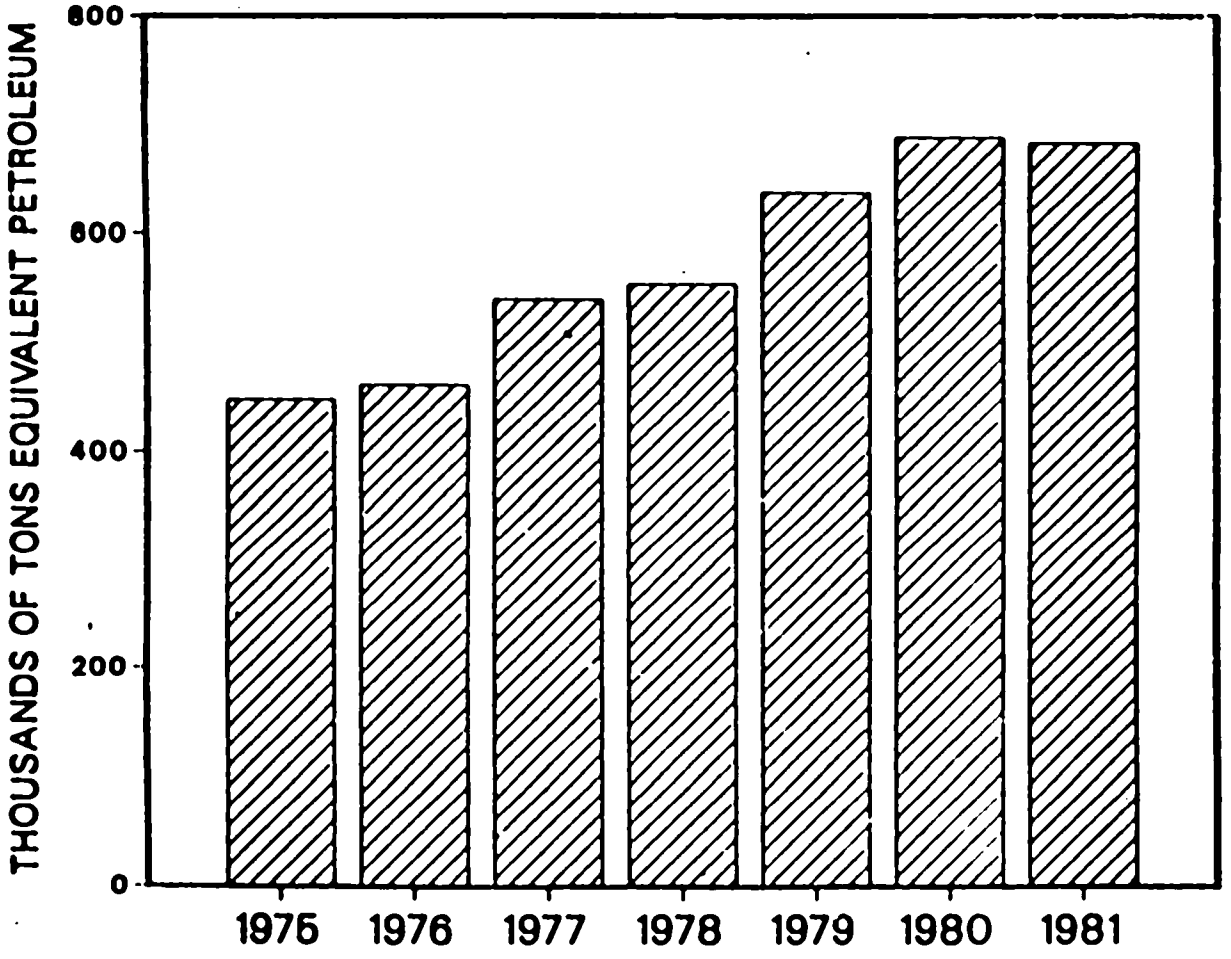

Figure I.1. Estimated Total Consumption of Transport Fuel in Tunisia.

Table I.1. Estimated Consumption of Transport Fuel in Tunisia 1975–1982
(thousands of tonnes equivalent petroleum)

	1975	1976	1977	1978	1979	1980	1981	1982
			Diesel					
Highway								
Automobile[a]	33.2	35.0	35.8	36.9	37.3	39.0	40.9	42.9
Light truck[b]	59.9	70.4	81.4	93.9	112.8	124.4	145.7	151.7
Heavy truck (part)[c]	20.5	20.3	24.5	24.6	26.4	29.1	32.1	NA
Bus[d]	35.4	36.3	43.0	43.7	45.0	45.5	48.2	NA
Taxi, louage[b]	19	20	20	22	24	26	28	30
Marine	43.0	48.4	46.1	55.6	69.1	61.5	56.2	64.9
Rail	20.9	19.9	22.0	21.9	22.7	24.5	26.7	NA
TOTAL	231.9	250.3	272.8	298.6	337.3	350.0	377.8	-
			Gasoline					
Automobiles[a]	110.5	116.6	119.3	122.9	124.3	129.9	136.3	144.0
			Residual					
Marine[e]	13.2	-	56.0	37.1	56.1	61.9	37.6	29.4
			Jet Fuel A					
Air[f]	92.2	94.0	90.4	94.0	119.3	146.0	131.0	121.3
TOTAL	447.8[e]	460.9[e]	538.5	552.6	637.0	687.8	682.7	-

What's definition? Includes 5.5 Ton Trucks?

[a]Assumes all gasoline use is by cars and uses total fuels sales data rather than estimates based on the National Survey of Vehicle Energy Use. Diesel use estimated as a constant fraction (0.3) of gasoline use.

[b]For an explanation of the method used see Appendix 3. Values in Table A.3.1 have been converted to tonnes equivalent petroleum.

[c]Excludes privately owned heavy trucks; includes only fuel use by the STM and SRTG's.

[d]Tour bus energy use estimated at 10% of total public bus energy use prior to 1981.

[e]Numbers before 1977 inconsistent with 1977 values.

[f]Total jet fuel A1 sales.

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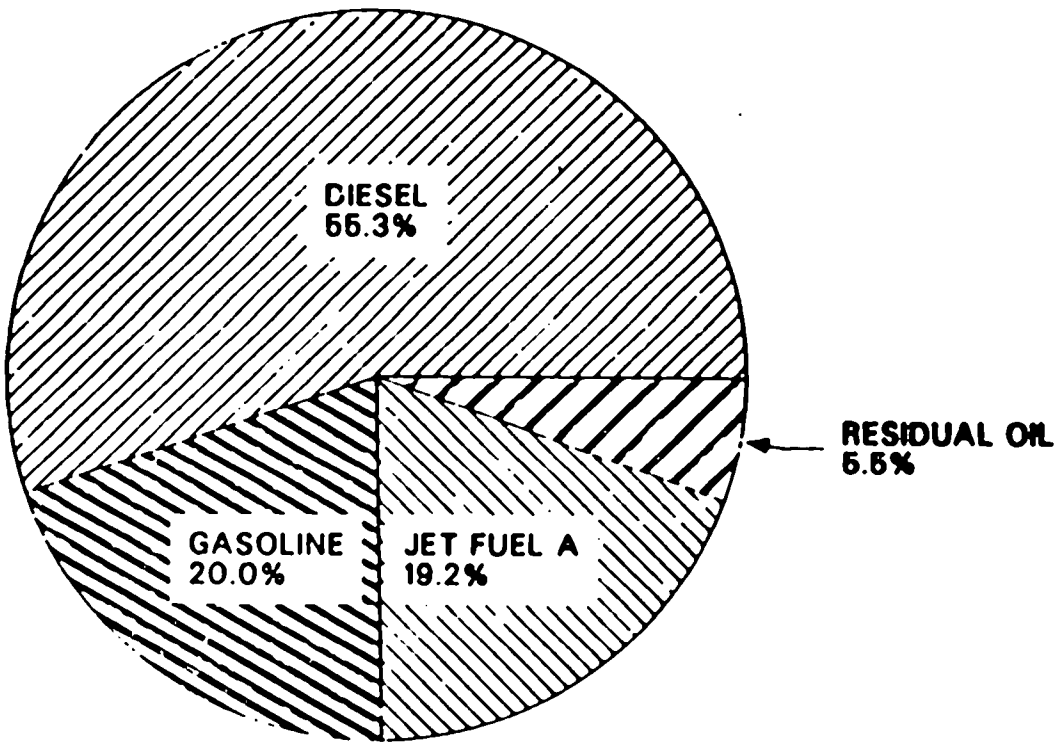

Figure I.2. Transportation Fuel Use by Type
Tunisia, 1981.

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Table I.2. Estimated Transportation Energy Use in Tunisia, 1981*
(tons equivalent petroleum)†

	Diesel		Regular gasoline	Premium gasoline	Residual oil
	1982	1981	1982		1981
Highway*					
Automobiles	42,882	-	35,646	89,926	
Light trucks	151,659	-	-	-	-
Heavy trucks (part)**	-	37,145	-	-	-
Buses	-	48,550	-	-	-
Taxis, louages	30,000	-	-	-	-
TOTAL HIGHWAY		310,236	35,646	89,926	
Rail					
Autorails		5,346			
Manoevres		1,967			
Locomotive de ligne		19,391	-	-	-
TOTAL RAIL		26,704			
Marine		56,225	-	-	37,649
			Gasoline		
Government (excluding agriculture)		16,982	- 2,734 -		
RAIL, HIGHWAY, MARINE* GOVERNMENT TOTAL		410,147	128,306		37,649
TOTAL FOR ALL FUEL TYPES* = 576,102					

*Highway use estimates for cars and light trucks are for 1982. They should be reduced 10% to approximate 1981 values.

†Conversion to TEP using 1.030 TEP/tonne, specific gravity of 0.83 for gasoil; 1.044 TEP/tonne, specific gravity of 0.74 for gasoline; 0.970 TEP/tonne, specific gravity of 0.95 for residual oil.

**Includes energy use by transportation company trucks only. Private heavy trucks may be half or more of the heavy truck population.

probably lots more!

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Energy Use, a new source of information on automobile and light truck energy use, is examined in detail. This new survey has provided a wealth of information on patterns of energy use and energy efficiencies of light duty highway vehicles. Additional data on bus and trucking company activities enable a reasonably complete accounting of highway energy consumption. These data are supplemented by crude estimates of taxi, long distance limousine (louage), and tourist bus energy use. Still missing are any data on privately-owned heavy trucks. Reasonably good data on railroad operations show that the mode's energy use has grown at about half the average annual rate for the sector as a whole, and roughly in proportion to the total tonne-kms carried. For the marine and air modes, fuel consumption statistics only are presented. Data on operations did not become available in time to be included in this study.

This report represents a first, yet substantial, effort to describe energy consumption and efficiency patterns and trends in the Tunisian transportation sector. Although important work still remains to be done, the description is substantially complete. The first part of this summary chapter presents the major findings of the study. The second part contains observations and suggestions on ways to improve efficiency and conserve energy.

Most transport fuels are mode-specific. Virtually all gasoline use is by automobiles with an unestimated but demonstrably small quantity consumed by motorcycles and mopeds. Jet fuel consumption is by commercial airlines and only the maritime mode uses residual oil. Diesel fuel

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is the exception. It is a multimodal fuel, consumed by automobiles, trucks, buses, locomotives, and ships.

Extremely rapid growth in diesel use by light trucks, associated with rapid growth of the light truck stock, is largely responsible for the overall high rate of increase in diesel fuel use. Light truck diesel use is estimated to have ballooned from 60,000 TEPs in 1975 to 152,000 in 1982, an average annual growth rate of over 14 percent. Most of the diesel time series, however, had to be estimated by methods described in Table I.1 and Appendix 3. For this reason, these conclusions must be regarded with caution. In addition, the figures in Table I.1 exclude privately-owned heavy truck fuel use which is unknown but could well be on the order of 10% of total transportation diesel use. lots of [illegible] include 5.5% trucks

Fuel sales to air and marine modes show unusual patterns over time. Jet fuel sales shot from 94,000 TEP in 1978 to 146,000 TEP in 1980, only to fall back to 121,000 TEP in 1982. Marine residual deliveries dropped from 56,000 to 37,000 TEP in 1978 but bounced back to 62,000 TEP in 1980. In 1982 residual sales to ships had fallen to 29,000 TEP. Fluctuations in marine diesel sales were less extreme, but still rather unusual. An investigation of the causes of these patterns was not carried out but Ministry of National Economy staff indicated that the 1980 peak in jet fuel sales was caused by foreign carriers purchasing subsidized Tunisian jet fuel. Such practices are costly to the Tunisian government and the possibility that they are occurring in the marine mode should be investigated.

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Summary

Transportation energy use in Tunisia is substantial, nearly 700,000 TEP in 1981. Furthermore it has been growing rapidly, at a rate of roughly 7% per year, since 1975. Diesel fuel (distillate) is by far the major energy source, accounting for 55 percent of the estimated 683,000 TEPs used in 1981. It is estimated that transportation use of diesel fuel has grown from about 230,000 TEP in 1975 to nearly 380,000 TEP in 1981, an average annual rate of over 8 percent. Gasoline use has grown only about half as fast as the total, averaging 3.6% per year from 1975 to 1981 (Figure I.3). Jet fuel, and marine fuel sales show unusually erratic growth patterns over the same period.

Much of this report is concerned with analysis of the "Enquette Nationale sur la Consommation Energetique des Vehicules" (National Survey of Vehicle Energy Use), a major survey of automobiles and light trucks undertaken by the Ministry of National Economy in 1982. Prior to this survey little was known about the usage rates of light vehicles and almost nothing was known about their energy use and efficiency. Indeed the size of the light vehicle stock and its composition had to be estimated in order to expand the survey results. The survey has been shown to be an important source of detailed data on the composition of the vehicle stock, its utilization, its energy efficiency, and energy consumption. Appendix 4 analyzes these questions in detail. Tables I.3–5, reproduced here, summarize the principal results with respect to composition of the stock, usage, and energy use. Of the estimated 152,000 light vehicles in use in Tunisia in 1982, almost 94,000 were private

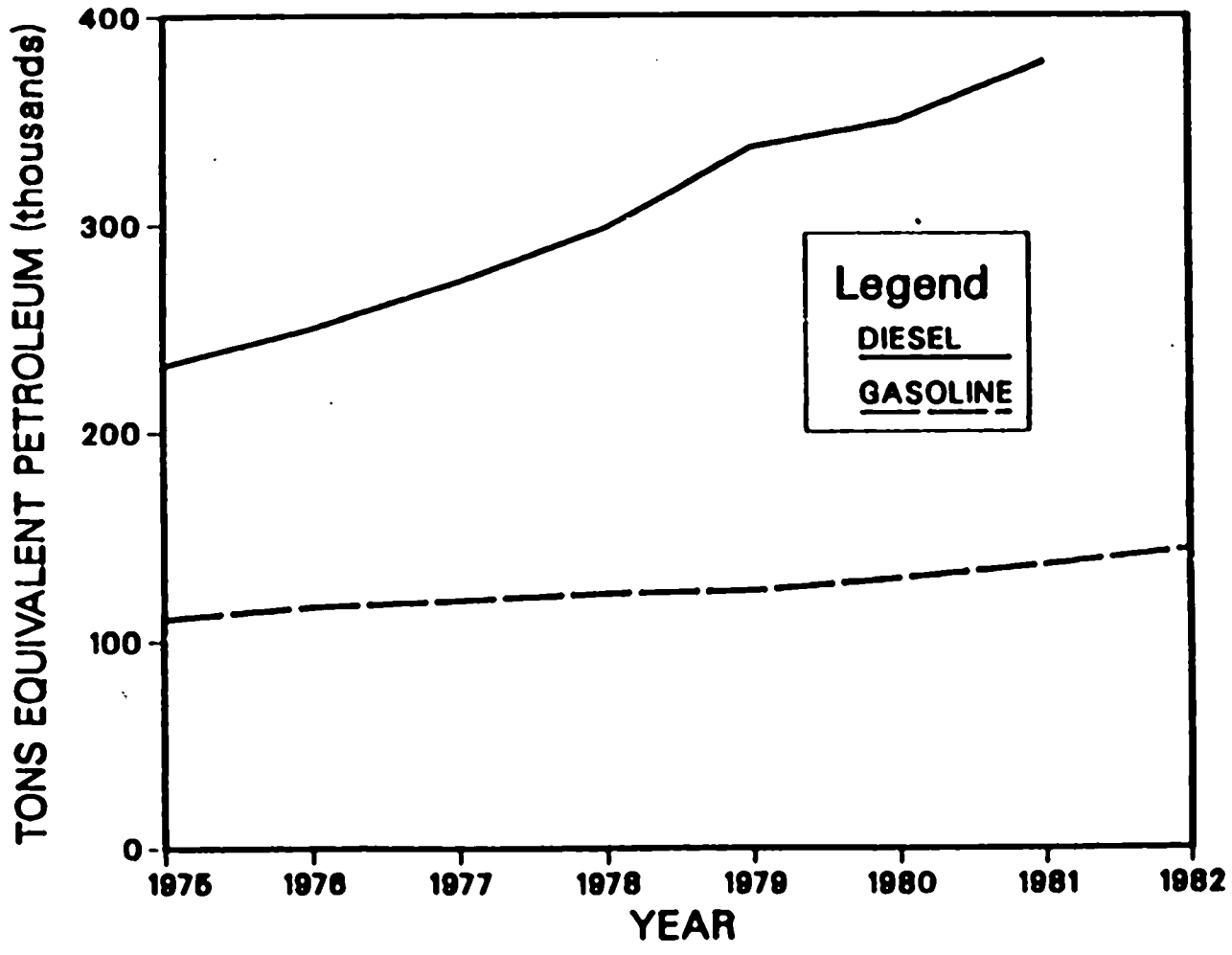

Figure I.3. Estimated Consumption of Transport Fuel in Tunisia 1975–1982.

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Table I.3. Adjusted* Estimates of Number of Vehicles by Type and Fuel Type Based on Inspection Center Sample

	Regular gasoline	Premium gasoline	Diesel	Propane	Total
Private car	26,567	55,526	11,263	348	93,704
Private light truck	227	209	32,681	127	33,244
Company car	2,643	11,634	2,414	110	16,801
Company light truck	84	155	8,131	254	8,624
Total	29,521	67,524	54,489	839	152,373

*Adjusted by correction for missing values by fuel type.

Table I.4. Estimated Annual Kilometrage for Light Vehicles

	Regular gasoline	Premium gasoline	Diesel
Private car	18,866	18,798	45,178
Private light truck	-	-	47,630
Company car	24,699	30,313	47,943
Company light truck	-	-	52,310

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Table I.5. Estimated Light Vehicle Fuel Efficiencies (liters/100 Km)

	Regular gasoline	Premium gasoline	Diesel
Private car	7.81	8.56	8.23
Private light truck	-	-	8.73
Company car	9.14	7.53	7.34
Company light truck	-	-	9.10

cars, and 33,000 were private trucks. Approximately 25,000 were company-owned vehicles. Essentially all of the light trucks (97.5%) are diesel powered. Less than twenty percent of the automobiles are diesel.

Analysis of data in the National Survey of Vehicle Energy Use revealed that diesel-powered light vehicles are driven twice as many kilometers as gasoline-powered vehicles (Table I.4). This may be due in part to the fact that most diesel vehicles are light trucks, in part to the fact that diesels are on the whole much newer vehicles, but it must also be partly due to the low cost of diesel fuel. In addition, the average fuel efficiency of diesel-engine vehicles in Tunisia is not noticeably better than gasoline-fueled vehicles (Table I.5). This result was supported by a regression analysis of efficiencies controlling for the mix of makes and models of vehicles. Due to the inherently greater efficiency of the diesel cycle over the otto engine cycle, diesels should, in theory, be about 30 percent more efficient. The failure to achieve this theoretical superiority in energy efficiency may be costing in the vicinity of 30–40 million liters per year, or about 30-40,000 TEP or 5% total Transport (E) use. 1b

As a result of their higher usage rates and comparable ℓ/100 Km, diesel light trucks and automobiles consume almost 40 percent more fuel than gasoline light vehicles despite the fact that they comprise only 36 percent of the vehicle stock.

The effects of vehicle maintenance practice on automobile and light truck fuel economy were explored by means of regression analysis. The results indicated that vehicles which had recently taken actions which reduced vehicle rolling resistance, which used a multiviscosity lubricating oil, or which used radial tires achieved better fuel economy. Efficiency improvements on the order of 10 percent per inadequately maintained vehicle should be readily achievable through these and other improved vehicle operating procedures. Some options, such as the use of radial tires, are already widespread among automobiles and thus little potential remains. Others such as the use of "fuel saver" oils are apparently not. Here government information and product labeling programs could help accelerate the adoption of these energy saving products. Maintenance practices (e.g. front end alignments, tune-ups, lubrication, brake adjustment) are clearly beneficial from an efficiency viewpoint. Their benefit to an individual vehicle, however, is entirely dependent on its current state of repair.

Energy efficiencies were estimated by fiscal horsepower (CV) class for the most common vehicle types in the National Survey to see whether the CV classification constituted a reasonable basis for vehicle efficiency taxation. The results suggest that CV class is a reasonable indicator of fuel efficiency. Before any taxing policies are made on

this basis, however, the engineering basis for the relationship between CV class and vehicle efficiency should be studied to determine what variance within classes is likely. Since efficiencies vary greatly from one vehicle to another, and since the technical efficiency of the vehicle stock is the primary and overwhelming determinant of realized efficiency (operational factors are, relatively speaking, minor determinants) it is suggested that the government consider a program of fuel economy information and labeling to assist consumers in making intelligent choices among vehicles. Energy efficiency should also be a factor considered in deciding which vehicle types to produce domestically.

The energy use of public buses is reasonably well known thanks to statistics provided to the Ministry of National Economy by STN (Societé de Transport Nationiale) and the SRTG's (Societés Regionales de Transport de Gouvernovats). Very high load factors are the primary reason the bus system is relatively efficient. Improved maintenance and careful consideration of the efficiency of vehicles purchased could probably improve efficiencies even further. The same observation applies to passenger rail service. Here the data clearly show that the introduction of energy inefficient equipment in 1980 increased fuel consumption rates. Still, overall, the passenger rail system is efficient by world standards due to its high load factors.

Truck energy use and efficiency data provided by SRTG's show large fluctuations from year-to-year which are not well understood. A simple statistical analysis has indicated that they are probably not due to

changes in the density of cargo (although it 's possible that data errors may have obscured an underlying relationship). Data provided by the STM (Societé de Transport Marchandises) show that for this second largest trucking company, increased energy intensity per vehicle mile is primarily due to increases in average truck size. Almost nothing is known about the energy use characteristics of heavy trucks not owned by transport companies. Their energy use has been excluded from this analysis, although it is probably on the same order of magnitude as energy use by the STM and SRTG's. The trucking mode is an area where additional data collection and analysis of non-company activity are warranted.

Energy use by taxis and louages (intercity taxis) is not well known although it appears they are substantial consumers of diesel fuel. A small scale effort to secure additional data is warranted.

For the marine sector, only total sales to marine operations and total consumption by the CTN are known at this time. The substantial excess of diesel sales over CTN consumption and the large deficit of residual oil sales relative to CTN consumption suggests the possibility that the prices of these fuels may not be in balance with prices in other Mediterranean ports. It is also possible that a large fraction of diesel sales are to smaller craft not operated by CTN. These questions should be looked into to determine whether changes in marine diesel prices are warranted.

Recommendations

Tunisia, like other less developed countries, faces a confluence of trends toward increasing petroleum use in the transportation sector. Economic development has generated rapid growth in the demand for both passenger and freight transportation services. At the same time the energy efficiency of transportation services is generally not improving or is decreasing. Finally, petroleum-based fuels either totally dominate the transport modes or are increasing in importance. As a result, economic growth generates rapidly increasing petroleum use in the transportation sector. This basic problem may be compounded by policies to subsidize freight transport fuels either directly or by controlling distillate fuel price with the intent of subsidizing agriculture or domestic heating. In fact, the majority of the fuel subsidy may be going to the transport sector where the low price will fail to stimulate needed efficiency improvements.

The Tunisian Government has made a very considerable effort to collect and analyze transport energy data, yet there still remain some gaps where additional information and further research are necessary. The first part of this section offers recommendations of areas where further research and data collection would prove beneficial. In many areas, however, existing information is sufficient to identify specific conservation policies which could be effective. Finally, and perhaps most importantly, the pattern and growth of consumption by mode and fuel type suggests that fuel pricing policies should be reconsidered.

Specific recommendations for each of these three areas are offered below.

Research and Data Needs

For Tunisia, the most important research areas are energy pricing policy effects and determining the energy savings and other impacts of policies to improve the efficiency of the stock of vehicles. In particular, what would be the impacts on the people and the economy in general of an increase in diesel fuel price to a level comparable to the price of gasoline? Also, what would be the effect of a vehicle taxation policy designed to encourage ownership of the most fuel efficient vehicles, and how should such a tax structure be designed? Finally, are there ways that industrial development policy can be used to promote energy conservation? Since locally produced motor vehicles will be given substantial market advantage, is it possible to produce only the most energy efficient vehicles locally?

It may be surprising to researchers accustomed to developed countries to discover how little is known about the stock of vehicles in use in Tunisia. Knowledge of the stock and its evolution is critical to estimating and understanding historical energy use and also forms a key element of predicting future energy use. The first item to be studied should be the evolution of the stock; separately for automobiles, light trucks, and heavy trucks. Secondly the evolution of its composition by type of fuel and puissance fiscale (size), or charge utile (capacity) in the case of trucks. Three items of data are relevant: 1) new registrations (immatriculations), 2) the estimated stock size, and 3)

vehicle scrappage or retirements. Such data are important to understanding how policies designed to improve the energy efficiency of the stock will affect energy demand.

The primary missing piece of the Tunisian transportation energy use picture is private heavy truck energy efficiency and use. We know that the national transport companies' vehicle stocks contained about 1600 vehicles in 1981. We also know that the Ministry of Transport computer data base indicates 3987 class 5 (heavy trucks) vehicles in 1981. Judging from the automobile and light truck stock estimates in this data base this probably represents 75–100% of the heavy truck stock. Thus, we have accounted for probably 30–40% of the truck stock over 3.5 tonnes capacity. Consumption of diesel fuel by the remaining portion of the truck stock is probably considerable. yes, I'd say so.

A third area for further study is appropriate methods for developing transportation energy use trends and forecasts. Most methods would involve projection of the growth of the energy-using stock which highlights the importance of the vehicle stock data. Most likely one would want to develop models capable of forecasting energy demand dependent on economic conditions and also of predicting the effects of prices, vehicle taxes, and stock efficiency improvements on energy use. The challenge is to develop models which are simple yet capture the process of stock evolution, efficiency, and usage, and which can be calibrated using existing data. The modeling approach should be transferable to other developing countries.

Finally, the Ministry of National Economy should be encouraged to produce an annual publication of transportation energy use estimates. This would serve at least two useful purposes. First, it would be an information resource provided by the Ministry to the rest of the country as a tangible result of the energy research. Second, it would focus attention within the Ministry on missing data and data inadequacies. These problems could be attacked and resolved in succeeding editions of the publication.

Transportation Energy Conservation Policy Recommendations for Tunisia

The results of the comprehensive study of transportation energy use in Tunisia indicate two general areas in which governmental action could promote energy conservation: 1) pricing and taxation of both fuel and vehicles, and 2) direct efficiency initiatives. The recommendations below are those which, in our judgement, appear to have the greatest conservation potential and which are most likely to be economically justifiable.

Pricing and Taxation Issues

The primary pricing issue, indeed the paramount issue overall is the price of diesel fuel. Maintaining a very large price differential between gasoline and diesel fuel, essentially perfectly substitutable transportation fuels, has created a tremendous incentive for diesel fuel use. This is evident in the very high utilization rates of diesel vehicles, in their unexpectedly small efficiency advantage over gasoline-powered vehicles, and in the rapid growth in the diesel stock. It is

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Is it subsidies?

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also possible that the low internal price of diesel fuel has encouraged excessive sales of marine diesel to foreign flag vessels. For all these reasons, it is appropriate to study the impact of increasing diesel fuel prices on the various economic sectors and sectors of the population. The data gathered to date are virtually sufficient in themselves for the transport sector portion of that study.

The question of sales of marine diesel fuel also seems worth investigating. If foreign flag vessels are being subsidized, this is clearly undesirable.

Finally, the possible use of the "puissance fiscale" (fiscal horsepower) classification, or some other, as a means of encouraging the registration of more efficient vehicles by means of excise or vehicle registration taxes should be investigated. This would include an evaluation of the engineering basis for the relationship between "puissance fiscale" or CV ratings and energy consumption rates. In this same vein, it is clear that the decision to manufacture a certain type of vehicle in Tunisia gives that vehicle type a tremendous advantage in price and availability over imported vehicles. Thus the efficiency of particular vehicles should be a consideration in the decision to manufacture domestically. This could well have the greatest influence of any single policy measure on the future evolution of the efficiency of the vehicle stock. Moreover, it is the technical efficiency of the vehicle stock which is the single most effective and most significant conservation measure.

Efficiency Initiatives

It appears that numerous opportunities for improving the energy efficiency of the existing stock of transportation equipment exist. Some are listed below.

(i) Radial tires for light trucks. It appears that while virtually all cars have radial tires, many light trucks are equipped with bias ply tires which have higher rolling resistance and thus increase fuel consumption in the neighborhood of 5%. This is ironic since light trucks travel twice as many miles per year as the average car and are somewhat more energy intensive. Since radials tend to last about twice as long as bias ply tires, the extra cost of radials should be recouped in two to four years based on extended tire life alone. In addition, the potential energy savings are on the order of 5 million liters of diesel fuel per year. ≈ 5000 TEP/yr

(ii) Encourage energy efficient vehicle maintenance. Analysis of the survey data indicates that certain maintenance actions could significantly improve the efficiency of a large portion of the vehicle fleet. A very low cost package of energy efficiency options could be developed and demonstrated. It should consist of the following kinds of items: checking and adjustment of idle fuel flow, idling speed, front wheel alignment, brake adjustment, tire pressure to maximum psi; changing of oil to fuel saver "SF" grade, replacement of air filter, lubrication of wheels.

(iii) Energy efficiency audits for truck and bus companies.

(iv) Public information programs to promote more widespread use of fuel saver oils and maintenance of tire pressures.

(v) Public information program on vehicle efficiencies. This will require the government to adopt a standard measure of vehicle efficiency such as the DIN standard. Two measures, one for congested driving conditions and one for free flowing driving, are better than one since they enable individuals to adjust the estimate to their own conditions.

Other initiatives are, of course, possible and worthy of consideration. Based on results of the Tunisian energy study, however, these appear to be the most significant ones.

Organization of the report

The organization of the remainder of the report is as follows. Chapter II is a detailed analysis of the Survey. Part II.A presents general results from the survey and examines its statistical validity. Part II.B develops estimates of energy use and efficiency by vehicle type and fuel type. Section II.C presents a regression analysis of vehicle fuel efficiencies on maintenance practices and other vehicle characteristics. Chapter III presents energy use data for buses, taxis, and louages, and Chapter IV deals with highway freight transport. No attempt to deal with private heavy truck energy use was made. Rail passenger and freight activity is the subject of Chapter V, while Chapter VI deals with marine energy use. Finally, Chapter VII presents a partial accounting of energy use by government vehicles.

II. Automobiles and Light Trucks

Until now, very little has been known about the energy consumption patterns of automobiles and light trucks in Tunisia. In 1982–83, as part of this study, the Tunisian Government carried out an ambitious survey of light vehicle energy use and efficiency (Enquette Nationale sur la Consommation Energetique des Vehicules). In its method, scope, and detail, this survey is probably unique in the world. Its significance, therefore, extends beyond the information it provides on the Tunisian energy situation since it may become a seminal effort for other countries. This chapter, supplemented by Appendix 4, delves into this survey in detail, considering its validity as well as drawing inferences regarding patterns of energy use and efficiency. The survey data are judged to be reliable, despite some potentially serious threats to their validity. This having been established, Section B develops estimates of energy consumption by vehicle type and fuel type. The analysis of effects of maintenance practices on operating efficiency in Section C illustrates the potential usefulness of the survey data for detailed, disaggregated analyses of energy use and conservation potential.

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II.A The Car and Light Truck Energy Consumption Survey

In 1982–83 a national survey of light duty vehicles (cars and trucks under 3.5 tonnes) was undertaken to determine their energy use and efficiency. A sample of 10,628 vehicles was taken at vehicle inspection centers (centres de visite technique) in Tunis, Sousse, Medenine, Sfax, and Kef. While the sample design calls for the inclusion of disproportionate numbers of company vehicles, virtually all the vehicles finally included were private vehicles. Out of the total of 10,628, 9,976 or 94% were privately owned. According to INS data presented above, 15% of the vehicles in the five centers are owned by companies, however, only 6% of the sample consists of company vehicles (Table II.A.1). Thus, company vehicles are somewhat underrepresented, apparently due to difficulties encountered in following up on company vehicle visits to the inspection centers to collect a complete set of answers to the survey questions.

The initial inspection station questionnaire collected basic data on the type of vehicle, its ownership, type of fuel used, number of engine overhauls, motors installed, odometer reading and cycle, position of fuel gauge indicator, date of first registration, and other factors dealing with usage and maintenance (a copy of the Centre de Visite Technique, CDVT, questionnaire is displayed in Appendix 1). Distribution of the responses by several of these variables can be seen in Tables II.A.2 and II.A.3. Just over half of the vehicles in the sample are fueled by gasoline, just under half by diesel, and about 1% by propane and other or unreported fuel types. As shown in Appendix 4, the vast majority of vehicles powered by diesel are light trucks.

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Table II.A.1. Distributions of Respondents* and Nonrespondents to Postcard Survey (percent in parentheses)

	Tunis	Sousse	Medenine	Sfax	Kef	Total
Nonrespondents	2391 (28.5)	2054 (24.5)	1498 (17.8)	1372 (16.4)	1075 (12.8)	8390 (78.9)
Respondents	671 (30.0)	459 (20.5)	318 (14.2)	419 (18.7)	371 (16.6)	2238 (21.1)
Total	3062 (28.8)	2513 (23.7)	1816 (17.1)	1791 (16.8)	1446 (13.6)	10628 (100.0)

	Private car	Private light truck	Company car	Company light truck
Nonrespondents	4990 (59.5)	2904 (34.6)	326 (3.9)	170 (2.0)
Respondents	1298 (58.0)	784 (35.0)	86 (3.8)	70 (3.1)
Total	6288 (59.2)	3688 (34.7)	412 (3.9)	240 (2.3)

*Includes only those respondents who could be matched to an Inspection Center questionnaire.

Table II.A.2. Distributions of Respondents* and Nonrespondents to Postcard Survey (percent in parentheses)

	Fuel type				Total
	Regular gasoline	Premium gasoline	Diesel	Propane	
Nonrespondents	1815 (21.9)	2598 (31.3)	3863 (46.5)	26 (0.3)	8302 (78.9)
Respondents	450 (20.2)	740 (33.2)	1019 (45.8)	17 (0.8)	2226 (21.1)
Total	2265 (21.5)	3338 (31.7)	4882 (46.4)	43 (0.4)	10528 (100.0)

	Vehicle age group					Total
	0–4	5–9	10–14	15–19	20 or more	
Nonrespondents	3065 (39.6)	2047 (26.4)	1329 (17.2)	854 (11.0)	447 (5.8)	7742 (78.7)
Respondents	979 (46.6)	486 (23.1)	309 (14.7)	197 (9.4)	129 (6.1)	2100 (21.3)
Total	4044 (41.1)	2533 (25.7)	1638 (16.6)	1051 (10.7)	576 (5.9)	9842 (100.0)

Table II.A.3. Distribution of the CDVT Sample

	Frequency	Percent
Type of fuel		
Type		
Regular gasoline	2,265	21.3
Premium gasoline	3,338	31.4
Diesel	4,882	45.9
Propane	43	0.4
Other and no answer	100	0.9
Odometer cycle		
Cycle		
First	3,583	33.9
Second	5,008	47.4
Third	1,972	18.7
Other and no answer	(65)	-
Engine rebuilds		
Number		
0	5,942	55.9
1	3,257	30.6
2	1,111	10.5
3	227	2.1
4	91	0.9
Engine replacements		
Number		
0	9,964	93.8
1	605	5.7
2	48	0.5
3	9	0.1
4	2	0.0

The original intent of the survey was to survey equal numbers of vehicles in each month. Operational difficulties, however, resulted in an uneven monthly distribution. As Table II.A.4 shows, the distribution by season of the year is reasonably even. With the distribution shown, a 10% above average rate of travel in the summer and a 10% below average rate in the winter, the given distribution would result in a bias in the estimated rate of travel of about three-tenths of one percent. Thus, the given distribution should be considered sufficiently uniform for all practical purposes. No seasonal reweighting of the sample is made in this study.

At the inspection station each vehicle selected for the survey was given five postcards to fill out and return at the next five refuelings of the vehicle. On these were to be recorded the amount and cost of the purchase, the fuel gauge indicator position before and after the purchase, the odometer reading, and date of purchase. Of the 10,628 vehicles survey at the CDVTs, 2,329 returned at least one card. Almost twenty percent, however, returned only one card, while 42% returned all five cards (Table II.A.5). Of the 2,329 postcard responses, 101 lacked identification numbers or had numbers which could not be matched with identification numbers in the CDVT sample. Of the remaining 2,228 records, 438 had only one card and 75 had serious errors. For these it is unlikely that even roughly accurate fuel economy numbers could be computed.

The very low response rate to the Carte Postale (CP) survey, only 22%, raises serious questions about the representativeness of this survey.

Table II.A.4. Distribution of Inspection Center (CDVT) Sample by Months and Seasons

	Frequency	Percent
March	963	9.1
April	1252	11.8
May	996	9.4
Spring	3211	30.2
June	886	8.3
July	739	7.0
August	911	8.6
Summer	2536	23.9
September	719	6.8
October	541	5.1
November	729	6.9
Fall	1989	18.7
December	961	9.0
January	990	9.3
February	941	8.9
Winter	2892	27.2
Total	10628	100.0

Table II.A.5. Distribution of Responses to Postcard Survey by Number of Cards Returned

Number of cards	Frequency	Percent
1	438	18.8
2	249	10.7
3	217	9.4
4	329	14.1
5	1080	46.4
>5	16	0.7

If the respondents to the CP survey are very different from the total included in the CDVT survey in ways that importantly affect fuel use, then analsyis or expansion of the CP survey could produce misleading results. The participants in the two parts of the survey can differ in observable and unobservable ways. An example of the latter is attitudes about vehicle maintenance or driving practices. It is possible that apparently similar groups could use their vehicles differently resulting in different energy efficiencies. Having noted this possiblity the correspondence between CDVT and CP survey respondents on important observable variables was explored under the assumption that if no important observable differences are found we are justified in considering the CP sample representative of both populations.

After matching all possible CP records to their CDVT records, the respondent and nonrespondent subpopulations were compared by means of cross tabulations and x^2 statistics. With over 10,000 observations, even

the slightest differences are likely to be found statistically significant using the χ^2 test. As a result, the χ^2 test significance levels are not of particular importance. Instead the reader should concentrate on whether the differences between the two subsamples are important and meaningful rather than on strict statistical significance.

Tables II.A.1, II.A.2, and II.A.6 compare the postcard (CP) and inspection station surveys with respect to center, vehicle type, fuel type, and age. While in all cases the χ^2 test rejects the homogeneity of the two subsamples, for practical purposes the differences are small: 28.5% of the nonrespondents come from Tunis while 30.0% of the respondents do. Sousse and Medenine have lower than expected response rates while Sfax and Kef are slightly above the average. In all cases the differences are moderate and correctible by properly weighting the sample. The correspondence by type of vehicle is even closer: in no case do the two percentage distributions differ by as much as two points (Figure II.A.1). The greatest difference in fuel type distributions is for premium gasoline where 31.3% of the nonrespondents but 33.2% of the respondents use that fuel (Figure II.A.2). The distributions by vehicle age are also close, but there is a clear tendency for respondents to own newer vehicles. Forty-seven percent of the respondents own vehicles 4 years old or younger while only forty percent of the respondents do. Since owners of newer vehicles tend to have higher incomes, we might expect to see a corresponding difference in vehicle usage patterns between the two groups. In particular we would expect the respondents, having slightly newer vehicles, to have slightly higher average usage rates.

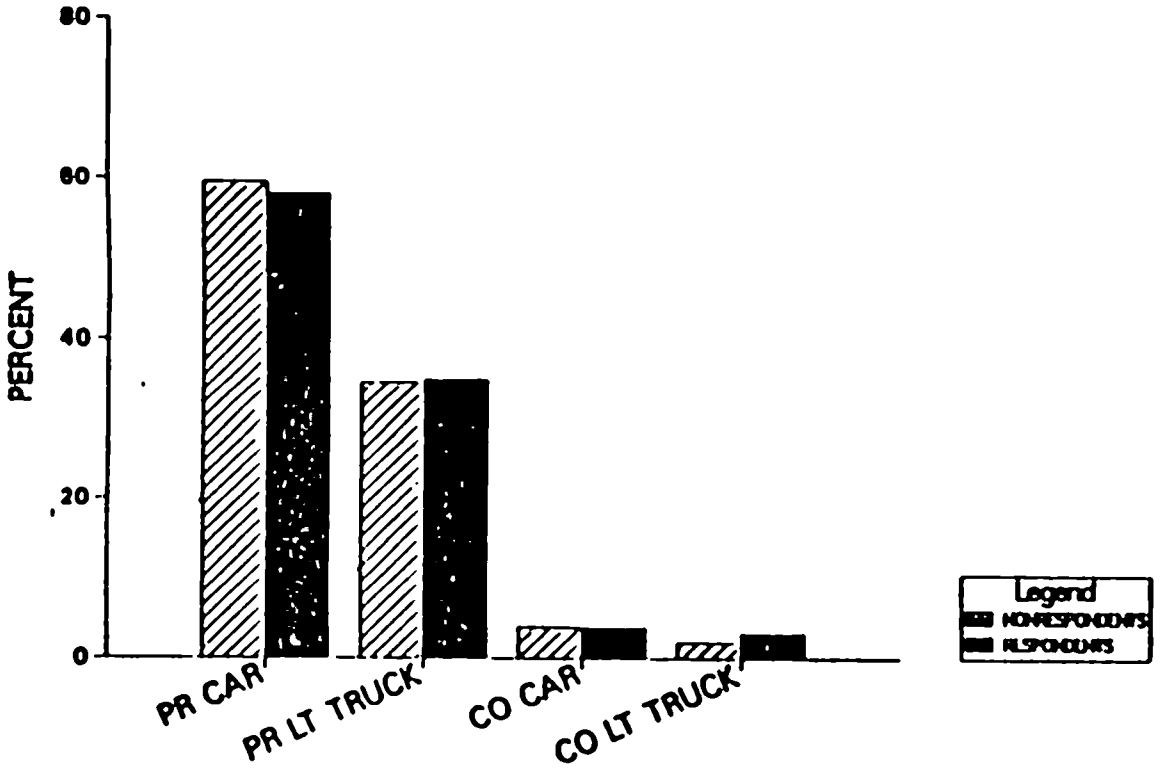

Figure II.A.1. Distribution of Respondents and Nonrespondents by Vehicle Type.

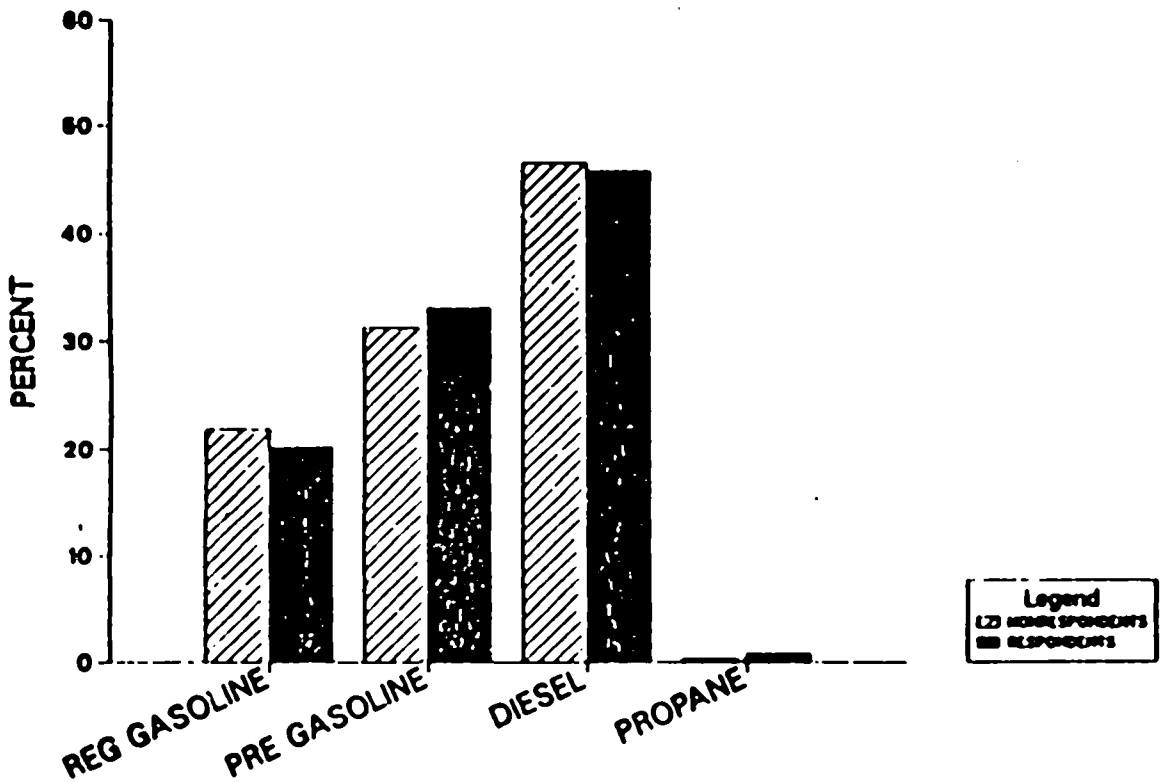

Figure II.A.2. Distribution of Respondents and Nonrespondents by Fuel Type.

To investigate the possible bias due to the differing age distribution of the postcard respondent subsample, average usage rates were computed for the four vehicle types using the odometer data provided in the inspection center (CDVT) survey (Table II.A.6). For each vehicle, average annual kilometrage was computed by adding the current odometer reading to the reported number of cycles minus one times 100,000, and dividing this estimate of total kilometrage by the age of the vehicle. The means computed from these estimates for the two groups do show some evidence of higher vehicle usage for the CP subsample. For private vehicles the difference is small, a 4.1% increase for cars and 5.6% for light trucks. For the relatively small company sample the difference is slightly larger, 7.9% for light trucks, and 5.7% for cars. Whether these differences are offset to any degree by higher fuel economy for newer vehicles is not known. In any case, the possibility of a small upward bias in fuel consumption estimates in the CP sample must be acknowledged.

A more detailed breakdown of vehicles in the two populatons shows just how closely the CP sample reflects the total. Table II.A.7 shows a breakdown of vehicles by make and model (marque and type) for the two surveys for the most common vehicles. Given the 22% response rate, the correspondence is remarkably good.

The distribution of observable variables may provide insights into whether the respondents differ with respect to unobserved attributes, such as attitudes. When response rates are as low as they are for the

Table II.A.6. Estimated Average Kilometers Per Year Based on Odometer Readings for Respondents and Nonrespondents to the Postcard Survey (unweighted)

	Nonrespondents	Respondents
	Private car	
Mean	16,540	17,210
Median	13,589	13,673
Sample size	4,449	1,190
	Private light truck	
Mean	34,592	36,517
Median	28,988	31,286
Sample size	2,699	745
	Company car	
Mean	33,294	35,188
Median	25,283	21,753
Sample size	282	83
	Company light truck	
Mean	43,033	46,437
Median	36,806	42,283
Sample size	156	67

Table II.A.7. Most Common Marques and Types of Vehicles in the Inspection Center (CDVT) and Postcard (CP) Survey

	Marques and types	Frequencies		Relative frequencies	
		CDVT	CP	CDVT	CP
Peugeot					
P404UXD	404UXD, 404U8D, 404U10D	2946	356	.28	.29
P404	404	742	139	.07	.06
P304	304M01	89	20	.01	.01
P204	204	152	38	.01	.02
P104	104A01	90	20	.01	.01
P403	403	217	44	.02	.02
		4263	917	.40	.41
Renault					
R2106	2106	212	45	.02	.02
R1397	1397	69	18	.01	.01
R1123	1123	93	25	.01	.01
R1222	1222	72	11	.01	.00
R1150	1150	57	11	.01	.00
R1170	1170	52	8	.00	.00
R1120	1120	48	10	.00	.00
		603	128	.06	.06
Citroen					
CAMJC	AM/JC, AMJC	292	80	.03	.04
CAKAK	AK/AK	79	23	.01	.01
CAYCD	AY/CD	44	20	.00	.01
CRBRE	RB/RE	87	20	.01	.01
		502	143	.05	.06
Fiat					
F127A	127A, 127	136	25	.01	.01
Isuzu					
IKBD26	KBD26, KB026	164	34	.02	.02
IKBD25	KBD25L	65	14	.01	.01
		229	48	.02	.02
Total		5706	1221	.54	.55
Sample size		10628	2228		

X 40

postcard survey (22%) this concern is serious indeed. However, the evidence presented above shows very little evidence of serious bias. For example, Figure II.A.3 compares the distribution of vehicles by age in the two subsamples. While the postcard survey respondents tend to own slightly newer vehicles there does not seem to be cause for great concern. In fact, none of the variables examined show reason for serious concern about non-response bias in the survey. For this reason in succeeding sections we proceed to analyze the data as if no bias problem were present. However, because of the very low response rate, determining the precision of the estimates is not emphasized.

Error Checking and Editing

Each data base was individually checked for errors, consistency, and reasonableness of the responses. The CDVT data base was found to have minimal serious errors. The CP data base, on the other hand, had substantial errors in four important areas: 1) too large (<800 km) increases in odometer readings, 2) inconsistent fuel gauge readings, 3) inconsistent fuel purchase records, 4) non-consecutive purchase dates. Over two hundred observations contained multiple errors. The observations containing errors were sorted by error type and individually examined. Most questionable records were either correctable or contained inconsequential errors (e.g., a date error on the second of five cards). Less than 200 records were judged unredeemable and 438 had only one postcard returned. Preliminary fuel economy calculations revealed that virtually all of the postcards with one observation had implausible

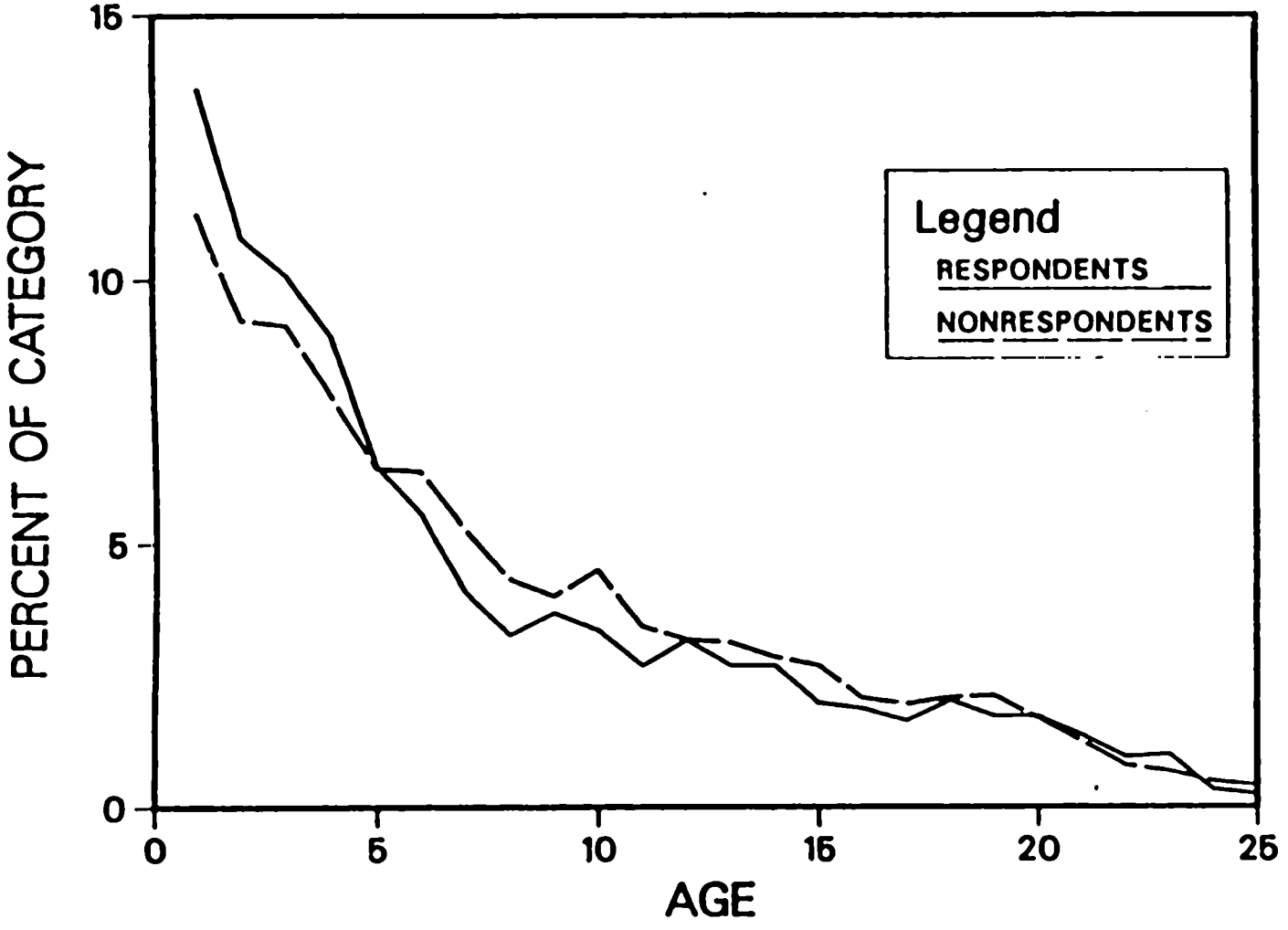

Figure II.A.3. Distribution of Vehicles by Age and Response to the Postcard Survey.

ch 4

fuel economy estimates due to very low kilometers travelled. In the final fuel economy calculations these records were deleted leaving a total of 1,715 records used.

II.B Fuel Consumption and Efficiency Estimates for Light Vehicles in Tunisia

This section describes the estimation of vehicle use, fuel use and energy efficiencies for automobiles and light trucks based on the National Survey of Vehicle Energy Use. The method of calculating these quantities is presented first followed by the estimates themselves.

For each record fuel consumption was calculated by summing the quantities of fuel purchased and adding an estimated change in tank inventory from the CDVT to the last postcard returned. Let q_i be the quantity of fuel recorded on postcard $i = 1,2,\ldots 5$, G, AV_i, and AP_i the fuel indicator position in eighths of a tank before and after the ith refueling, respectively. The quantity of fuel contained in one-eighth of a tank was estimated by the following

$$F = \frac{\sum_i q_i}{\sum_i (AP_i - AV_i)} \cdot \qquad (1)$$

The total amount of fuel consumed from the beginning to ending odometer reading was then calculated as

$$Q = \sum_{i=1}^{N} q_i + F(G - AP_N) \qquad \text{if } (G - AP_N) \leq (G - AV_N) \qquad (1a)$$

or

$$Q = \sum_{i=1}^{N-1} q_i + F(G - AV_N) \qquad \text{if } (G - AP_N) > (G - AV_N) \ . \qquad (1b)$$

In most cases the change in tank level was only 1 or 2 eighths. Even so, for a vehicle traveling a total of only 52.6 km and average 10 ℓ/100 km, a 1 liter error in the tank inventory estimate would lead to an

order-of-magnitude error in the estimation of fuel efficiency. The elimination of vehicles having returned only one postcard was necessary to hold down this source of error. Even so, estimating errors should be expected to be quite large.

There are two possible methods of estimating annual fuel consumption by vehicle type from the survey data. The first is simply to divide the total liters consumed by each vehicle by the length of time it took to consume the fuel (date of last postcard minus date of inspection station visit. The average liters per day by vehicle type and fuel type is obtained in the normal way from these data. Multiplying these average daily consumption rates by 365.25 gives an estimate of average annual liters consumed per car and multiplying these by the estimated number of cars by type contained in Appendix 4 provides an estimate of total consumption. The second method consists of computing average fuel efficiencies based on the postcard surveys, multiplying by estimated average annual miles derived from the CDVT odometer readings, and finally by the number of vehicles by type. In principle, both methods should give similar results. Differences may result because the odometer-based annual kilometrage estimates represent an average over the many years that vehicles in the stock have been in operation, while the survey data are only for the particular months of the survey. Also, if the number of odometer cycles is underestimated, the average kilometers per year would be greatly underestimated. One should expect such underestimation to be most pronounced for older vehicles. The data in

Table II.B.1, for example, show that vehicles using regular grade gasoline (which tend to be older vehicles) have much lower odometer-based estimates.

Estimates of annual kilometrage based on the two methods are consistently higher for the postcard survey data. For gasoline-powered vehicles the differences tend to be smaller than those for diesel vehicles. Kilometrage for diesel private cars is twice as high when calculated using the postcard data. For private light trucks the postcard survey estimate is 35 percent higher (Table II.B.1). As the data in Table II.A.6 demonstrated, these differences are not due to differences in the composition of the two samples to any significant extent. There is a possibility that the postcard survey method itself could produce an upward bias in vehicle use estimates. Although the distribution of the postcard sample is effectively uniform over time, the amount of time a vehicle spends in the postcard survey is inversely related to its rate of usage. Thus a vehicle being used heavily would remain in the survey a short time and an infrequently used vehicle a short time. It is not possible to evaluate the extent of bias this might create. However, it is not possible to explain the different changes in diesel and premium gasoline vehicle usage due to this effect. A more plausible explanation might be that vehicle usage rates have generally been increasing over time. In such circumstances current usage, as represented by the postcard estimates would be higher than historical average usage as represented by the odometer based estimate. The fact that diesel fuel price has been controlled since 1974 and is

Table II.B.1. Estimated Average Annual Kilometrage Using Survey Odometer and Postcard Kilometrage Estimates (weighted by center and vehicle type)

	Regular gasoline		Premium gasoline		Gasoil	
	Odom.	C.P.	Odom.	C.P.	Odom.	C.P.
Private car						
Mean	13,572	18,866	17,322	18,798	20,595	45,178
Median	11,580	12,883	14,881	15,280	15,233	28,475
Sample size	1,844	319	2,893	574	912	135
Private light truck						
Mean	21,694	-	37,095	-	35,155	47,630
Median	12,265	-	19,645	-	29,617	37,735
Sample size	23	3	15	4	3,361	534
Company car						
Mean	40,077	24,699	35,500	30,313	27,361	47,943
Median	19,923	13,458	25,306	29,050	28,954	35,127
Sample size	81	24	202	22	79	12
Company light truck						
Mean	-	-	-	-	41,992	52,310
Median	-	-	-	-	38,962	41,281
Sample size	1	0	4	1	213	52

currently less than half that of gasoline could account for the very large increases in diesel vehicle usage. If this explanation is correct, then government fuel pricing policies have inadvertently contributed to increased diesel fuel consumption. It is also likely that the number of odometer cycles has been underestimated in many cases, resulting in underestimation of average kilometers per year.

Patterns of vehicle usage are revealed in the data in Tables II.B.1—II.B.2. Private automobiles receive the least usage, about half as much as company-owned vehicles and light trucks. Vehicles which use premium gasoline are somewhat more intensively used than vehicles which use regular gasoline. As Figure II.B.1 illustrates, vehicles using regular tend to be older which is surely the reason for their lower utilization rates. The startling fact is that diesel vehicles receive much more usage than gasoline vehicles. In part this is because most diesel vehicles are light trucks. Yet as Table II.B.1 shows diesel vehicles of the same type are used considerably more intensively. It seems very likely that lower diesel fuel prices are a large part of the explanation.

Estimates of liters per day derived from the postcard survey are presented in Tables II.B.3—II.B.4. The averages provided are weighted by the expansion factors contained in Appendix 4. Weighted averages will be used throughout this discussion. The difference in fuel consumption rates between gasoline and diesel fuel powered vehicles is the most striking aspect of the data. Diesel vehicles consume fuel at about twice the rate of gasoline-powered cars (Tables II.B.3—II.B.4).

Table II.B.2. Estimated Average Kilometers Per Year Based on Odometer Readings (weighted by center and vehicle type)

	Vehicle type			
	Private car	Private light truck	Company car	Company light truck
Mean	16,709	35,056	35,788	40,948
Median	13,621	29,500	24,614	38,466
Sample size	5,689	3,444	365	223

	Fuel type			
	Regular gasoline	Premium gasoline	Diesel	Propane
Mean	15,788	20,328	32,872	43,197
Median	11,738	15,375	26,487	14,510
Sample size	1,949	3,114	4,565	38

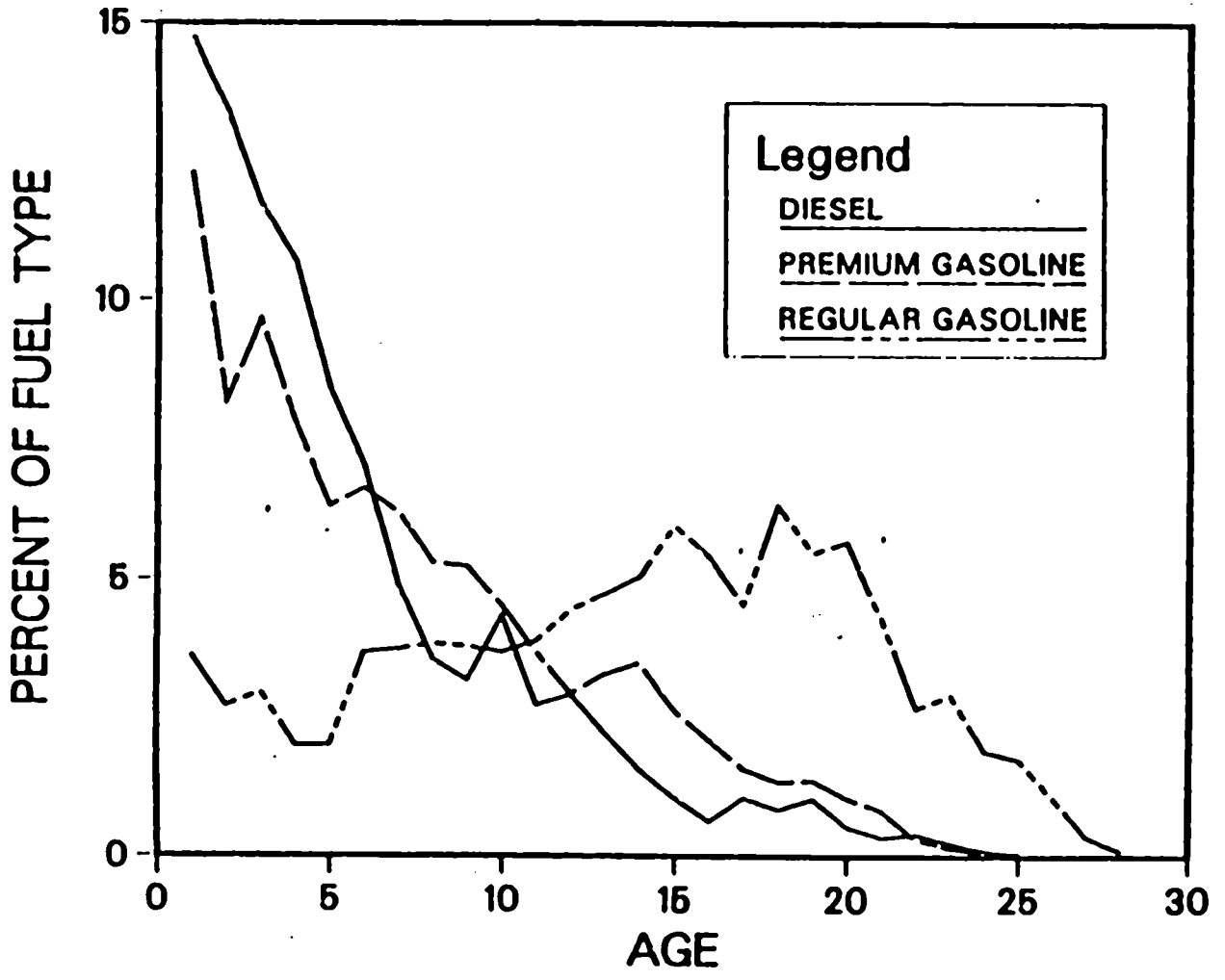

Figure II.B.1. Distribution of Automobiles and Light Trucks by Age and Type of Fuel.

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Table II.B.3. Estimated Liters Per Day
(weighted by center and vehicle type)

	Regular	Premium	Diesel	Propane
Mean	4.34	4.70	11.39	24.93
Median	3.32	3.60	8.65	10.79
Sample size	354	606	759	14

	Private car	Private light truck	Company car	Company light truck
Mean	5.00	11.63	9.30	12.65
Median	3.79	9.54	5.24	10.49
Sample size	1054	574	58	57

Table II.B.4. Estimated Liters Per Day
(weighted by center and vehicle type)

	Regular	Premium	Diesel	Propane
		Private car		
Mean	4.14	4.43	10.13	6.14
Median	3.33	3.49	6.67	6.15
Sample size	327	580	139	5
		Private light truck		
Mean	-	-	11.59	18.28
Median	-	-	9.38	14.76
Sample size	3	4	555	6
		Company car		
Mean	6.18	6.25	9.63	-
Median	3.26	7.47	10.80	-
Sample size	24	21	12	1
		Company light truck		
Mean	-	-	13.15	-
Median	-	-	10.49	-
Sample size	0	1	53	2

Likewise, company vehicles of all types tend to consume fuel at higher rates than privately-owned automobiles. Privately-owned trucks, which are all diesel, are comparable to company vehicles in their fuel use rates.

For most vehicle types, the estimated mean fuel consumption rate is higher than the median. This is indicative of a skewed distribution of consumption rates in which relatively few vehicles with high rates of usage or high ℓ/100 Km, or both, raise the mean consumption rates. While estimated standard deviations of the means are not presented here, the reader is cautioned that they are relatively large, often approaching the magnitude of the mean itself. This is probably partly a result of the inherent imprecision of the postcard survey data which relies on 2 to 5 refillings to estimate fuel consumption rates as well as a reflection of the true variability in the population. The high variability of the data together with the low response rate to the survey require that the fuel use estimates be viewed with caution.

Estimated annual fuel consumption based on mean liters per day (Table II.8.4) is shown in Table II.8.5. These estimates were obtained by multiplying the estimated liters per day times 365.25 times the estimated number of vehicles in each of the eight categories with sufficient representation (more than 5 observations) in the sample. The single most significant result of these estimates is the very large quantity of diesel attributed to light vehicles, nearly 230 million liters per year. This is nearly a quarter of total consumption of distillate in Tunisia in 1982. Almost two-thirds of the diesel consumption is accounted for by

Table II.B.5. Estimated Light Vehicle Fuel Consumption by Fuel Type and Vehicle Type Using Liters Per Day (millions of liters per year)

	Regular	Premium	Diesel	Propane
		Private car		
Using				
Mean ℓ/day	40.17	89.84	41.67	0.78
		Private light truck		
Using				
Mean ℓ/day			138.35	0.85
		Company car*		
Using				
Mean ℓ/day	5.97	26.56	8.49	-
		Company light truck		
Using				
Mean ℓ/day	-	-	39.05	-
Total	46.14	116.40	227.56	-

*Estimates based on sample sizes of less than 30 vehicles per category.

private light trucks, with private automobiles consuming only about 18%. (Figure II.B.2).

Estimated gasoline consumption amounts to 163 million liters, most of which appears to be premium gasoline. Actual total consumption of gasoline in Tunisia in 1982 was reported to be 168 thousand TEP's (about 218 thousand liters). Since the estimate of 163 liters excludes administration vehicles and taxis, as well as other minor categories such as motorcycles, it seems reasonable. However, consumption of premium gasoline is estimated to be 116 million liters, whereas government statistics record 98 thousand TEP's (about 127 million liters). Thus the premium gasoline estimates appears high relative to regular. In this regard, the estimates for company vehicles, especially automobiles, might be considered suspect since they are based on such a small sample of vehicles. We have already noted the fact that the survey may overrepresent newer vehicles which tend to use premium gasoline. On the whole, however, the estimates are at least reasonable approximations, and can provide a great deal of useful information about both absolute and relative magnitudes of light vehicle fuel consumption.

An alternative set of estimates based on vehicle lifetime average Km/year calcualted using CDVT odometer readings, and fuel efficiencies in ℓ/100 Km estimated from the CP survey is presented in Table II.B.6. As is to be expected, these estimates are lower than those based on ℓ/day rates from the CP survey. In our judgement the ℓ/day estimates (Table II.B.5) should more accurately reflect the current situation in Tunisia.

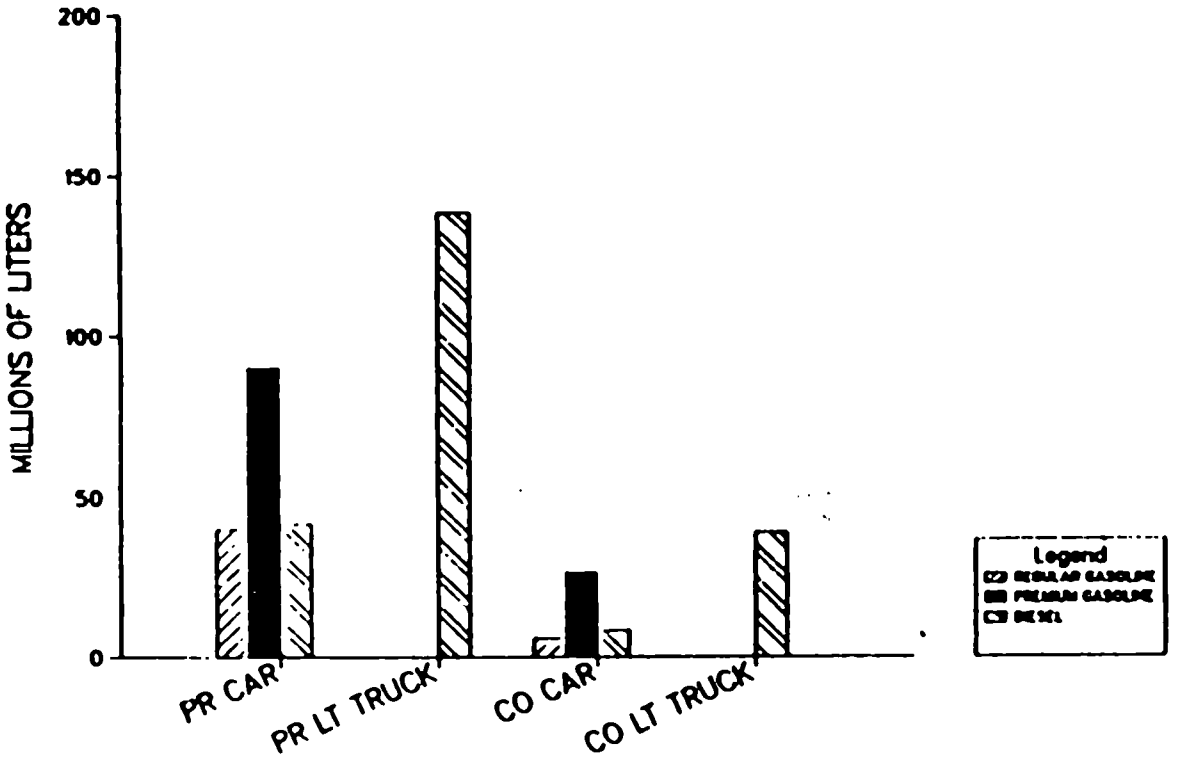

Figure II.B.2. Estimated Light Vehicle Fuel Use by Fuel Type and Vehicle Type, 1982
Millions of Liters Per Year.

x 56

Table II.8.6. Alternative Estimates of Light Vehicle Fuel Consumption Based on Average Annual Kilometrage From Odometer Readings and Average ℓ/100 km From Postcard Survey (10^6 liters)

	Regular gasoline	Premium gasoline	Diesel
Private car	28.16	82.33	19.09
Private light truck	-	-	100.30
Company car	9.68	31.10	4.85
Company light truck	-	-	31.07
Total	37.84	113.43	155.31

Vehicle Efficiency Estimates

For each observation, total consumption of fuel and total km travelled were estimated, and liters per 100 km estimates obtained by simple division. Mean fuel efficiencies by vehicle type and fuel type are presented in Tables II.8.7–II.8.8. Estimates have been weighted by number of vehicles by type of center, and the estimated km/day for each vehicle. This estimate comes closest to total liters over total kilometers and thus represents a mean for the entire parc.

Company automobiles appear to be the most efficient vehicle type at 7.4 ℓ/100 km. The relatively small sample size, however, requires caution in interpreting this estimate. Certainly cars are more efficient than light trucks, but only by about 5–15%. Part of the reason for this may be the fact that virtually all light trucks are diesel powered. All

Table II.B.7. Estimated Liters per hundred Kilometers (weighted by kilometrage)

	Regular gasoline	Premium gasoline	Diesel	Propane
Mean	8.00	8.36	8.58	6.80
Median	9.11	8.51	8.88	8.48
Sample size	344	604	743	14

	Private car	Private light truck	Company car	Company light truck
Mean	8.34	8.70	7.42	8.82
Median	8.72	8.92	7.86	9.81
Sample size	1041	558	59	57

Table II.B.8. Estimated Liters per Hundred Kilometers (weighted by kilometrage)

	Regular gasoline	Premium gasoline	Diesel	Propane
		Private car		
Mean	7.81	8.56	8.23	-
Median	9.29	8.57	8.35	-
Sample size	317	578	138	4
		Private light truck		
Mean	-	-	8.73	-
Median	-	-	8.94	-
Sample size	4	2	540	4
		Company car		
Mean	9.14	7.53	7.34	-
Median	8.09	7.35	8.97	-
Sample size	24	22	12	1
		Company light truck		
Mean	-	-	9.10	-
Median	-	-	10.26	-
Sample size	0	1	53	1

else equal, diesel-powered vehicles should be about 25% more efficient than equivalent gasoline-powered vehicles.

Fuel efficiency estimates by fuel type (Table II.B.7 indicate gasoline and diesel vehicles achieving roughly equivalent fuel efficiencies. This result at first seems surprising. Most diesel light vehicles, however, are light trucks. It is possible that the trucks either due to usage or size are inherently less efficient. On the other hand, it may be that due to the cheapness of diesel fuel drivers of diesel vehicles are less inclined to seek the highest possible fuel efficiency. This topic is given further analysis in Section II.C.

The calculated efficiencies in the range of 8–9 ℓ/100 km, are efficient by the standards of many developed countries. The light duty vehicle stock efficiency in 1982 for the United States, for example, was about 14–14.5ℓ/100 km. The vehicle stock in Tunisia, however, consists of much smaller vehicles which are inherently much less energy intensive. It seems very likely that the energy efficiencies achieved by light vehicles in Tunisia are capable of being improved significantly in view of the composition of the vehicle stock. An exploratory investigation of this topic is presented in Section II.C.

More detailed breakdowns by vehicle type by fuel type are presented in Table II.B.8. In this table we see that private automobiles using premium gasoline are slightly less efficient than those using regular and that older private cars using regular are the most efficient private vehicles. Once again, however, diesel vehicles do not show evidence of the theoretically expected efficiency advantage of 25%. A further

analysis of the data, taking into account vehicle size, to determine whether diesel cars tend to be larger and thus less efficient or whether deficiencies in vehicle design or operation are responsible for their failure to achieve their potential fuel economy advantage is undertaken in the following section.

II.C Effects of Vehicle Maintenance and Other Factors on Fuel Consumption and Implications for Conservation Planning

In addition to information on the vehicle itself, the National Survey included questions concerning the maintenance and usage of each vehicle. For purposes of formulating conservation policy, it is useful to know whether maintenance practices can have a beneficial effect on vehicle fuel efficiency. For example, if it can be shown that radial tires, fuel saver oils, frequent tune-ups or other factors can produce significant fuel savings, the Government might wish to consider information programs or other policies to encourage the adoption of fuel efficient vehicle maintenance practices. This chapter describes a first attempt to identify and quantify relationships between vehicle maintenance and usage practices and fuel economy, as measured in liters per 100 kilometers, by means of regression analysis. A set of variables characterizing maintenance practices and other environmental and usage factors affecting fuel efficiency were defined using the survey data. Stepwise regression analysis was then used to identify the most important variables influencing fuel economy. The analysis relies heavily on the use of "dummy" variables (which take on the value of 1 if a condition is present and are zero otherwise). In general, the ability of the regression equations to explain the variability of fuel consumption rates across vehicles in the survey was modest. No equation achieved an R^2 better than 0.15. Nonetheless, parameter estimates for variables included in the equations were consistent with prior expectations and suggest that improved maintenance practices can save significant amounts of fuel in Tunisia.

Variables describing 14 maintenance, usage, or environmental factors known to influence vehicle fuel economy were defined based on survey questions. In addition, (0, 1) dummy variables were included to account for the vehicle type. Two separate regression analyses were performed. In one dummy variables for each make and model (marque and type) of vehicle (for example, Peugeot 404, or Citroen AMJC) were included. In the other, vehicles were classified by fiscal horsepower (puissance fiscal, or CV) and dummy variables for each CV class were included instead of marque and type dummies. The marques and types associated with each marque and type variables are listed in Table II.C.1, and those associated with each puissance fiscale (chevaux, CV) class in Table II.C.2. In both cases only the most common marques and types have been included in the regression analysis.

Four variables pertaining to tires and rolling resistance were defined. RADIAL is simply the number of radial tires on the vehicle. Thus the estimated coefficient for this variable should be multiplied by four to obtain the difference between all bias ply versus all radial tires. Two other variables pertain to tire inflation pressure. INFLATE is a count of the number of tires underinflated when the vehicle passed through the inspection station. MAINTEN is a dummy variable equal to one if the respondent claimed to regulate tire pressure one or more times per month and zero otherwise. Because neither variable entered into preliminary analyses and because of the dubious validity of MAINTEN it was not included in the final analyses. ROLL is a dummy variable which is set to one if any of the following maintenance actions which

II.C.1. Vehicle Marques and Types Included in the Fuel Economy Regression Analysis

Marque and type	Frequency count		Code name of dummy variables
	CDVT	CP	
Peugeot			
404UXD	2420	544	P4UXD } Intercept
404U10D	296	64	P4UXD } Intercept
404U8D	230	48	P4UXD } Intercept
404	742	139	P404
403	217	44	P403
304M01	89	20	P304
204	152	38	P204
104M01	90	20	P104
Renault			
R2106	212	45	R2106
R1397	69	18	R1397
R1123	93	25	R1123
Citroen			
AMJC	292	80	CAMJC
AKAK	79	23	CAKAK
AYCD	44	20	CAYCD
RBRE	87	20	CRBRE
Fiat			
127A	105	21	F127A
127	31	4	F127A
Isuzu			
KBD26	164	34	IKBD26
KBD25L	65	15	IKBD25

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II.C.2. Regression Analysis of Vehicle Fuel Consumption
List of Marques and Types Included by CV Class

Puissance	Marque and type
9	Fiat 132A
	Renault R1151, R1152
8	Fiat 116
	Peugeot 404UXD, 404, 404U10D, 404U8D, 404U8D 404L, 404D, 404LD, 403, 403B8D, 403B7
	Renault R1150
7	Citroen GX/GB
	Fiat 124A
	Peugeot 403B7, 403B8D, 304M01
	Renault R1170, R1330, R1224, 134000
6	Fiat 128A, 128
	Peugeot 204
	Renault R1132, R1190
5	Fiat 850, 127A, 127, ZFA1270, ZFA1270, 100G
	Renault R1123, R1130, R1180, R1222, R2106
4	Citroen RB/RE
	Fiat 126A
	Renault R1120, 1227000, 1397000
3	Citroen AM/JC,AMJC, AMB, AK/AK, AY/CD, RB/RC
	Fiat 110F

would improve vehicle rolling resistance had been performed the last time vehicle maintenance was performed: 1) brake adjustment, 2) steering adjustment, 3) rotation, 4) alignment.

The variable TUNE was set to 1 if the last maintenance included the replacement of spark plugs, filters, or a complete tune-up (reglage moteur), and zero otherwise. The dummy variable OIL was set to one if the questionnaire reported that a multi-viscosity oil was used and was set to zero otherwise. It would have been desirable to limit this variable to oils with friction reducing (SAE SF-grade) additives, but such information was not available. Finally, MAINFREQ represents the reported frequency of vehicle maintenance in terms of average number of months between maintenance. It should be noted that maintenance includes repairs and thus frequent maintenance may denote both a vehicle in good operating condition or exactly the opposite.

Two other variables described vehicle characteristics. The DIESEL dummy variable was set to one if the vehicle used diesel fuel and zero otherwise. ACCKM was the total cumulative kilometrage of the vehicle in kilometers. ACCKM was defined as the current odometer reading, plus the cycle minus one times 100,000. It was presumed that accumulated wear would reduce fuel economy. The vehicle age in years, AGE, was included in preliminary analyses but never entered and was dropped from final analyses in favor of ACCKM.

Three variables describing usage characteristics were included. FREIGHT was set to one if the vehicle was used to transport merchandise and zero otherwise. PERSON equals the reported number of passengers

typically carried by the vehicle. COMPANY was set to one for company vehicles and zero for privately owned vehicles. WINTER was set to one for a vehicle entering the survey in the months of November through February, and zero otherwise. Cold weather affects both the engine warm-up time and operating temperature. Lower temperatures tend to increase fuel consumption. Finally a set of five dummy variables representing the five centers, Tunis, Sfax, Sousse, Medenine, and Kef, were included to reflect whatever unique operating conditions might exist in each region.

A maximum R^2 stepwise regression technique was used to select variables for inclusion in the analysis. For both the marque and type, and puissance fiscale equations vehicle type dummy variables were included in all regressions. The stepwise technique was used to select among the remaining variables. The SAS (SAS Institute, 1983 edition) Stepwise procedure was used throughout. The maximum R^2 method selects those variables which, for a given model size (number of explanatory variables) provide the highest level of statistical explanation (as measured by R^2). Thus at each step a new variable is added and previously included variables may be retained or replaced. Only records with 3 or more postcards returned were used in this analysis.

Tables II.C.3 and II.C.4 present results of the marque and type dummy variable regressions. Table II.C.3 shows results of the first-step regression containing only the vehicle type dummy variables. The intercept term represents the arithmetic mean efficiency of all Peugeot 404UXD's in liters per 100 Km. By adding the coefficient of the dummy

Table II.C.3. Fuel Consumption Regression Analysis Marque and Type Dummy Variables

Variable	R^2 = 0.11			Prob > F
	Coefficient estimate	Standard error		
Intercept (Peugeot 404UXD)	9.52	-	-	-
Peugeot 404	2.31	0.53	19.1	0.0001
403	0.51	0.86	0.36	0.55
304	0.18	1.20	0.02	0.88
204	−0.16	0.87	0.03	0.85
104	−1.21	1.36	0.8	0.37
Renault 2106	−1.51	0.72	4.4	0.03
1397	−2.13	1.19	3.2	0.07
1123	−0.69	1.00	0.5	0.49
Citroen AM4JC	−2.56	0.59	19.0	0.0001
AKAK	−0.71	1.05	0.5	0.49
AYCD	−2.62	1.05	6.2	0.01
RBRE	−2.10	1.15	3.3	0.07
Fiat 127 &127A	−2.10	.0.91	5.4	0.02
Isuzu KBD26	−0.30	0.93	0.1	0.75
KBD25	−1.09	1.51	0.5	0.47

Sample size = 792

X

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Table II.C.4. Fuel Consumption Regression Analysis Marque and Type Dummy Variables "Best" 23 Variable Model

Variable	Coefficient estimate	Standard error	F	Prob > F
Intercept (Peugeot 404UXD)	11.72	-	-	-
Peugeot 404	1.18	0.70	2.9	0.09
403	−0.71	0.95	0.6	0.45
304	−1.10	1.29	0.7	0.39
204	−1.67	1.04	2.6	0.11
104	−2.28	1.46	2.5	0.12
Renault 2106	−2.76	0.85	10.7	0.01
1397	−3.58	1.33	7.2	0.007
11XX	−2.11	1.13	3.5	0.06
Citroen AMJC	−3.98	0.79	25.2	0.0001
AKAK	−1.79	1.12	2.6	0.11
AYCD	−3.83	1.18	10.5	0.001
RBRE	−3.28	1.29	6.5	0.01
Fiat 127 & 127A	−3.37	1.05	10.4	0.001
Isuzu KBD26	−0.66	0.95	0.5	0.49
KBD25	−1.09	1.50	0.5	0.47
Freight	−1.92	0.58	10.9	0.001
Sousse	−0.83	0.40	4.3	0.04
Radial	−0.21	0.10	4.0	0.04
Company	1.10	0.57	3.7	0.05
Rollig resistance	−0.60	0.32	3.6	0.06
Winter	0.54	0.32	2.9	0.09
Kilometrage	0.0000032	0.0000023	2.0	0.16
Oil	−0.34	0.33	1.0	0.31

$R^2 = 0.16$ Sample size = 792

variable for a different marque and type to the intercept one obtains the average fuel consumption rate for that particular vehicle type. For example, the average efficiency for a Citroen AMJC would be,

$$9.52 + (-2.56) = 6.96 .$$

Estimated standard errors, F statistics, and significance levels are provided for each coefficient. The usual caveat concerning the interpretation of these values in a stepwise regression analysis applies (see, e.g. Draper and Smith, 1981).

Table II.C.4 presents results for the best (in terms of maximum R^2) 24 variable (15 marque and type dummies plus 9 other independent variables) model. Only three explanatory variables are statistically significant at the 0.05 level. The other variables have higher significance levels. More importantly the R^2 for the model is only 0.12, indicating that most of the variance in liters per 100 Km remains unaccounted for. A large proportion of this must be due to the undoubtedly large measurement error in the postcard survey fuel consumption estimates. It seems likely also that unknown other factors affect fuel economy at least as much as the factors included. These may include such things as driver behavior, environmental conditions, traffic, and inherent vehicle-to-vehicle differences within a vehicle type.

All variables have appropriate signs and reasonable magnitudes. The signs of FREIGHT and COMPANY are <u>a priori</u> indeterminate. It may seem surprising that all else equal, vehicles engaged in freight transport consume less fuel per 100 Km. This may be due to a greater

tendency to be operating under fully warmed-up conditions on uncongested roads more of the time, or to better maintenance or other, unknown factors. The effect of colder ambient temperature on vehicle fuel economy is illustrated by the variable WINTER. Colder temperatures cause an estimated average 0.5 ℓ/100 Km fuel consumption penalty.

All three variables representing fuel efficient maintenance and operation have negative signs, indicating association with lower fuel consumption rates. Their combined effect is to lower the fuel consumption by 18% for a 10 ℓ/100 Km vehicle. Maintenance to improve rolling resistance has an estimated effect of −0.6 ℓ/100 Km, multiviscosity oil of −0.3 ℓ/100 Km, and all radial versus all bias ply tires of just over −0.8 ℓ/100 Km. Given the imprecise nature of these variables, it is no surprising that their statistical significance is generally low. The consistency of signs and plausibility of magnitudes (in principle even greater reductions in fuel consumption are possible) suggest that the results should be given credence. The estimated 18% efficiency improvement of a well maintained over a poorly maintained vehicle is reasonable.

The above analysis was duplicated using fiscal horsepower class (CV or chevaux) dummy variables in place of marque and type dummy variables with consistent results. Table II.C.5 contains the estimated coefficients for the equation including only the CV class dummy variables. With the exception of CV7 to CV8, fuel consumption rates increase consistently with increasing fiscal horsepower class (Figure II.C.1). Even this inconsistency disappears when other factors are taken into account. Energy intensive CV9 vehicles consume almost twice as much fuel per Km

Table II.C.5. Fuel Consumption Regression Analysis Fiscal Horsepower Dummy Variables

Variable	$R^2 = 0.10$		F	Prob > F
	Coefficient estimate	Standard error		
Intercept (CV9)	13.46	-	-	-
CV3	−6.10	1.48	16.97	0.0001
CV4	−6.08	1.58	14.74	0.0001
CV5	−4.98	1.47	11.46	0.0001
CV6	−3.89	1.57	6.13	0.01
CV7	−3.14	1.54	4.14	0.04
CV8	−3.55	1.43	6.14	0.01
Sample size = 913				

x 72

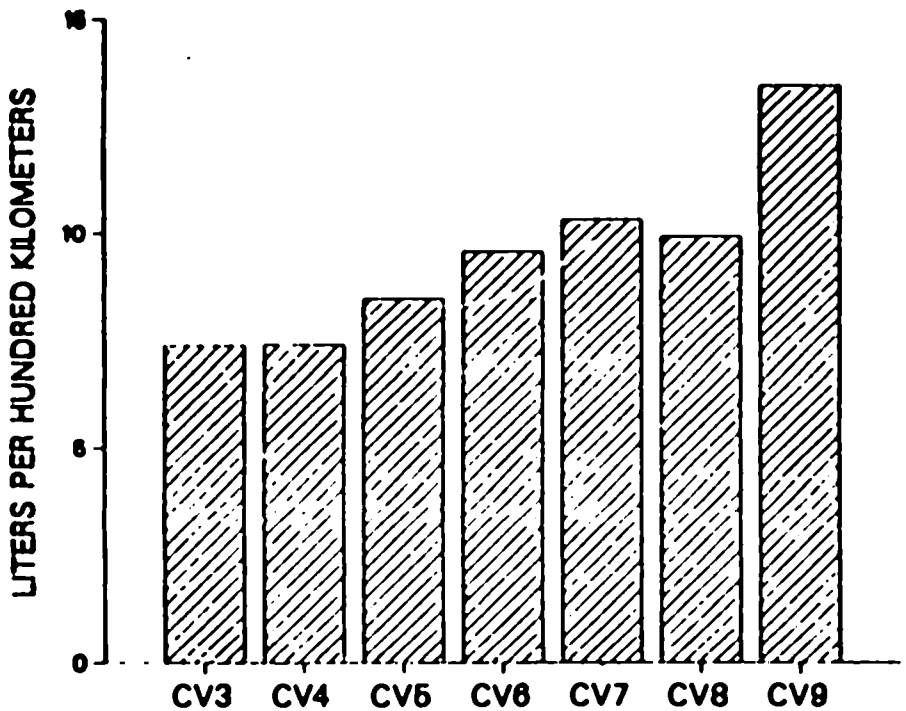

Figure II.C.1. Mean Fuel Consumption Rates by Fiscal Horsepower Liters Per Hundred Kilometers.

as efficient CV3's (13.5 vs 7.4 ℓ/100Km). Thus, despite important variations in fuel efficiency across marques and types within a CV class, the CV classification can be considered a reasonable approximation to efficiency classes. As a result, it could be a useful basis for policies aimed at improving the fuel efficiency of the vehicle parc. Before specific policies are formulated, however, the engineering basis for the fuel economy differences between fiscal horsepower classes should be studied.

Table II.C.6 presents results of the "best" 15 variable model. These results are very consistent with those of the previous marque and type regression. Once again signs and magnitudes of coefficients are plausible and consistent with prior expectations. The only additional vehicle characteristic variable is DIESEL. As expected, diesel fuel use is lower, all else equal, but only by about 10%.

A somewhat surprising result in both analyses is the relatively small fuel economy advantage of diesel engines. In principle diesels should be 25–30 percent more efficient on a ℓ/100 Km basis. Instead, they are about 10 percent more efficient. Given the approximately 11 percent higher energy content of diesel 'uel on a volumetric basis, this implies that light vehicle diesels in Tunisia are no more energy efficient that gasoline powerplants. The failure of diesel cars and light trucks to achieve their theoretically superior energy efficiency is a subject well worth investigating further in view of the fact that light vehicles apparently consume more diesel fuel than gasoline.

Table II.C.6. Fuel Consumption Regression Analysis Fiscal Horsepower Dummy Variables "Best" 16 Variable Model

Variable	R^2 = 0.12 Coefficient estimate	Standard error	F	Prob > F
Intercept (CV9)	13.93	-	-	-
CV3	-5.97	1.45	16.9	0.0001
CV4	-5.78	1.55	13.9	0.0002
CV5	-4.74	1.44	10.8	0.001
CV6	-3.94	1.53	6.6	0.01
CV7	-2.64	1.51	3.1	0.08
CV8	-2.06	1.44	2.0	0.15
Radial	-0.34	0.10	11.3	0.0008
Winter	0.86	0.29	8.6	0.004
Freight	-1.21	0.49	6.1	0.01
Sfax	0.85	0.36	5.5	0.02
Medenine	0.83	0.42	4.0	0.05
Company	1.07	0.55	3.8	0.05
Rolling resistance	-0.56	0.29	3.7	0.05
Kilometrage	0.0000037	0.000002	3.4	0.06
Diesel	-0.98	0.55	3.2	0.07
Oil	-0.47	0.30	2.5	0.11
	Sample size = 913			

The results of this analysis should be considered indicative rather than definitive. Nonetheless, the results do suggest a significant conservation potential for improved maintenance, use of fuel saver oils, radial tires and other known energy conserving practices. The potential of such practices to reduce fuel consumption is, of course, limited by the extent to which they have already been adopted. Table II.C.7 contains the frequencies with which four of the conservation actions considered in this analysis were mentioned by vehicle owners in the National Survey. Only those marques and types included in the fiscal horsepower regression analysis are included in this table.

Almost two-thirds (64%) of the respondents had four radial tires and only 12 percent had four bias ply tires. Thus despite the fact that radial tires will significantly improve fuel economy, their potential to further improve efficiencies in Tunisia is limited. A breakdown of radial tire use by vehicle type shows that 42% of private light trucks and 38% of company light trucks had at least one bias ply tire. For both private and company light trucks almost one-third (32%) had two or more bias ply tires (Table II.C.8). The tendency for bias ply tires to be more common on light trucks is quite surprising given the much higher usage and fuel consumption rates of these vehicles. The longer tread life and fuel economy advantages of radials are greater the greater the annual kilometrage and the higher the rate of fuel consumption. Assuming a 3.4 percent reduction in ℓ/100 Km per radial tire and using the distribution by type in Table II.C.8, it can be calculated that

Table II.C.7. Relative Frequencies of Energy Efficient Actions in Fiscal Horsepower Subsample

Radial tires

No. of radials	Frequency	Relative frequency (%)
0	779	12.3
1	178	2.8
2	804	12.7
3	516	8.2
4	4047	64.0

Multiviscosity oil

Type	Frequency	Relative frequency (%)
Single	3390	53.6
Multi	2935	46.4

Rolling resistance

	Frequency	Relative frequency (%)
No recent maintenance	3698	58.5
Recent maintenance	2627	41.5

Tune-up

	Frequency	Relative frequency (%)
No recent maintenance	4597	72.7
Recent maintenance	1728	27.3

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Table II.C.8. Relative Frequencies of Radial Versus Bias Ply Tires, by Vehicle Type
(frequency/percent of vehicle type)

Number of radial tires*	Vehicle type				Total
	Private car	Private light truck	Company car	Company light truck	
0	341 11.2%	376 12.9%	25 13.6%	37 20.4%	779 12.3%
1	81 2.7%	90 3.1%	1 0.5%	6 3.3%	178 2.8%
2	320 10.5%	463 15.9%	6 3.3%	15 8.3%	804 12.7%
3	207 6.8%	294 10.1%	4 2.2%	11 6.1%	516 8.2%
4	2092 68.8%	1695 58.1%	148 80.4%	112 61.9%	4047 64.0%
Total	3041	2918	184	181	6325

*Assumes all vehicles have four tires.

private light truck energy use could be reduced by 3% overall, by uniform use of radial tires. This amounts to about four million liters of diesel fuel per year.

More than half of the respondents did not use a multiviscosity oil. Since not all multiviscosity oils have fuel saving additives, the percent using fuel saver oil is probably considerably less than 46%. Promoting more widespread use of fuel saver oils is a conservation policy which should be explored by first determining which brands contain fuel saver additives and then using the survey data to determine their share of the market. While our statistical analysis has suggested an efficiency improvement potential of about 5 percent for multiviscosity oils, test data from the U.S. indicate a greater potential for true fuel saver oils in the neighborhood of 8%.

Forty-two percent of the survey respondents indicated they had recently performed some maintenance to improve rolling resistance while only 27 percent had tuned their vehicle's engine either by replacing spark plugs, adjustment, or replacing filters. While it is not possible to even crudely estimate the energy saving potential of increased maintenance in these areas, the statistical analysis suggests that some potential does exist, an improvement on the order of several percent.

Fuel efficiency improvements obtainable through increased or improved vehicle maintenance tend to be modest in size, on the order of 10 percent. They are, however, low in cost and can be put into effect almost immediately. Furthermore, they are generally cost-effective and result in a net benefit to the vehicle owner. Ten percent of total

light vehicle fuel use is a considerable amount, on the order of 40 million liters of motor fuel per year.

III. Highway Passenger Transport — Public Carriers

As in other less developed countries, the public transport sector has a major role in highway passenger transport and is a major energy consumer. This chapter first presents data obtained from public bus companies, for both inter- and intracity operations. Energy use data for bus companies are reasonably complete and accurate. Crude estimates of energy use are then derived for taxi and louage (intercity limousine) and tourist bus operations.

A. Buses

Bus transportation in Tunisia can be divided into three sectors: 1) interurban transport by the Societé Nationale de Transport (SNT), the Societé Nationale de Transport Rural et Intraurbain (SNTREI), newly created in 1982 form the SNT, and interurban activities of the 12 Societés Regional de Transport Gouvernerats (SRTG), 2) intraurban transport within the greater Tunis metropolitan area by SNT, and intraurban transport in other major cities by the SRTG's, 3) hotel, tourist, and other private bus activity.

In 1981 the SRTG's carried 124.24 million passengers and consumed 26.7 million liters, or 22.8 thousand TEP of diesel fuel. SNT autobuses used 18.3 million liters or 15.6 thousand TEP diesel to transport 245 million intracity passengers. SNT buses (autocars) used only 5.3 million liters (4.5 thousand TEP) to carry 12.5 million passengers (Table III.A.1). In total, the 2,138 public buses in service in 1981 consumed 50.3 million liters, or 43.0 thousand TEP of diesel fuel. To this total tourist buses and mini buses add perhaps 6.1 million liters.

Table III.A.1. Public Bus Activity and Energy Use, 1975–1981

	1975	1976	1977	1978	1979	1980	1981
SRTG's[1]							
Number of vehicles	943	1044	1030	1026	1076	1112	1196
Vehicle-km × 10^6	62.63	66.31	72.95	72.29	71.06	77.49	79.35
Passengers × 10^6	100.86	103.82	108.78	106.39	105.13	112.12	124.24
Diesel fuel used [ℓ × 10^6]	20.15	19.38	24.39	23.60	24.14	25.94	26.68
ℓ/100 km	32.16	29.22	33.43	32.64	33.96	33.47	33.62
SNT autobus							
Number of vehicles	498	534	599	631	638	642	759
Vehicle-km × 10^6	23.72	25.07	29.09	31.87	32.93	33.14	41.94
Average km/day	152	163	164	171	181	166	182
Passengers × 10^6	159.5	179.2	203.1	209.1	221.4	230.2	245.0
Diesel fuel used [ℓ × 10^6]	11.32	12.85	14.68	16.47	17.82	17.12	18.27
ℓ/100 km	47.72	51.24	50.47	51.66	54.10	51.67	43.55
SNT autocar							
Number of vehicles	176	150	150	168	201	201	228
Vehicle-km × 10^6	13.81	14.24	14.66	14.49	14.97	13.36	15.36
Average km/day	265	310	327	288	237	214	231
Passengers × 10^6	12.05	12.30	12.44	11.29	12.03	12.04	12.54
Diesel fuel used [ℓ × 10^6]	6.21	6.36	6.61	6.44	5.89	5.29	5.34
ℓ/100 km	44.99	44.69	45.06	44.46	39.31	39.62	34.78
Total							
Number of vehicles	1617	1728	1779	1825	1915	1955	2183
Vehicle km × 10^6	110.16	105.62	116.70	118.65	118.96	123.99	136.65
Passengers × 10^6	272.41	295.32	324.32	326.78	338.56	354.36	381.78
Diesel fuel used [ℓ × 10^6]	37.68	38.59	45.68	46.51	47.85	48.35	50.29
ℓ/100 km	37.09	36.54	39.14	39.20	40.22	39.00	36.80

[1]These data may contain substantial errors.

Source: Data furnished by the SRTGs and SNT.

Table III.A.2. Breakdown of Diesel Fuel Use and Energy Intensity by SRTG, 1975–1981

	1975		1976		1977		1978		1979		1980		1981	
	Fuel	ℓ/100 Km	Fuel	ℓ/100 Km	Fuel	ℓ/100 Km	Fuel	ℓ/100 Km	Fuel	ℓ/100 Km	Fuel	ℓ/100 Km	Fuel	ℓ/100 Km
Beja	967,677	34.65	881,375	27.22	965,636	30.08	915,459	29.62	902,295	29.67	1,070,347	28.66	1,156,397	28.17
Bizerte	763,923	47.06	997,043	48.63	1,506,437	55.77	1,109,000	40.32	1,206,315	45.26	1,222,451	41.47	1,348,303	44.75
Gabes	1,181,335	29.68	1,424,891	31.52	1,673,414	32.12	1,923,801	34.98	1,994,608	37.16	1,921,578	34.40	2,087,254	37.82
Gafsa	1,300,880	24.89	1,269,000	24.17	1,269,480	23.78	1,400,280	26.06	1,448,280	25.25	1,519,800	24.48	1,644,960	22.58
Jendouba	334,559	28.01	327,563	31.27	382,271	30.24	385,320	30.24	454,043	32.08	610,694	32.43	613,941	27.39
Kairouan	902,149	33.06	912,043	31.85	912,660	32.01	989,751	29.47	1,107,155	30.06	1,506,312	25.45	1,458,875	26.82
Kasserine	992,631	21.19	1,001,223	24.51	1,026,309	21.58	1,112,906	20.38	1,229,107	21.24	1,382,642	27.51	1,421,912	29.12
Kef	553,425	12.89	584,392	13.93	522,967	10.72	709,854	16.90	645,925	15.43	835,411	20.03	947,681	24.48
Medenine	662,950	32.05	841,707	32.05	963,313	32.05	829,770	32.05	1,127,636	36.24	1,234,552	36.24	1,188,243	36.24
Nabeul	1,866,469	28.88	2,959,698	37.83	2,208,317	28.51	2,310,502	29.32	2,340,106	31.14	2,552,603	32.05	2,699,668	32.76
Sfax	5,465,162	47.26	2,698,911	23.32	5,871,675	44.48	6,262,531	46.31	6,262,531	45.07	6,707,125	46.89	6,122,567	48.01
Sousse	5,150,000	32.19	5,480,000	32.17	7,100,000	37.73	5,650,000	32.66	5,475,000	37.03	5,970,000	33.88	5,935,000	31.88
Total	20,147,160	32.16	19,337,846	29.22	24,393,479	33.43	23,599,174	32.64	24,137,595	33.96	25,939,957	33.47	26,678,120	33.62
Fuel/M	21,365		18,561		23,683		23,001		22,433		23,327		22,306	

Source: Data furnished by the SRTG's to the Ministry of National Economy.

Table III.A.3. Breakdown of Buses in Service and Passengers Carried by SRTG, 1975–1981

	1975		1976		1977		1978		1979		1980		1981	
	Number of vehicles	Passenger km	Number of vehicles	Passenger km	Number of vehicles	Passenger km	Number of vehicles	Passenger km	Number of vehicles	Passenger km	Number of vehicles	Passenger km	Number of vehicles	Passenger km
Beja	38	1,934,182	40	2,209,383	44	2,280,708	42	2,260,264	47	2,129,536	48	2,490,241	54	2,775,505
Bizerte	37	2,962,219	35	3,959,246	38	5,900,000	36	5,639,011	38	5,299,345	41	6,123,760	49	7,364,000
Gabes	72	6,000,000	92	6,800,000	90	7,115,025	99	7,645,996	104	7,574,259	104	7,997,573	93	8,332,125
Gafsa	64	5,012,000	60	5,104,000	62	5,154,000	76	5,209,000	73	5,664,000	81	5,805,000	99	5,700,000
Jendouba	19	1,117,562	18	993,811	18	1,065,814	16	972,587	21	1,062,578	27	1,393,229	35	1,766,038
Kairouan	52	1,963,415	52	1,980,710	50	1,879,612	63	2,041,336	84	2,047,951	84	2,626,572	63	3,135,062
Kasserine	61	2,478,536	73	1,939,056	66	2,260,904	66	2,434,733	65	2,410,306	73	2,446,753	81	2,667,273
Kef	44	2,575,434	56	2,366,202	50	2,651,831	46	2,294,384	49	2,200,761	58	2,121,247	67	1,946,516
Medenine	40	1,627,056	48	1,543,991	48	1,704,805	47	1,666,177	51	1,844,874	50	2,000,240	60	2,307,054
Nabeul	82	6,523,126	84	7,951,423	73	8,734,604	74	8,260,040	80	8,616,440	84	9,364,499	94	10,470,233
Sfax	252	39,205,464	277	39,884,390	285	40,825,546	279	40,375,153	281	41,200,554	276	42,610,172	290	47,763,045
Sousse	182	29,000,000	209	29,000,000	266	30,000,000	181	27,500,000	183	25,000,000	194	28,000,000	206	30,000,000
Total	943	100,061,796	1,014	103,010,017	1,030	100,700,971	1,026	105,387,404	1,076	105,129,604	1,112	112,123,294	1,196	124,244,459
Passenger km/vehicle	106,158		99,442		105,612		103,691		97,704		100,830		103,883	

Source: Data furnished by the SRTG's to the Ministry of National Economy.

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Table III.A.4. Breakdown of Public Bus Fleet by Type, 1975–1977

	1975	1976	1977
Autobus			
Number	887	989	1,034
Passenger capacity	84,255	94,842	99,360
Capacity/vehicle	95.0	95.9	96.1
Autocar			
Number	599	689	733
Seats	27,646	32,071	34,182
Seats/vehicle	46.15	46.55	46.63
Minibus			
Number	139	224	232
Seats	2,255	3,845	3,996
Seats/vehicle	16.2	17.17	17.22

Source: Louis Berger International, Inc., "Etude de la Coordination des Transports," Vol. 5, Tunis, November, 1979, p. R19.

Data on taxis and louages are scant yet it appears they may contribute in the vicinity of 35 million liters to public transport fuel use. Assuming all of this to be diesel fuel leads to a very approximate estimate of 91.4 million liters or 78.1 thousand TEP.

By combining the data furnished by SNT with bits of information from the Louis Berger and SEMA studies it becomes possible to make a rough calculation of the energy intensity for autocars in 1977. It should be noted that these data sources are not necessarily compatible and that combining them may lead to erroneous results. For example, combining the vehicle kilometers from the SNT data with the passenger-kilometers from SEMA results in an average of 47.5 passenger-kilometers per bus-kilometer which is greater than the 46.1 seats per bus given by Louis Berger.

Utilizing the 82% average load factor given by SEMA in conjunction with the capacity from Louis Berger and the fuel use as provided by SNT results in an energy intensity estimate of 1.19 ℓ/100 passenger-kilometers. This is the best estimate which can be prepared at this time.

B. Tourist Buses

According to data collected by the Ministry of National Economy staff there were 317 buses and 163 minibuses in Tunisia operated by tourist agencies and hotels (Table III.A.5). Data on total kilometrage and fuel consumption were obtained for a small number of agencies (Table III.A.6) which apparently account for a large fraction of the stock. For this sample the average bus traveled 35,000 Km/year and consumed 14,000

Table III.A.5. Tourist Buses

	Agences deVoyages		Hotels	
	1977	1981	1977	1981
Buses				
Number	153	238	77	79
Seats	7,753	12,739	3,956	4,217
Seats/vehicle	50.7	53.5	51.4	53.4
Minibuses				
Number	85	100	55	63
Seats	1,362	1,580	872	1,032
Seats/vehicle	16.0	15.8	15.9	16.4

NA — Not available.

Source: Louis Berger International Inc., "Etude de la Coordination des Transports," Vol. 5, Tunis, November, 1979, p. R21, data for 1981 supplied by the Ministry of National Economy.

Table III.A.6. Tour Bus Energy Use 1981

Agency	Total Km	Total fuel (liters)	ℓ/100 Km	Number of vehicles
		Autocars and buses		
Carthage Tours	792,277	289,189	36.5	15
Tourafric	1,472,803	662,761	45.1	36
Transtour	856,518	291,924	34.1	37
Total	3,121,598	1,243,874	39.8	88
	mean ℓ/vehicle-year = 14,135			
		Minibuses		
Atlas Voyage	1,498,200	422,180	28.2	23
Carthage Tours	322,368	56,266	17.5	6
Transtour	192,392	32,943	17.1	13
Total	2,012,960	511,389	25.4	42
	mean ℓ/vehicle-year = 12,176			
Total buses and minibuses	5,134,558	1,755,263	34.2	130

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ℓ of fuel at an average efficiency of 40 ℓ/100 Km. The average minibus travelled 48,000 Km/year and used 12,000 ℓ of fuel at an average efficiency of 25 ℓ/100 Km.

The estimates in Table III.A.5 can be used to expand energy use to the total parc, assuming the remaining vehicles have the same usage rates and efficiencies. This results in an estimated total fuel consumption of 4.5 million liters for tourist buses and 2.0 million liters for minibuses, for a combined total of 6.5 million liters. This is assumed to be entirely diesel fuel. Because of their small numbers, higher energy efficiency, and lack of data on energy consumption, we neglect the energy use of Land-Rovers and voitures.

C. Taxis and Louages

According to statistics provided by the Ministry of National Economy staff, there were 3,586 taxis in operation in Tunisia. Of these, almost two-thirds, 2,284 operate in Tunis or its suburbs. A small, informal survey of taxis in Tunis was undertaken by the Ministry staff. Results from only six vehicles were available at the time of writing. Estimated efficiencies for these vehicles ranged from 5.0 to 11.7 ℓ/100 Km, generally within the range of vehicle stock.

In order to obtain even a crude estimate of taxi fuel use it is necessary to make some very strong assumptions. It is hoped that these can be refined at a later date using the taxi survey data. Assume that the average annual kilometrage for a taxi is 75,000 Km. This is about four times the rate for the average vehicle and is equivalent, for example, to driving 10 hrs/day, 250 days/year at an average speed of 30

Km/hr. Assume that the average taxi has a fuel consumption rate of 8.2 ℓ/100 Km, the same as that for a diesel private automobile. The estimated total fuel consumption for taxis is then

$$3586\ (75{,}000/100)\ 8.2 = 22.1 \text{ million } \ell/\text{year}\ .$$

In order to reflect the crudity of this estimate, we round it to 20 million liters per year. Until more detailed data become available we assume that all of this is diesel.

According to the Ministry of National Economy staff there are 1,439 louages in Tunisia. Louages are intercity taxis or limousines. A non-random sample of 50 is being taken by the Ministry staff but results are not yet available. In order to determine an approximate magnitude of consumption we will again make some crude assumptions which one hopes can be refined as data become available. Assume that louages average 400 Km/day, 250 days/year for a total of 100,000 Km/year. Assuming 10 ℓ/100 Km to account for the greater vehicle size and weight of passengers results in an estimated total consumption of 14.4 million liters. To be conservative and to reflect the crudeness of this estimate we round it to 14 million liters. Again we assume this to be entirely diesel fuel.

Based on these very crude estimates it seems reasonable to assume that in the vicinity of 30–40 million liters or 25–35 TEP 10^3 of diesel fuel are consumed annually by taxis and louages. Obviously these estimates represent only the grossest approximation and should be used with caution.

IV. Highway Freight Transport

Highway freight activity can be divided into three parts: 1) freight transport by the Sociétés Regionales de Transport (SRTG), 2) transport by the Societé de Transport de Marchandises (STM), and 3) independent activity by companies and individuals. With the exception of the SRTG and STM energy use, vehicle stock and activity data for the highway freight mode are incomplete. For the independent trucking segment, insufficient data are presently available. Data from the 1977 study by Louis Berger indicate that there were over 10,000 independent trucks in use in Tunisia in 1977, however the authors caution that the data are not reliable. It appears that most of the independent trucks are small, under 5 tonnes. The number greater than 10 tonnes cu (charge utile or capacity) appears to be roughly comparable to the number of trucks owned by the SRTG's and STM.

Energy use data for the SRTG's indicates that 24.4×10^6 ℓ of diesel fuel were consumed in 1981 at an average efficiency of 46.2 ℓ/100 km. This 20.9×10^3 TEP constituted less than 3% of total diesel fuel use in Tunisia in 1981. STM energy use in 1981 amounted to 12.7 million liters consumed at an average efficiency of 45.4 ℓ/100 Km. The 10.9 TEP of the STM together with the 20.9 of the SRTG's amounted to 31.76 TEP's or 4% of total diesel use in Tunisia in 1981 (Table IV.1, Figure IV.1).

Independent heavy truck energy use is essentially unknown. The SRTG and STM data are sufficiently complete at this time to permit some analysis of energy intensity. An unsuccessful attempt to explain energy intensity changes across gouvernerats is described below.

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Table IV.1. Fuel Use by Highway Freight Companies 1975–82
(10^3 liters)

	SRTG		STM		Total fuel use
	Fuel use	ℓ/100 Km	Fuel use*	ℓ/100 Km	
1975	15,092.8	33.47	8,930.4		24,023.2
1976	14,159.9	29.90	9,599.3		23,759.2
1977	17,675.6	34.97	10,979.5	51.6	28.655.1
1978	18,372.1	37.16	10,429.9	46.9	28,802.0
1979	18,780.4	38.30	12,059.1	49.7	30,839.5
1980	20,465.1	41.19	13,614.7	52.4	34,079.8
1981	24,443.6	46.15	13,139.9	47.1	37,583.5
1982			15,059.3	46.1	

*Calculated based on cost data provided by STM.

Source: Ministry of National Economy staff.

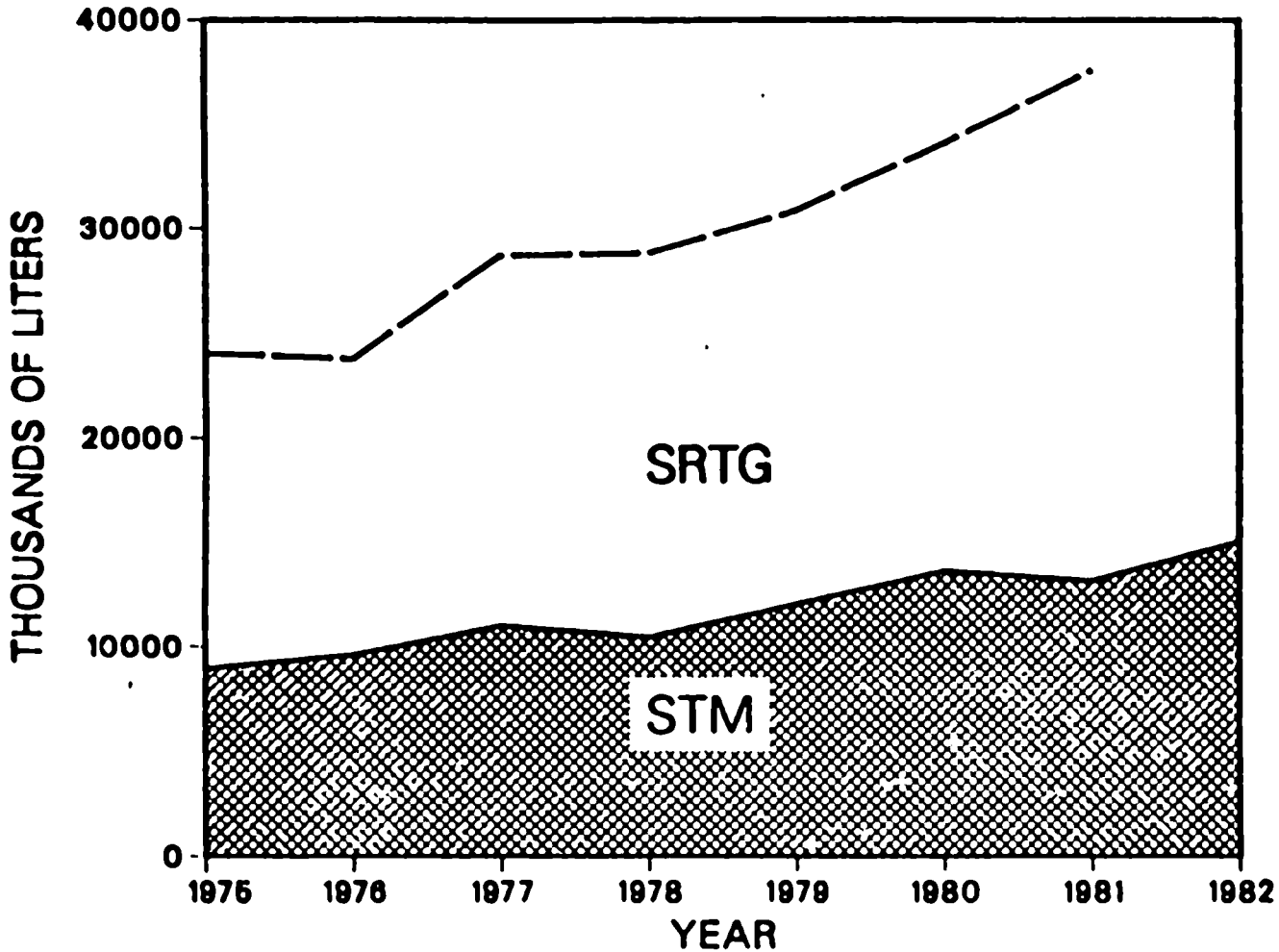

Figure IV.1. Fuel Use by Highway Freight Companies 1975–1982
Thousands of Liters of Diesel.

Data for the STM trucking operations show a continuing increase in truck miles from 1977 to 1982 accompanied by fluctuations in fuel use per kilometer on the order of 10% (Table IV.2). As a result total fuel use actually declined from 1977–78 and again from 1980–81 despite increases in truck travel. More detailed data on trucking activity by type of service and size of truck suggest that most, if not all, of the variation in efficiency can be explained by increases in the size of vehicles (capacities) and changes in the mix of commodities carried.

While average liters per 100 Km bounced from 52 to 47 back to 52 and then down to 46, liters per tonne-Km declined almost consistently from 0.056 to 0.045. It should be noted that the tonne-Km data in Table IV.2 are not actual tonne-Kms but rather one-half of total truck capacity miles. That is, an assumed load factor of 50% was used for each year. This makes it possible to calculate average in-use truck capacity, which, except for 1980, has increased steadily. The increased use of larger trucks is the reason why liters/100 Km declined only 11% from 1977 to 1982, while liters/tonne-Km declined 20%.

A more detailed breakdown of activity for the years 1977 and 1982 (Tables IV.3–IV.4) illustrates both the tendency towards larger trucks and changes in the mix of trucking activities. High capacity activities such as long haul trucking and bulk liquids shipments tended to increase rapidly, while small load goods distribution declined. The trend is not uniform, however, and varies from year to year. Nevertheless it appears that changes in both the types of commodities handled by STM and increases in truck size have contributed to increased energy efficiency per tonne-Km.

Table IV.2. STM Diesel Fuel Use and Efficiency

	Fuel consumption in 10^3 liters	Kilometers 10^3	Liters per 100 Km	Tonne-Km 10^3	Liters per tonne-Km	Average capacity (tonnes)	Number of vehicles
1975	8,930.367	NA	NA		NA	-	-
1976	9,599.318	NA	NA		NA	-	-
1977	10,979.520	21,257.730	51.6	195,920.41	0.056	18.43	500
1978	10,429.897	22,221.739	46.9	210,526.15	0.050	18.95	537
1979	12,059.071	24,267.004	49.7	243,631.48	0.049	20.08	529
1980	13,614.676	25,975.709	52.4	272,525.28	0.050	20.98	577
1981	13,139.916	27,868.904	47.1	281,879.28	0.047	20.23	771
1982	15,059.333	32,676.782	46.1	335,374.77	0.045	20.53	664

NA — not available.

Source: "Consommation gasoil en Tunisie," Ministrie de l'Economie Nationale," estimeé de les achats en dinars," 8.83.

Table IV.3. Societé de Transport de Marchandises Breakdown of Trucking Activity by Type
1982

Activity	Tonne-km*	Km	Tonnes/load	Average truck capacity
Agence Port†	17,265,921	1,785,018	9.67	19.3
Agence Marché†	2,154,169	688,407	3.13	6.3
Cereal	32,145,838	2,767,517	11.62	23.2
Cement	14,169,928	1,350,335	10.49	21.0
Total short haul	65,735,856	6,591,277	9.97	19.9
Long haul	104,819,051	6,932,530	15.12	30.2
Bulk liquids	63,983,430	5,119,816	12.50	25.0
Oil and wine	6,683,165	510,278	13.10	26.2
Total general	241,221,502	19,153,901	12.59	25.2
Stone and gravel	94,153,269	13,522,881	6.96	13.9
Total STM	335,374,771	32,676,782	10.26	20.5

*Tonne-Km were calculated by STM assuming a 50% load factor for all trucks.

†Agence Port is comprised of container transport, agence Marché of small load goods distribution.

Source: Ministre de l'Economie Nationale, September, 1983.

Table IV.4. Societé de Transport de Marchandises Breakdown of Trucking Activity by Type
1977

Activity	Tonne-Km*	Km	Tonnes/load	Average truck capacity
Agence Port	8,453,768	1,258,939	6.71	13.4
Agence Marché†	4,000,208	1,318,026	3.03	6.1
Cereal	9,754,544	1,262,189	7.73	15.5
Cement	10,114,218	928,762	10.89	21.8
Total short haul	32,322,738	4,767,916	6.78	13.6
Long haul	51,435,091	3,278,913	15.72	31.4
Bulk liquids	32,848,591	2,505,321	13.11	26.2
Oil and wine	11,605,569	1,034,034	11.22	22.4
Total general	128,211,989	11,578,184	11.07	22.1
Stone and gravel	67,708,424	9,679,546	7.00	14.0
Total STM	195,920,413	21,257,730	9.22	18.4

*Tonne-Km were calculated by STM assuming a 50% load factor for all trucks.

†Agence Port is comprised of container transport, agence Marché of small load goods distribution.

Source: Ministre de l'Economie Nationale, September, 1983.

For SRTG trucks the energy intensity of freight movements in terms of liters per truck-Km has increased 37% since 1975 (Table IV.5). To some extent this change should be explainable by changes in the weight of cargo carried. It may also be due to changes in the truck stock, trip lengths, velocity, or load factors (including empty backhaul). To a limited extent it is possible to analyze this question with available data.

Rose (1979) offers a simple formula for the resistance to straight line movement of trucks over level terrain.

$$R_t = (W_e + W_c)(a + bv)S + cC_dA_fV^2 \qquad (1)$$

where R_t = total resistance to motion (tonnes),

W_e = vehicle weight (tonnes),

W_c = cargo weight (tonnes),

a,b = coefficients of tire rolling resistance,

S = road surface coefficient,

c = coefficient for aerodynamic drag term,

C_d = aerodynamic drag coefficient,

A_f = vehicle frontal area (m^3), and

V = velocity (Km/h).

We may assume that energy use per truck-Km is proportional to resistance and, therefore

$$\left(\frac{\ell}{100\ km}\right)_t - \left(\frac{\ell}{100\ km}\right)_{t-k} = K(R_t - R_{t-k})$$

$$\Delta\ EI = K[(W_{ct} - W_{ct-k})(a + bv)S]\ . \qquad (2)$$

Table IV.5. Activities of the Societés Regionales de Transport de Gouvernerats

	Fuel consumption	Vehicle kilometers	ℓ/100 Km	Tonnage transported	Number of vehicles
1975	15,092,840	45,096,671	33.47	4,326,812	822
1976	14,159,930	47,363,675	29.90	5,012,775	862
1977	17,675,555	50,538,348	34.97	7,141,638	898
1978	18,372,065	49,436,890	37.16	5,505,481	878
1979	18,780,449	49,038,959	38.30	5,503,060	872
1980	20,465,148	49,681,719	41.19	7,462,899	942
1981	24,443,620	52,966,576	46.15	8,847,872	1,006
Growth rate (1975–81)	+8.4	+2.7	+5.5	+12.7	+3.4

If we also assume the velocity does not change, then

$$\Delta EI = \alpha(W_{ct} - W_{ct-k}) \ . \tag{3}$$

If velocity has changed, but the change is the same in all regions

$$\Delta EI = K[(W_{ct} - W_{ct-k})(a + b(V_t - V_{t-k})S] + cC_dA_f(V_t^2 - V_{t-k}^2)$$

or (4)

$$\Delta EI = \alpha(W_{ct} - W_{ct-k}) + \beta \ .$$

If the change has not been the same in all regions then we will have omitted variables bias when we try to estimate α and β.

Since we do not know the tonnes per truck kilometer we will approximate it as follows:

$$\frac{\text{tonnes}}{\text{truck}} = \frac{(\text{tonnes transported})(\text{mean trip length})}{(\text{truck-Km})}$$

$$= a\,\frac{(TT)}{(Km)} \tag{5}$$

where a = mean trip length for a ton of cargo. If this is the same in t and t-k then we have,

$$\Delta EI = \alpha^* \left[\left(\frac{TT}{Km}\right)_t - \left(\frac{TT}{Km}\right)_{t-k}\right] + \beta \ . \tag{6}$$

Tables IV.6 and IV.7 give values for ΔEI and $\Delta(\frac{TT}{Km})$ for 1975–81 by region. Figure IV.2 shows a plot of the data in Table IV.6. A fit of equation (6) to the data is unsuccessful. Clearly either some of the assumptions do not apply, some of the data are in error, or tons per truck does not explain the changes in energy intensity, or a combination of the three. Given the fact that energy use and energy intensity have

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Table IV.6. Changes in Energy Use and Related Factors, 1975–1981

Region	Δ EI (%)	Δ KmP (%)	Δ Carburant (%)	Δ TT (%)	Δ Vehicules
Beja	–1.2	+43.1	+41.4	+27.9	0.0
Bizerte	+12.5	+61.4	+81.6	+92.6	+12.5
Gabes	+67.5	+9.0	+82.5	+81.4	+48.1
Gafsa	–38.5	+101.8	+24.1	+288.7	+24.1
Jendouba	+11.4	+152.1	+181.0	+206.3	+127.8
Kairouan	+39.4	+186.8	+299.9	+1,759.7*	+188.5
Kaserine	+58.3	+2.2	+61.8	+55.1	+22.0
Kef	+49.6	+14.5	+71.2	–0.9*	+28.6
Medenine	+8.2	–20.1	–13.6	+24.5	–29.5
Nabeul	+44.5	+33.5	+104.3	+121.6	+7.4
Sfax	+12.7	–2.2	+10.3	+23.3	+11.3
Sousse	+11.4	–3.6	+7.4	–17.6	–14.4
Total	+37.9	+17.5	+62.0	+104.5	+22.4

*Possibly erroneous data.

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Table IV.7. Changes in Energy Intensity Per Truck Kilometer (KmP) and in Tonnes Transported (TT) per Truck Kilometer, 1975–81

Region	EI_{75}	EI_{81}	Δ EI	$\frac{TT}{KmP}_{75}$	$\frac{TT}{KmP}_{81}$	$\Delta(\frac{TT}{KmP})$
Beja	31.09	30.71	–0.38	0.1001	0.0894	–0.0107
Bizerte	40.00	45.00	5.00	0.1029	0.1227	0.0198
Gabes	39.34	65.89	26.55	0.0948	0.1578	0.0630
Gafsa	34.49	21.21	–13.28	0.1485	0.2859	0.1374
Jendouba	33.50	37.33	3.83	0.0802	0.0975	0.0173
Kairouan	36.51	50.91	14.40	0.0415	0.2420	0.2005
Kasserine	31.74	50.25	18.51	0.0452	0.0686	0.0234
Kef	29.20	43.67	14.47	0.1014	0.0877	–0.0137
Medenine	37.25	40.32	3.07	0.0449	0.0700	0.0251
Nabeul	26.77	38.69	11.92	0.0636	0.1056	0.0420
Sfax	33.74	38.03	4.29	0.0822	0.1036	0.0214
Sousse	29.00	32.30	3.30	0.1701	0.1454	–0.2047

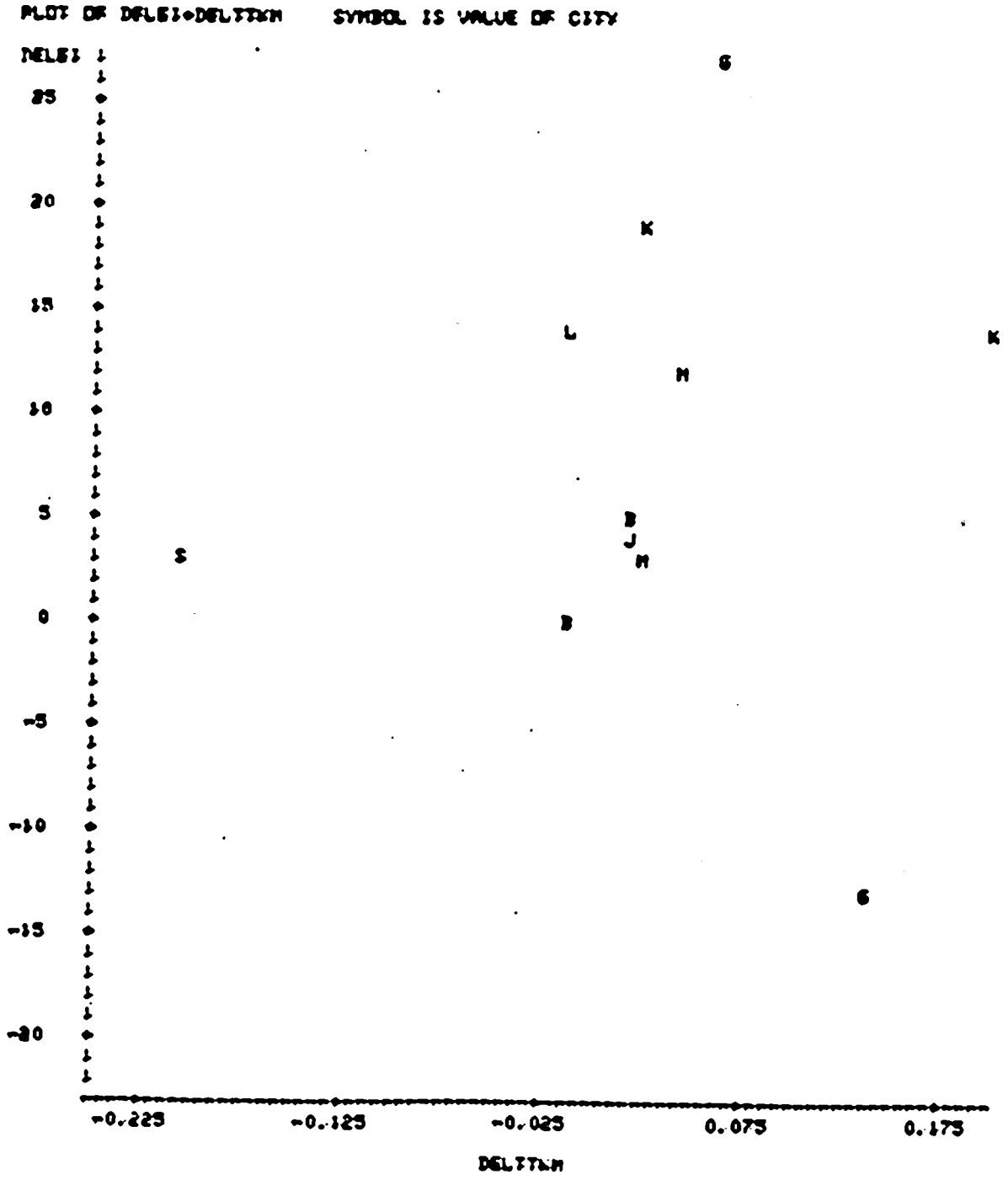

Figure IV... Change in Energy Intensity (ℓ/100 Km), DELEI, vs. Change in Tonnes Transported per Truck-Km, DELTTKH for SRTG's, 1975–81.

both increased significantly, and the fact that this is not readily explained by increased truck loadings (in tonnes), it might be useful to do some case studies to see if opportunities for efficiency improvements exist. It may be that dramatic increases in truck size are primarily responsible. Another possibility is that less efficient trucks have been purchased in recent years. Yet another is that keeping fuel costs low has become less important to freight companies.

This brief analysis is not exact by any means, it simply indicates that there is more going on than a simple change in tonnes transported per truck mile. Some interesting possibilities for case study might be, for example (ref. Table IV.6): 1) Gafsa, where tonnes transported have increased much faster than Km-parcouru, but energy intensity has gone down, 2) Kef, where the reverse is the case, and perhaps 3) Gabes, where it appears that increases in tonnes-transporté may entirely explain increases in energy intensity, and 4) Kairouan where the data may be in error.

The overall vehicle stock size has been increasing at about 3.5%/year. In some regions the increase has averaged almost 20%/year (Kairouan). This rate of increase suggests a strong possibility of improving the efficiency of the stock by purchasing the most efficient vehicles available. Whether this is already being done remains to be seen. Case studies could investigate the reasons for increasing energy intensities and determine if opportunities for significant conservation exist.

V. Rail Transport

The Tunisian rail system consumed 31.2 million liters (26.7 TEP) in carrying 1 billion passenger-km and 1.7 billion tonne-km of traffic in 1981.* Passenger travel nearly doubled between 1975 and 1981 according to SNCFT statistics. Rail freight activity in 1981 was one-third higher than its 1975 level. The total of 26.7 TEP of diesel fuel made up over 3% of total diesel fuel use in Tunisia in 1981 (Table V.1).

Passenger Rail

Rail passenger traffic, in the areas served, represents a very important and economical means of transportation. Over all the routes served by SNCFT in 1977, it has been estimated that rail accounted for roughly 30% of the passenger traffic. In the intercity market, SNCFT's share drops to about 18% with the exception of the Tunis-Sousse-Sfax route where the rail share of total traffic is about 35%.†

Tables V.2 and V.3 present statistical summaries of rail passenger traffic and the equipment used, respectively.

Table V.4 provides calculated data which gives some insight into the changes in energy intensity to be expected over time. Of these, the gross tonnage per passenger kilometer is the most important. At relatively low operating speeds the energy used in rail traffic is to a very large part determined by the gross tonnages moved provided no drastic changes occur in the traction efficiencies. A doubling of tonnages moved

---

*We neglect in this study electricity use by the TGM, a small light rail line serving Tunis, Carthage and other suburbs.

†Source: SEMA, "Plan Directeur des Transports Terrestres," Tunis, December, 1979.

Table V.1. Rail Activity and Energy Use, 1975–1982

	1975	1976	1977	1978	1979	1980	1981	1982
Passenger								
Passenger-km × 10^6	588.04	640.81	712.55	705.33	737.31	862.05	1010.65	944.04
Freight								
Tonne km × 10^6	1283.2	1276.8	1338.8	1373.3	1478.6	1710.6	1720.1	1588.48
Total								
Tonnes* of diesel × 10^3	20.262	19.326	21.387	21.219	21.998	23.794	25.927	NA
in liters × 10^6	24.412	23.284	25.767	25.565	26.504	28.668	31.237	NA
Tonnes of lubricants	528	518	509	502	496	654	NA	NA
in liters × 10^3	562	552	542	535	528	697	NA	NA

*Uses 10^3 liters to tonnes conversion factor of 0.83.

NA — Not available.

Table V.2. Rail Passenger Movements, 1975–1982

	Grande lignes			Banlieue			Total		
	Passengers 10^3	Passenger-km 10^6	Mean trip length [km]	Passengers 10^3	Passenger-km 10^6	Mean trip length [km]	Passengers 10^3	Passenger-km 10^6	% Banlieue
1975	4092	380.77	93.1	15944	207.27	13.0[1]	20036	588.04	35.2
1976	4326	420.26	97.1	16966	220.56	13.0	21292	640.81	34.4
1977	4476	448.92	100.3	20279	263.63	13.0	24755	712.55	37.0
1978	4281	454.18	106.8	19319	251.15	13.0	23570	705.33	35.6
1979	4091	459.16	112.2	21396	278.14	13.0	25487	737.31	37.7
1980	4451	555.86	124.9	23554	306.20	13.0	28005	862.05	35.5
1981	4796	674.12	140.6	25887	336.53	13.0	30683	1010.65	33.3
1982	4175	579.26	138.7	28060	364.78	13.0	32235	944.04	38.6

[1]Estimate provided by SNCFT.

NA — Not available.

Source: SNCFT, "Rapport D'Activité, Exercise 1980," Edition Provisoire, Tunis, February, 1981 and tables furnished by SNCFT.

Table V.3. Passenger Rail Rolling Stock, 1972–1981

	1972	1976	1979	1980	1981
Automotrices-intercity					
300 CV	21	13			
600 CV	12	12	12	12	12
1000 CV		14	14	14	14
1300 CV			4	20	20
Average CV per unit	409	644	880	1,026	1,026
Intercity cars					
Number	118	91	62	NA	94
Seats available	11,000	9,300	6,314	NA	9,450
Seats per unit	93	102	102	NA	101
Banlieues cars					
Numbers	32	56	53	NA	67
Passenger capacity[1]	8,414	11,149	10,969	NA	13,500
Passenger capacity[1]/car	263	199	207	NA	201

[1]Includes standing room.

NA – Not available.

Source: SNCFT, "Rapport D'Activité, Exercise 1980," Edition Provisoire, Tunis, February, 1981: tables furnished by SNCFT.

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Table V.4. Indicators of Rail Passenger Energy Intensity

	Passenger-km 10^6	TKBR[1] 10^6	Train-km 10^3	TKBR per passenger-km	Passenger-km per train-km	TKRB per train-km
1975	588.04	206	4012	.350	146.6	51.35
1976	640.81	225	4197	.351	152.7	53.61
1977	712.55	303	3613[2]	.425	197.2[2]	83.86[2]
1978	705.33	326	4568	.462	154.4	71.37
1979	737.31	319	4617	.433	159.7	69.09
1980	862.05	362	5945	.420	145.0	60.89
1981	1010.65	386	NA	.382	NA	NA

[1]Gross car tonne-kilometers, tonnage-kilometrique brut remorque.

[2]Potentially erroneous value.

NA — Not available.

Source: Basic data was furnished by SNCFT.

will have roughly an equal effect on the total energy used. The last two columns in the table provide an indication of the average train size and, hence, some idea of the potential efficiency improvements inherent in larger trains. Increasing the average train size will generally result in efficiency improvements through reductions in aerodynamic drag per car, improvements in the gross ton per passenger ratio (if no extra power units are added), and by permitting the operation of the power units in the more efficient full power portion of the operating curve.

Rail Freight

Rail freight is a rather specialized transportation mode in the sense that most activities center around only a few routes and cargoes. In 1980, phosphates and iron ore accounted for 73% of all rail freight tonne kilometers and 64% of all tons shipped by rail while accounting for roughly 90% of all movements of these products. The majority of this traffic passes over the Gafsa-Sfax and Gafsa-Gabes routes.

Table V.5 provides a summary of the rail freight traffic activity for 1975 to 1981. Tables V.6 and V.7 present the characteristics of the rolling stock used in these activities.

Presented in Table V.8 are some of the factors determining the energy efficiency of the movements. The gross car tonnage per revenue tonne kilometer is extremely useful since at lower speeds it is to a very large extent the total tonnage which has to be moved which determines the energy use. Furthermore this calculated value provides some insight into the average load factor. A value of 2.0, for example, states that for every tonne of freight moved one tonne of car also had

Table V.5. Rail Freight Activity, 1975–1981

	Heavy			Diverse			Total		
	Tonne	Tonne-km	km/tonne	Tonne	Tonne/km	km/tonne	Tonne	Tonne-km	km/tonne
1975	4431	956.8	215.9	2159	326.45	151.2	6590	1283.2	194.7
1976	4466	960.0	215.0	2191	316.78	144.6	6663	1276.8	191.6
1977	4803	1009.2	210.1	2204	329.60	149.55	7007	1338.8	191.1
1978	4902	1010.3	206.1	2409	362.98	150.68	7311	1373.3	187.8
1979	4840	1066.3	220.3	2785	412.34	148.06	7625	1478.6	193.9
1980	5304	1240.4	233.9	3039	470.19	154.72	8343	1710.7	205.0
1981	NA	NA	NA	NA	NA	NA	NA	1720.1	NA

NA — Not available.

Source: SNCFT, "Rapport D'Activité, Exercise 1980," Edition Provisoire, Tunis, February, 1982 and tables furnished by SNCFT.

Table V.6. Characteristics of Freight Cars

	Numbers of cars	Capacity [tonnes]	Average capacity [tonnes]
1977	2851	35,500	12.5
1979	5625	NA	NA
1980	5728	NA	NA
1982	4961	139,838	28.2

NA — Not available.

Source: Louis Berger International Inc., "Etude de la Coordination des Transports," Vol. 5, Tunis, November, 1979, p. F18; SNCFT, "Rapport D'Activite, Exercise 1980," Edition Provisoire, Tunis, February, 1982; tables furnished by SNCFT.

Table V.7. Locomotive Characteristics

	1972	1976	1979	1981
400 CV	16	16	16	16
600 CV	52	33	42	25
1000 CV	21	18	18	18
1400 CV	6	6	26	26
1800 CV				10
2200 CV	3	27	27	27
Total	98	100	129	122
Average power per unit [CV]	751	1120	1127	1223
Average tractive weight ([tonnes]	55.6	64.7	64.5	65.8

Source: Tables furnished by SNCFT.

Table V.8. Indicators of Rail Freight Energy Intensity

	Tonne-km [10^6]	TKBR[1] [10^6]	Train-km [10^3]	TKBR-per tonne-km	Tonne-km per train-km	TKBR per train-km
1975	1283.2	2626.8	3613	2.05	355.2	727.0
1976	1276.8	2656.5	3384	2.08	480.6	785.0
1977	1338.8	2880.6	3536	2.15	378.6	814.6
1978	1373.3	2632.0	3856	1.92	356.1	682.6
1979	1478.6	2801.1	4058	1.89	364.4	690.3
1980	1710.7	3102.1	5627	1.81	304.0	551.3
1981	1720.1	3072.7	NA	1.79	NA	NA

[1]Gross car tonne-kilometers, tonnage kilometrique brut remorque.

NA — Not available.

Source: Basic data was furnished by SNCFT.

to be moved. In other words on the average, roughly 1/2 of the total energy used would be used purely for moving the cars which carry the freight. Ratios for fully loaded cars should be on the order of 1.25 TKBR per cargo tonne kilometer but this must be verified for the cars in use in Tunisia today. The last two columns in Table V.8 provide information on the average train size. The 304 tonne-km per train km correspond to an average train size of about 22 cars which is quite short from the energy efficiency point of view. Longer trains tend to be more energy efficient due to the lower aerodynamic drag per car and by permitting the locomotives to be run at or near their peak efficiency which occurs at or above 0.75 full power.

Potential areas of investigation for energy savings include:

1) Reducing the empty backhauls in the general freight traffic.
2) Utilizing larger trains.
3) Maintaining the rolling stock for maximum efficiency.
4) Modifying operating procedures wherever possible to maximize energy efficiency.
5) Developing special equipment and procedures for the special conditions of the iron ore/phosphate traffic.

Locomotive Operations

Energy use data broken down by passenger and freight operations are not available. Energy use by type of locomotive do exist and can be used to derive efficiency estimates on a locomotive-Km basis (Table V.9). These estimates are of limited usefulness since they ignore important operational factors such as load factor and train size.

Table V.9. Energy Consumption and Efficiency by Locomotive Type SNCFT 1975–1981, in Liters (ℓ/Km in parentheses)

	Autorails	Manoevre	Locomotives deLigne	Total
1981	6,253,767 (1.44)	2,300,415 (1.60)	22,682,451 (3.65)	31,236,633
1980	5,747,084 (1.38)	2,206,715 (1.58)	20,713,796 (3.58)	28,667,595
1979	3,494,891 (1.16)	2,735,087 (1.98)	20,273,554 (3.22)	26,503,532
1978	3,681,219 (1.27)	2,442,679 (1.42)	19,440,179 (3.14)	25,564,782
1977	4,409,061 (1.22)	1,702,395 (1.30)	19,665,650 (3.24)	25,767,106
1976	4,719,781 (1.22)	1,307,148 (1.20)	17,257,000 (3.08)	23,283,929
1975	4,021,687 (1.23)	1,518,157 (1.36)	18,871,899 (3.33)	24,411,743

Nonetheless they do provide a gross indication of energy efficiency trends. The data in Table V.9 show a trend of increasing fuel consumption per locomotive-Km for all locomotive types. In the case of autorails, it is known that the introduction of more energy-intensive Ganz-Mavag locomotives in 1980 caused a jump in energy intensity and overall energy use. Increases in Manoevres and Locomotives de ligne energy intensity suggest that improved operating practices as well as consideration of the efficiency of new equipment could reduce energy intensities and energy use.

VI. Marine Transport

The principal marine transport agency in Tunisia is the Compagnie Tunisienne de Navigation (CTN). The Gabes Chimie Transport is the only other significant agent but its activities are limited to the transportation of phosphoric acid. According to the Etude de la Coordination des Transports vol. V, page M59 by Louis Berger (1979) the CTN accounted for 47% of the freight tonnage handled by Tunisian ports in 1977. Since Tunisian ships and ships of other countries may or may not buy fuel in Tunisian ports, and since small private craft also use diesel fuel, total fuel sales in Tunisia to marine vessels may exceed or be less than consumption by the CTN.

Table VI.1 presents statistics for diesel and residual oil consumption by the CTN for 1979 and 1980. CTN diesel consumption averaged approximately 50,000 TEPs for the two years. Residual oil use was slightly higher, averaging about 55,000 TEPs.

Data on total sales of marine fuel acquired by the Ministry of National Economy staff differ from the CTN consumption data (Table VI.2). Sales of diesel fuel are slightly higher, 61,514 TEPs in 1980. According to these data sales of marine diesel peaked in 1979 at 69,123 TEPs, declined to 56,225 TEPs in 1981 and then rebounded to 64,918 in 1982. This represents 8 percent of total diesel consumption in 1981 (812,300 TEPs). Total residual sales reported, however, are lower than reported CTN residual consumption. The majority of CTN residual oil use is by chartered ships and it is possible that they purchase significant quantities of fuel outside of Tunisia. Marine residual oil sales represent only about 3 percent of reported national consumption.

Table VI.1. Fuel Use by the Compagnie Tunisienne de Navigation (CTN)

	1979		1980	
	Diesel	Residual oil	Diesel	Residual oil
		Metric tonnes		
CTN ships	37,606.270	16,605.415	35,858.519	18,605.416
Chartered ships	14,145.509	37,530.140	10,575.551	41,035.037
		TEP		
CTN ships	38,734	16,107	36,934	18,047
Chartered	14,570	36,404	10,893	39,804
Total	53,304	52,511	47,827	57,851

Tonnes metric converted to Tonnes Equivalent Petroleum's using:

Residual oil 0.970 TEP/metric tonne.
Diesel 1.030 TEP metric tonne.

Table VI.2. Marine Fuel Sales by Fuel Type*
(TEPs)

	Diesel bunkering	Diesel coastwise	Diesel total	Residual oil bunkering	Residual oil coastwise	Residual oil total
1982	48,222	16,695	64,918	24,724	4,715	29,440
1981	48,296	7,929	56,225	35,647	2,002	37,649
1980	49,986	11,529	61,514	61,125	790	61,914
1979	54,650	14,473	69,123	55,146	906	56,052
1978	41,684	13,876	55,560	35,714	1,420	37,134
1977*	28,069	18,019	46,088	52,060	3,891	55,951
1976	28,994	19,449	48,443	14,977	-	-
1975	25,623	17,411	43,034	10,940	2,246	13,186
1974	19,979	21,230	41,209	12,758	1,547	14,305
1973	19,929	4,992	24,921	18,756	1,557	20,313

*Data prior to 1978 exclude SNDP deliveries of gasoil. Metric tonnes converted to TEPs using 0.970 TEP/tonne for residual oil; 0.083 metric tonnes per hundred liters and 1.030 TEP/tonne for diesel.

Data supplied by the staff of the Ministry of National Economy.

VII. Energy Use by Government Vehicles

Since the National Survey of Vehicle Energy Use excluded government vehicles, the Ministry of National Economy (MEN) obtained data from several government administrations concerning energy use by their vehicles. Data were also obtained from the Societé Nationale de la Distribution de la Petrole concerning total sales to all government administrations, offices, and transport companies (Table VII.1). These data show that 27,233 TEPs of diesel fuel were sold to government administrations in 1982, excluding transportation companies. Only 5,703 TEPs of gasoline were sold to the same agencies. Although only a partial breakdown of this energy consumption by ministry is available, it appears that agriculture and defense are by far the largest consumers (Tables VII.2 and VII.3). Some further work is necessary to correctly interpret these numbers since it is clear that the total amount of gasoline obtained by summing the consumption of the agencies reporting is greater than the total sales reported by SNDP. Most likely the excess is purchased at retail outlets.

Nonetheless, an estimate of non-agricultural energy use by government vehicles can be obtained by subtracting the Ministry of Agriculture's total from the reported SNDP deliveries. This results in an estimate of 16,982 TEPs of diesel and 2,734 TEPs of gasoline, about 2% of total diesel and about 1.6% of gasoline use in Tunisia in 1982.

Table VII.1. Fuel Sales to Government Agencies and Societés de Transport by Type of Fuel (M^3)

	1980			1981			1982		
	Diesel	Premium	Regular	Diesel	Premium	Regular	Diesel	Premium	Regular
Administrations	27,497	1,201	4,823	27,815	1,245	5,295	28,430	1,249	5,777
Transport companies*	49,659	370	-	60,800	440	-	61,409	418	-
SNCFT	1,320	86	79	1,325	82	64	7,893†	84	24
Offices	3,214	189	105	5,762	245	123	3,425	271	84
Total excluding transport companies	30,711	1,390	4,928	33,577	1,490	5,418	31,855	1,520	5,861
in TEPS	26,255	1,074	3,807	28,705	1,151	4,186	27,233	1,174	4,528
Total for transport companies	50,979	456	79	62,125	522	64	69,302†	502	24
in TEPS	43,582	352	61	53,111	403	49	59,246	388	19

*Excludes SNCFT.

†Probably erroenous.

Conversions: 1000 ℓ/m^3; 1000 ℓ = 0.8549 TEP diesel, 0.77256 TEP gasoline.

Source: Societé Nationale de la Distribution de la Petrole.

Table VII.2. Fuel Consumption by the Ministry of Agriculture 1982 (in 10^3 ℓ)

	Diesel	Essence
Automobiles and all-terrain	1526.4	3250.8
Light trucks	1128.0	-
Trucks	909.0	-
Tractors	8427.0	-
Moby	-	590.6
Total in liters (10^3)	1190.4	3841.4
in TEPS	10250.6	2967.7

Source: Table prepared by M. Letaief, Le Chef de Services des Transports, Ministry of Agriculture.

Table VII.3. Partial Accounting of Government Use of Transportation Fuels 1982

Administration	Diesel	Regular gasoline	Premium gasoline	Gasoline 100/130	Jet A1
Defense	9,006,850	1,070,830	1,702,400	100,278	1,993,870
Higher ed. and res.	22,880	22,080	-	-	-
Information		10,000			
Youth and sports*	265,200	75,600	108,000		
STEG†	1,265,000			-	-
		Essence			
Agriculture	12,006,800	3,839,900			
Total accounted for -					
in liters	22,566,730	6,828,810		100,278	1,993,870
in TEPs	19,292,297	5,275,665		77,470	1,638,164

*Based on monthly consumption.

†Data from Societé Tunisienne de l'Electricite et du Gaz, as amended by M. Ahmed Ounali of MEN, 8/26/83.

Source: M. Hamouda of MEN, July 23, 1983.

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Appendix 1

Vehicle Inspection Station Questionnaire

REPUBLIQUE TUNISIENNE

MINISTERE DE L'ECONOMIE NATIONALE
DIRECTION DE LA CONSOMMATION ET DES SOURCES ALTERNATIVES D'ENERGIE

MINISTERE DU TRANSPORTS ET DES COMMUNICATIONS
SERVICE DES TRANSPORTS TERRESTRES

Numéro de contrôle [1–6]

Code Carte [7] [1]

Date [8–13]

Jour Mois Ann

ENQUETE NATIONALE SUR LA CONSOMMATION ENERGETIQUE DES VEHICULES

1. Nom et prénom du propriétaire / locataire [14–33]

Nom (en majuscule) Prénom

2. Adresse du propriétaire / locataire [34–57]

[58–63]

2b. Autres localisations possibles : _____

3. Plaque d'Immatriculation _____ [64–73]

Reservee a l'Administration

4. Marque du Véhicule _____ [74–75]

5. Type du Véhicule _____ [76–80]

6. Numero Série du Type _____ [81–90]

7. Date du 1ère mise en circulation _____ [91–94] Mois Année

8. Date de la dernière mutation _____ [95–98] Mois Année

Code Carte [7] [2]

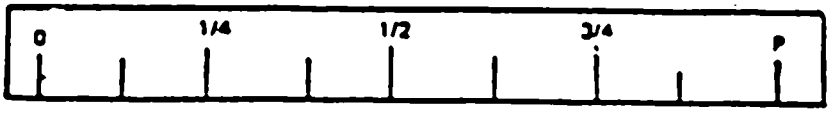
9a. Numéro du téléphone a domicile _____ [8–13]

9b. Numéro du téléphone au Bureau _____ [14–19]

Reservee a l'Administration

10. Qu'elle est votre occupation principale ? _____ [20–23]

11. Marquer d'une croix sur le schéma ci-dessous la position actuelle de l'indicateur du carburant _____ [24]



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12. Nature du carburant utilisé .....
(Indiquer d'une croix la reponse)

25

1. ☐ Essence normale
2. ☐ Super
3. ☐ Gasoil
4. ☐ Gaz propane

13a. Indiquer le kilométrage actuel ..... 26–32 ☐☐☐☐☐☐

— et quel est son cycle ? 33
(Indiquer d'une croix la reponse)

1. ☐ 1er Cycle
2. ☐ 2eme Cycle
3. ☐ 3eme Cycle

13b. Est-ce que la réponse pour le cycle est sûre ou estimée ? 34
(Indiquer d'une croix la reponse)

1. ☐ Sûre
2. ☐ Estimee

14. Combien de rodages est-ce que vous avez effectués ? ..... 35 ☐ Fois

15a. Combien de moteur a eu le véhicule y inclus le moteur actuel ? ..... 36 ☐ Moteurs

15b. Est-ce que la réponse pour le nombre de moteurs est sûre ou estimée : 37

1. ☐ Sûre
2. ☐ Estimée

16. En général, combien de personne (s) conduit (sent) le véhicule ? 38
(Indiquer d'une croix la reponse)

1. ☐ Une
2. ☐ Deux
3. ☐ Trois
4. ☐ Quatre
5. ☐ Autres

Spécifier .....

17. Pendant l'annee dernière quelle a été, approximativement, la proportion d'usage du vehicule pour :

— se rendre au lieu du travail (encadrer une reponse)

0 $\frac{1}{4}$ $\frac{1}{2}$ $\frac{3}{4}$ 100 %

— d'autres usages professionnels (encadrer une reponse

0 $\frac{1}{4}$ $\frac{1}{2}$ $\frac{3}{4}$ 100 %

— l'utilisation personnelle (encadrer une reponse)

0 $\frac{1}{4}$ $\frac{1}{2}$ $\frac{3}{4}$ 100%

Réservée à l'Administratio

39 ☐

40 ☐

41 ☐

18a. Combien de personnes et quel est le tonnage de marchandise transporté, en moyen, par deplacement ? .....

41–42 [ ][ ] Personnes

43–46 [ ][ ][ ][ ] Kgs/mar.

18b. Si le véhicule est utilisé pour le transport de marchandise, quelle est, en general, la nature de la marchandise ? .....

Réservée à l'Administration

47–48 [ ][ ]

19. Quelle est la distance moyenne, par déplacement ? .....

49–50 [ ][ ] Kms

20. Autre que le lavage et le graissage, quelle est la fréquence d'entretien du véhicule ?

1. une fois tous le

ENQUETEUR : Remplir l'un ou l'autre (1 ou 2)

2. une fois tous le

51–55 [ ][ ][ ][ ][ ] Kms

56–57 [ ][ ] Mois

21. Qu'est-ce qui a été fait la dernière fois pour le véhicule lors de l'entretien ?
(Enquêteur, demander après chaque réponse "et quoi d'autres ?")

1. _____

2. _____

3. _____

4. _____

5. _____

Réservée à l'Administration

58–59 [ ][ ]

60–61 [ ][ ]

62–63 [ ][ ]

64–65 [ ][ ]

66–67 [ ][ ]

68 [ ]

69–70 [ ][ ]

22. Quel type d'huile moteur utilise pour votre véhicule ?
S.v.p., indiquer la marque et la viscosité.

Marque : _____

Viscosité : _____

71

23. Quelle est la fréquence du contrôle de la pression des pneus ? .....
(Indiquer d'une croix la réponse)

1. [ ] Une fois toutes les 2 semaines et plus

2. [ ] Une fois par mois

3. [ ] Moins qu'une fois par mois.

ENQUETEUR : Repondre aux questions 24–26 suite a une observation personnelle.

24. Combien de pneus sous-gonflés dans le véhicule ? _____ 72 [ ] Pneus

25. Type et nombre de pneus _____ radial 73 [ ] Pneus

_____ à plis 74 [ ] Pneus

26. Le véhicule dispose t-il d'acclimatisation ? _____ 75
(Indiquer d'une croix la réponse)

1. [ ] Oui

2. [ ] Non

Un copie de la carte postale

MINISTERE DE L'ECONOMIE NATIONALE

MINISTERE DES TRANSPORTS ET DES COMMUNICATIONS

1–6

Numéro de contrôle

Réservée à l'Administration .....

1. Date d'achat : _____ JOUR _____ MOIS _____ ANNEE — 7–12

2. Quantité de carburant acheté : _____ lts. — 13–14

3. Montant total payé : _____ Dinars — 15–19

4. Indication du compteur (kilométrage) à l'achat du carburant : _____ kms. — 20–25

5. Avez-vous rempli le réservoir : _____ Oui _____ Non — 26

6. Marquer d'une croix sur les schémas ci-dessous la position de l'indicateur du carburant avant et après l'achat du carburant : — 27

Avant: 0 1/4 1/2 3/4 P

Après: 0 1/4 1/2 3/4 P — 28

130

Appendix 2

Conversion Factors Used in This Report

Petroleum product	TEP/tonnes	Specific gravities
No. 2 fuel oil (residual oil)	0.970	0.95
Diesel	1.030	0.83
Gasolines	1.044	0.74
Kerosene, jet fuel	1.040	0.79

Appendix 3

Estimation of the Growth of Light Truck Diesel Fuel Use and Taxi and Louage Diesel Fuel Use 1975–81

Estimation of the growth in light truck diesel fuel use is difficult since the stock has only been crudely estimated for years prior to 1982 and since changes, if any, in efficiencies and utilization rates are unknown. The method used here relies primarily on light truck registration data. A simplistic model of light truck scrappage is applied to these data and the stock in each year is thereby estimated. A constant rate of annual fuel consumption per truck is multiplied times the estimated stock to derive an estimate of fuel use. The method is crude and the results should be considered approximate at best.

The scrappage model assumes that a constant proportion, δ, of last year's stock, S_{t-1} will be scrapped in the current year, t. Adding registrations in year t, R_t, results in an estimate of the current stock:

$$S_t = R_t + (1 - \delta)S_{t-1} .$$

In order to use this approach it is necessary to have estimates of the initial stock in year t_0, and of the scrappage rate δ. Since registration data for 1972–81 are available, 1971 was taken to be the base year. The 1971 light truck stock was assumed to be 10,500 units, and δ was chosen (by iteration) to equal 0.13. This rate of scrappage may seem high, but it was necessarily so, in order to keep estimated stock in 1981 below that of 1982.

Based on the National Survey of Vehicle Energy Use results, it was assumed that the average light truck consumes 4,346 liters of diesel

fuel per year (11.9 × 365.25). Estimated total fuel use was further adjusted to account for the fact that 97.5% of light trucks are diesel powered and that, according to Ministry of Transport data, 2.8% are owned by the Government. The fuel use estimates given in Table A.3.1 pertain to non-government vehicles only.

Estimated stock in 1981 is 41.4 thousand units, just slightly lower than the estimate of 41.9 which results from our expansion of the National Survey of Vehicle Energy Use. Estimated diesel fuel use for 1981 is correspondingly lower than the 1982 survey-based estimate since a constant fuel consumption per vehicle has been assumed. (It is possible, though by no means certain, that the rate of usage per vehicle has been growing over time. If so, historical usage may be over-estimated.) Estimated stock for 1972 and 1977 are reasonably close to equally crude estimates for those years derived by Louis Berger International, Inc. (1979, pp. R123 and R130), of 12,000 and 26,000 units, respectively. The estimates presented in Table A.3.1 are indeed crude, but probably the best that can be done without additional information.

Extrapolation of taxi and louage energy use was done even more simply. Louis Berger provides estimates of the taxi and louage stock for 1962, 1972 and 1977 as shown in Table A.3.2.

Following the procedure used in Chapter III, taxis were assumed to consume 6150 liters of diesel fuel per vehicle per year. This was multiplied by the estimated number of taxis and rounded to the nearest million liters. For louages the same procedure was used with an estimate of 10,000 liters per year per vehicle.

Table A.3.1. Estimated Growth in the Light Truck Stock and Diesel Fuel Use

Year	Registrations	Estimated stock (thousands)	Estimated diesel consumption (millions of liters)
1972	3,390	12.52	51.59
1973	3,175	14.07	57.96
1974	2,890	15.13	62.33
1975	3,850	17.02	70.08
1976	5,185	19.99	82.33
1977	5,735	23.12	95.24
1978	6,555	26.67	109.86
1979	8,825	32.03	131.93
1980	7,470	35.34	145.54
1981	10,625	41.37	170.38
1982*		41.89	177.40

*1982 data based on the National Vehicle Survey results contained in this report.

Table A.3.2. Estimated Taxi and Louage Stock and Energy Use

	1962	1972	1977	1982
Stock				
Taxi	896	2,300	2,452	3,856*
Louage	527	724	810	1,439*
Estimated energy use (10^6 ℓ)				
Taxi		14	15	20
Louage		7	8	14

*Ministry of National Economy staff.

Source: Louis Berger, International, Inc., R123.

Appendix 4

The Automobile and Light Truck Vehicle Stock

In 1982, there were approximately 152,000 cars and light trucks in Tunisia excluding government vehicles, according to the best data available at the time of writing this report. Of these, about 28% are trucks or camionettes. Based on the National Survey and other data there were approximately 110,000 automobiles and 42,000 light trucks on the road in 1982. Of this total, in 1982 71% of the vehicles passed through the five centers included in the National Survey of Vehicular Energy Use (Table A.4.1). This section describes how these estimates and others used to develop expansion factors for the survey were determined.

Probably the best estimate of non-government automobiles and trucks in use in Tunisia is the number of vehicles which successfully take the required annual vehicle inspection. Based on a census of vehicles at the inspection centers (Centres de Visite Technique) in 1978, Louis Berger (1979) estimated that 104,677 vehicles were certified in that year. The data Berger presents indicate that 152,513 vehicle visits were made and 127,556 inspections were made. For the year 1977 Berger derived independent estimates of vehicles in use from two other sources: 1) 92,500 vehicles, using vehicle registrations (cartes grises) and 2) 100,000, using a survey of vehicle license plate serial numbers (there are known to be 10,000 vehicles per number). Berger estimated that there were about 11,000 government vehicles in use in 1978. He estimated the total for 1977 using inspection station counts plus government vehicles at approximately 109,500 (Table A.4.2).

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Table A.4.1. Numbers of Vehicles Certified (Acceptes) by the Centres de Visite Technique, 1980–81

Center	1980	1981	1982
Tunis	65,459	73,533	72,886
Sfax	14,558	20,447	18,114
Sousse	13,887	15,802	17,714
Medenine	5,617	6,227	6,312
Kef	2,414	2,619	2,840
Subtotal	101,935	118,628	117,866
Beja	3,101	2,760	3,210
Gafsa	2,938	3,501	3,939
Gabes	6,169	6,511	8,552
Kairouan	3,184	3,565	4,169
Bizerte	5,282	5,962	7,272
Siliana	659	1,011	1,319
Sidi Bouzid	1,782	1,933	2,534
Nabeul	7,422	7,769	9,238
Zaghouan	1,325	1,248	2,261
Jendouba	2,034	2,561	2,907
Kasserine	1,683	2,030	2,414
Tatouiun	-	-	1,471
Total	137,514	157,479	167,152

Table A.4.2. Estimates of the Car and Truck Parc

Louis Berger, 1977, cartes grises (registration cards)	92,500
Louis Berger, 1977, license plate survey	100,000
Louis Berger, 1977, centre de visite technique	109,500
1980, vehicles accepted at the centres de visite technique	137,514
1981, vehicles accepted at the centres de visite technique (5 centers)	157,479

According to data obtained by the Ministry of National Economy, 137,514 cars and trucks (voitures, camions, and camionettes) were reported accepted (acceptes) at the inspection centers in 1980, 157,479 in 1981, and 167,152 in 1982.

According to INS data on vehicle registrations 14,179 automobiles and light trucks (tourismes, commerciales, and camionettes) were registered for the first time in 1978, 20,207 in 1979, 18,125 in 1980, and 23,960 in 1981.

In the analysis of the National Vehicle Energy Consumption Survey below, we have used the total number of vehicles accepted at the inspection stations in 1982 to derive expansion weights for the survey. On the one hand, the total number of cars and trucks 167,152, contains both government vehicles and trucks over 3.5 tonnes. On the other hand, the survey covers only Tunis, Sousse, Sfax, Medenine, and Kef which together comprise only 117,866 of the 167,152 cars and trucks accepted at the inspection stations. To expand the data for the five centers to the

total stock for 1982, we simply use the ratio (167,152/117,866) = 1.4182. This forms the first element of the formula for expanding the sample.

Data on the distribution of vehicles by type of ownership and the division between light and heavier trucks (> 3.5 tonnes) exists only for vehicles registered in recent years. The total number of cars, light trucks and heavy trucks reported in this data base is 113,816 for 1982. Although this accounts for only about 2/3 of the estimated stock in 1982 it was considered useful for the approximation of the relative proportions of vehicles by center and type. The data from the Ministry of Land Transport divide vehicles into cars, light trucks, and heavy trucks (heavyweights > 3.5 tonnes) and subdivide each category by types of ownership: société (company), proprietaires (private), and administrations (government). Within each category vehicles are further subdivided by fuel type: gasoline, diesel, other. Since fuel type was not a factor used in stratifying our sample, this latter breakdown was ignored. These data were used to estimate the division between company and private vehicles by center to develop expansion factors for the sample (Table A.4.3). In the data presented in this report it was assumed that administrative vehicles did visit the inspection stations but were not included in the survey.*

73% of the total company cars and trucks and 90% of the government cars and trucks recorded in these data for all of Tunisia are located in Tunis. For example, in Tunis 32% of camionettes in these data are owned

*Personal communication, October 4, 1983, M. M. el Gharbi, Ministere de L'Economie Nationale.

Table A.4.3. Distribution of Vehicles by Type and Ownership in the Five Centers According to the Ministry of Land Transport Data Base (number/percent of type)

	Private	Company	Government	Total
Car (voiture)	43,523 78%	8,330 15%	3,733 7%	55,586 100%
Light truck (camioinette)	14,373 74%	4,087 21%	962 5%	19,422 100%
Heavy truck (poid lourds)	718 26%	1,421 52%	574 21%	2,713 100%
P.L. % of trucks	5%	26%	37%	12%

by companies while for the rest of Tunisia only 7% are. Thus for most purposes a survey of company vehicles in Tunisia could be carried out almost entirely in Tunis. It appears that roughly 12% of the trucks in the five centers are heavy trucks, the remaining 88% being light trucks.

The expansion factors shown in Table A.4.4 are comprised of four basic elements. The first factor expands the data for the five centers in 1982 to the global Tunisian stock in 1982. As discussed above this factor is 1.4182 and is the same for all centers and categories. The second element is the total number of vehicles accepted at that center in 1982. The third, and most critical factor is the relative proportion of vehicles of a given type to total cars, light trucks, and heavy trucks at the center in question. All three numbers have been drawn from the Ministry of Land Transport data base. It remains only to divide this "desired" total by the number of vehicles of the given category which are contained in the survey. Since the National Survey of Vehicle

Table A.4.4. Vehicle Stock Expansion Factors

	Expansion to 1982 Tunisian stock		Total accepted at CDVT		Private cars / total "voitures et camions" from Ministry of Transport		Category total from Inspection Center		Category total from Postcard (usable responses)
					Voiture Privée				
Tunis	(1.4182)	=	(72886)	=	$\frac{30289}{41320 + 11983}$	=	2123	or	406
Sousse	(1.4182)	=	(17714)	=	$\frac{2529}{2729 + 1828}$	=	1535	or	240
Medenine	(1.4182)	=	(6312)	=	$\frac{2423}{2578 + 2345}$	=	931	or	92
Sfax	(1.4182)	=	(18114)	=	$\frac{7508}{8154 + 5223}$	=	1141	or	208
Kef	(1.4182)	=	(2840)	=	$\frac{774}{787 + 819}$	=	558	or	95
					Voiture Société				
Tunis	(1.4182)	=	(72886)	=	$\frac{7423}{41320 + 11983}$	=	146	or	15
Sousse	(1.4182)	=	(17714)	=	$\frac{184}{2729 + 1828}$	=	63	or	3
Medenine	(1.4182)	=	(6312)	=	$\frac{117}{2578 + 2345}$	=	110	or	22
Sfax	(1.4182)	=	(18114)	=	$\frac{579}{8154 + 5223}$	=	67	or	13
Kef	(1.4182)	=	(2840)	=	$\frac{27}{787 + 819}$	=	26	or	6
					Camionette Privée				
Tunis	(1.4182)	=	(72886)	=	$\frac{5917}{41320 + 11983}$	=	719	or	127
Sousse	(1.4182)	=	(17714)	=	$\frac{1480}{2729 + 1828}$	=	877	or	90
Medenine	(1.4182)	=	(6312)	=	$\frac{2176}{2578 + 2345}$	=	721	or	98
Sfax	(1.4182)	=	(18114)	=	$\frac{4043}{8154 + 5223}$	=	552	or	96
Kef	(1.4182)	=	(2840)	=	$\frac{757}{787 + 819}$	=	819	or	147
					Camionette Société				
Tunis	(1.4182)	=	(72886)	=	$\frac{3151}{41320 + 11983}$	=	74	or	12
Sousse	(1.4182)	=	(17714)	=	$\frac{197}{2729 + 1828}$	=	38	or	8
Medenine	(1.4182)	=	(6312)	=	$\frac{90}{2578 + 2345}$	=	54	or	12
Sfax	(1.4182)	=	(18114)	=	$\frac{619}{8154 + 5223}$	=	31	or	9
Kef	(1.4182)	=	(2840)	=	$\frac{30}{787 + 819}$	=	43	or	16

Energy Consumption has two parts, an inspection station survey (CDVT) and a postcard subsample (CP) two counts are required. In Table A.4.4 the first, and largest is the CDVT count, the second, smaller number being the CP count.

Applying these factors to the survey data base results in the detailed breakdown of the vehicle parc shown in Tables A.4.5 and A.4.6. Because not all vehicles in the surveys reported both vehicle type and fuel type, there are slight differences between estimates broken down in different ways. It is comforting to note that there are again only slight differences between estimates based on the full CDVT sample (Table A.4.5) and the CP subsample (Table A.4.6) despite the low rate of response (about 25%) to the postcard survey.

The picture of the Tunisian vehicle parc portrayed by these data is numerically dominated by automobiles and by privately-owned vehicles (it should be noted that the estimates exclude government, "administration," vehicles). The sample of company vehicles, however, is disproportionately small. For this reason these, and other estimates concerning company vehicles in this report should be regarded with caution. Nonetheless, it appears that approximately 127,000 of the estimated 152,000 non-government light vehicles in Tunisia in 1982 were privately owned. Approximately 54,000, or 35% use diesel fuel and of these the majority, about 41,000 are light trucks.

Throughout this report, the CDVT based estimated in Table A.4.5 will be used to expand average vehicle fuel consumption rates to the total stock.

Table A.4.5. Estimated Number of Vehicles by Type and Fuel Type Based on Inspection Center (CDVT) Sample (sample size in parentheses)

Private cars	Private light trucks	Company cars	Company light trucks	Total
93,704 (6288)	33,244 (3688)	16,801 (412)	8,624 (240)	152,373 (10628)

	Regular gasoline	Premium gasoline	Diesel	Propane	Total
Private cars	26,492 (2151)	55,369 (3107)	11,231 (981)	347 (26)	93,439 (6265)
Private light trucks	226 (27)	208 (16)	32,523 (3594)	127 (12)	33,083 (3649)
Company cars	2,368 (86)	10,423 (211)	2,163 (83)	99 (1)	15,052 (381)
Company light trucks	83 (1)	153 (4)	8,017 (224)	251 (4)	8,503 (233)
Total	29,168 (2265)	66,152 (3338)	53,935 (4882)	822 (43)	150,078 (10528)

Table A.4.6. Estimated Number of Vehicles by Type and Fuel Type Based on Postcard (CP) Sample (sample size in parentheses)

Private cars	Private light trucks	Company cars	Company light trucks	Total
93,445 (1041)	33,253 (558)	16,802 (59)	8,624 (57)	152,124 (1715)

Regular gasoline	Premium gasoline	Diesel	Propane	Total
24,905 (344)	69,477 (604)	55,290 (743)	2,129 (14)	151,801 (1,705)

	Regular gasoline	Premium gasoline	Diesel	Propane	Grand total
Private cars	22,952 (317)	59,522 (578)	10,439 (138)	347 (5)	
Private light trucks	212 (3)	272 (3)	32,337 (540)	300 (6)	
Company cars	1,741 (24)	9,551 (22)	4,550 (12)	960 (1)	
Company light trucks	0 (0)	132 (1)	7,965 (53)	523 (2)	
Grand total					151,803 (1705)

The inspection center survey data make it possible to determine the age distribution of the light vehicle stock. Figure A.4.1 shows this distribution by fuel type. The most striking aspect of the age distributions is the fact that the vast majority of diesel vehicles are less than 8 years old. Most of these, of course, are light trucks. The rapid buildup of diesel stock is contemporaneous with the large price differential between gasoline and diesel fuel. To what extent the growth in diesel stock was caused by the much lower price of diesel fuel is not known, but it must surely represent a major incentive to owning a diesel vehicle. Figure A.4.1 also reveals that vehicles using regular grade gasoline tend to be much older than those using premium.

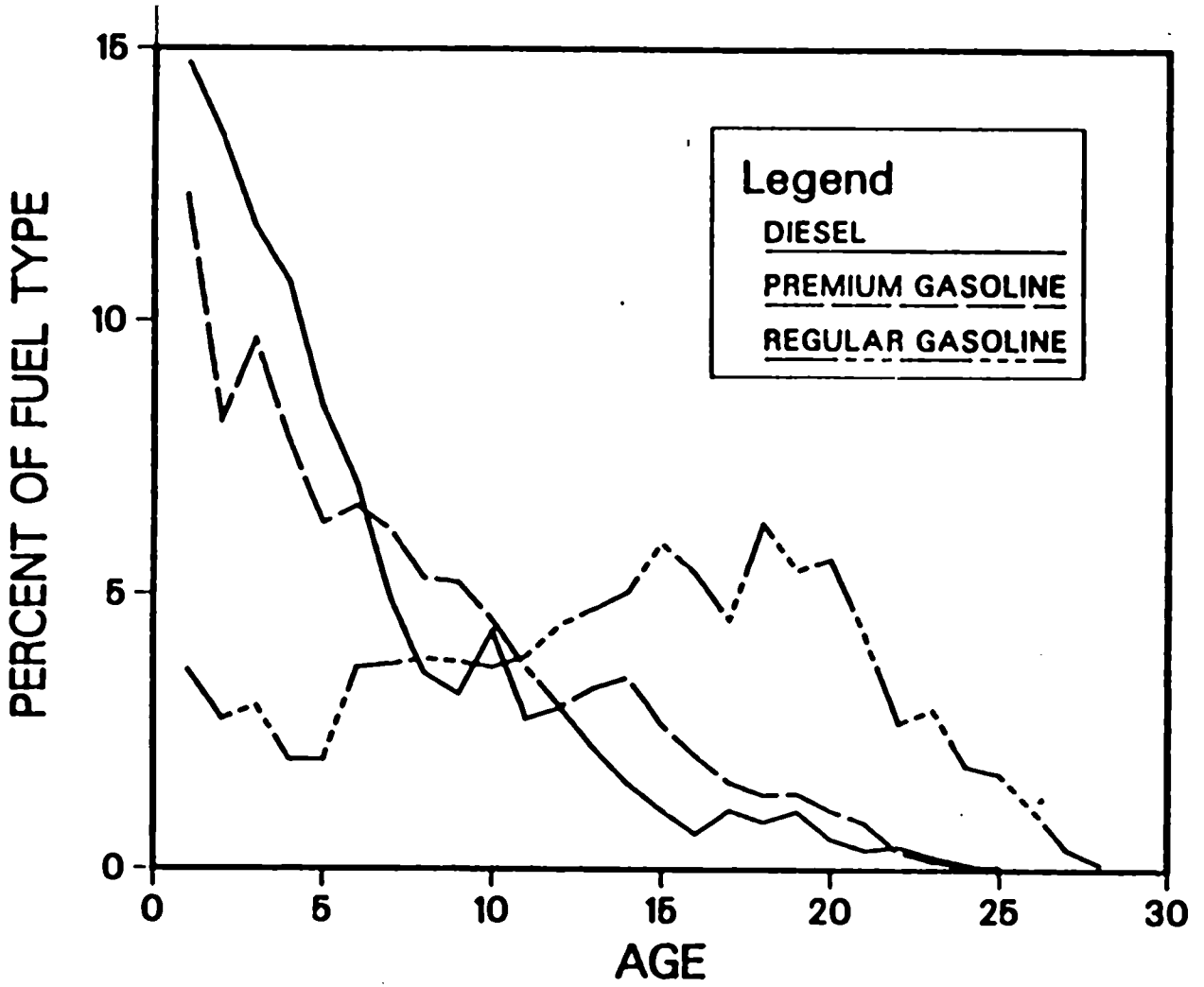

Figure A.4.1. Distribution of Vehicles by Age by Fuel Type.