NATIONAL TRANSPORT RESEARCH CENTRE

FUEL CONSUMPTION STUDY

NTRC-54

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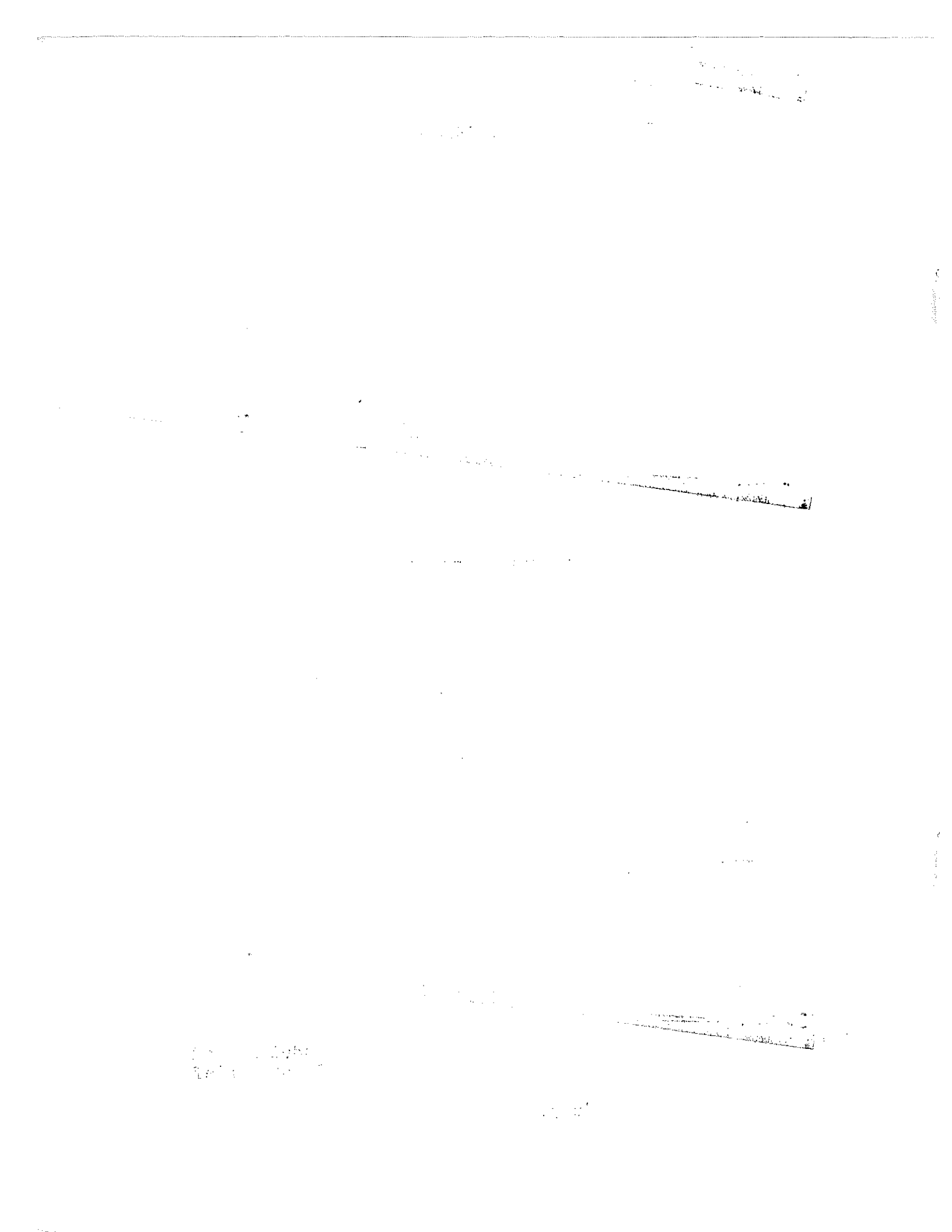
July, 1981



C O N T E N T S

ACKNOWLEDGEMENT

A number of Government Organizations extended their cooperation by providing their vehicles and workshop facilities for experiments of this study. Particular mention may be made of the Punjab Road Transport Board who provided their buses free of cost. The Punjab Urban Transport Corporation provided some of the buses free of cost and some on hire. The Capital Development Authority allowed the use of their several Water Tankers free of cost. However, the availability of water tankers was restricted with the onset of summer when the tankers were busy for supplying water.

The contribution of vehicles and workshop facilities by these organizations greatly facilitated the work of this study. Their cooperation is greatfully acknowledged.

July, 1981

supplies of large fleets, determination of costs and fares for formulation of policies, concerning pricing, investement, operations etc.

The Planning Division and other agencies concerned with development of transport services and infrastructure including the Ministry of Communications, Provincial Planning and Highways Departments, Transport Authorities need the information for three main uses viz: (i) estimation of vehicle operating costs for determining transportation costs of different types of traffic - passenger, goods, etc.; (ii) estimation of variations in vehicle operating costs in varying traffic conditions e.g. according to speed, grade, etc. for appraisal of highway improvement projects and feasibility studies; and (iii) Formulation of policies for energy conservation and efficiency of transport services, etc.

The information is also of significant importance from many other aspects. For example, fuel costs have a direct bearing on pricing policies and operating practices of both private and commercial transport vehicles. For private operators fuel costs constitute immediate out of pocket expenses and enter into decision making about the use of a vehicle in the short run. This has affected the ridership and profitability of public transport in the developed countries and can have unfavourable effects in the developing countries as well.

Commercial operators equate their short run marginal costs with fuel expenses only and can reduce their rates to the level of fuel costs in slack seasons and in cut throat competition. This aspect is important for tax and pricing policies concerning public and private transport. Reliable information on fuel consumption will be helpful in formulating policies concerning pricing and allocation of resources between public and private sectors.

The relationship between fuel consumption and speed of the vehicle is of significant importance and may be noted briefly. Variations in fuel consumption in response to changes in speed, form a 'U' shape curve. Starting from stationary position, the consumption is high. As a vehicle moves consumption declines upto a certain extent but again starts rising with increase after a certain limit. Very few operators know correctly the level of speed at which the consumption is minimum.

Although average fuel costs would generally be known to the operators, very few of them are aware of variations in consumption in response to changes in speed. They cannot effect savings in fuel costs. This is evident from theoverspeeding even by commercial vehicles which are more cost conscious. Small changes in operating speeds can bring in considerable economy in fuel costs.

The importance of savings in fuel costs has considerably increased with the increase in petroleum

prices over the last decade. Heretofore, speed regulations were made with the sole objective of road safety, speed limits are now being imposed for economy in fuel consumption as well.

Inspite of its importance, very little information is available in documented from about the behaviour of fuel consumption in varying operating conditions. This study is designed to provide such information which will be useful for vehicle operators in general, for public and private sector agencies concerned with operation and management of transport services and planning & Development of transport services and road infrastructure in the country. The information will also be helpful in regulating speed with a view to savings in energy use.

A Highway Speed Survey[2] carried out by this office earlier provides information on operating speeds of various types of vehicles on different categories of roads. The results of the present study combined with the speed survey will provide more realistic estimates of vehicle operating costs close to actual operating conditions.

The knowledge about the behaviour of fuel consumption with respect to changes in speeds can lead to operation of vehicles at levels where fuel consumption is minimum. Thus considerable savings can be affected in the consumption of fuel in the country.

The available information and need for this particular type of study are given in chapter II. Chapter III gives scope and methodology describing details of vehicles selected for tests, road sections and methods of measurement. The main results of the study are contained in chapter IV which gives relationship between speed and fuel consumption in detail. A number of graphs showing such relationships are given togehter at the end of the chapter IV. Chapter V gives results of fuel consumption tests on buses in actual operating conditions. Chapter VI makes a comparison of fuel consumption between Government & Private Buses to reflect their relative maintenance conditions. The effect of grade on fuel consumption has been examined in chapter VII. Chapter VIII compares the results of the study with Bus Make Study earlier carried out by this Centre. The conclusions and recommendations are given at the end in chapter IX. Statistical data containing details of results is placed at Annexure A. Annexure B gives data on fuel consumption by buses in urban operating conditions. Annexure C shows some data from World Bank Study.

(1) Dr. M. Abdullah, Professor & Head of the Department of Engineering University of Peshawar, " Energy Use in Transport System" National Transport Research Centre, Government of Pakistan, No. NTRC-49, February, 1981.

(2) Abdul Majeed "Highway Speed Survey" National Transport Research Centre, Government of Pakistan, No. NTRC-51, November, 1980.

Chapter II

REVIEW OF AVAILABLE INFORMATION

Estimates of fuel consumption can be made theoratically on the basis of engine characteristics like size, power, piston displacement, RPM, torque, etc. Technical specifications provided by manufacturers can be used for this purpose. However, there are variations in specifications between various models of the same make and the output of engines declines with their age as well. There would be large variations in theoratical estimates of fuel consumption and some sort of average would have to be found. It would also be difficult to get output according to original specifications. The theoratical estimates reflect ideal conditions which could be aimed at but not achieved. This suggests the need for empirical tests of fuel consumption in actual operating condition.

Besides, once a vehicle is purchased, technical conditions cannot be changed by the operator. Technical characteristics would, therefore, play a part in the decision for the purchase of a particular type of vehicle. Once this decision has been made, costs would depend upon operating and maintenance conditions of the vehicle. Hence there is need for study of fuel consumption in actual operating conditions.

Fuel consumption in actual operating conditions will depend upon age of vehicle, maintenance condition of the engine type of road surface, grade, extent of load, etc. Given all

diesel engines because of greater efficiency. The vehicle composition used in the World Bank Study is out of line with our fleet.

Secondly, the study is based on road conditions in the United States which are quite different from Pakistan. A paved road in the United States is much superior than the one in Pakistan. There will be corresponding differences in the results and these are not reflected in the report.

Thirdly, as indicated in a TRRL Review,[3] the interval used in the Report relates to American conditions and has been compiled by using a combination of primary and secondary sources, logic and judgement. The data is not relevant for developing countries.

In view of the above, the results of the World Bank Study are not applicable to our conditions. The vehicle composition and their characteristics have changed over the years all over the world. The data is therefore out of date.

Kenya Study:

A more recent study made by the Overseas Unit of the Transport and Road Research Laboratory of U.K. in collaboration with the International Bank for Re-construction and Development is "The Kenya Road

Transport Cost Study: Research on Vehicle Operating Costs".[4] The purpose of this study was to provide data for developing countries. This study was much wider in scope and coverage and among other things, is intended to varify and supplement the De Weille data.

Fuel consumption tests for this study were carried on three vehicles only including a Cortina Estate Car, a Land Rover and a Bedford Lorry the last one in three load conditinns i.e. empty, half loaded and full loaded. Tests were made over a larger number of road sectinns.

Unlike De Weille, the results of the Kenya Study provide continuous relatinnships between the dependent and independent variables. These relationship can profitably be used in other developing countries where appropriate.

However, of the three vehicles used for tests, two are not commonly used in Pakistan viz Cortina Estate Car and Land Rover. The third vehicle Bedford Lorry, although the same make as commonly used in Pakistan appears different in technical specifications as it is of smaller pay load. The data of the Kenya Study is therefore not sufficient for our vehicle fleet which consists of Bedford Trucks and Buses, Ford Transit Wagon, Suzuki Van and Small Japanese Cars.

In addition to above, the roads and environmental conditions differ from country to country. For example, in the Kenya Study the emphasis is on grades according to

these variables, fuel consumption will vary according to speed of the vehicle. Most of the other variables exert their influence through changes in speed. It is, therefore, imperative to study in depth the behaviour of fuel consumption in response to changes in speed.

In view of the importance of fuel consumption for estimating vehicle operating costs for management and control of transport operations, appraisal of highway improvement projects and feasibility studies, a number of studies have been carried out in various countries at national and international level. The foremost among these studies is the one published by the World Bank as Staff Occasional Paper No. 2 on "Quantification of Road Users Savings".(1) Substantial work has also been done in this field by the Transport and Road Research Laboratory of U.K. in their Kenya Road Transport Cost Study.(2) Both the studies have been used for investment appraisal of transport projects and vehicles operating cost estimation. A brief review of these studies with particular reference to their application to operating conditions in Pakistan will be useful.

The World Bank Study:

The World Bank Study,(1) provides physical quantities of various cost components for the seven categories of vehicles including three cars and four trucks of which only one truck of the largest size is of diesel engine and all

others are of Petrol engine. The specifications of vehicles are given in Annexure C.

The primary tabulation of the Report gives physical quantities of fuel consumption for level tangent paved road at speeds ranging from 24 Km per hour to 113 Km per hour for all the seven categories of vehicles. Further variations in consumption according to type of road (Paved, Gravel, Earth) rate of rise and fall, degree of curvature, etc. are given in terms of percentage increase or decrease over the quantities of level tangent roads. Similarly, estimates of other cost components are given according to different speed levels. The types of road surfaces considered in the study are paved, gravel and earth. The rates of rise and fall are 1,2,4,6 and 8%.

For application in our conditions, there are several drawbacks in the above study. First, the vehicles used are quite out of line with the fleet commonly found in the country, particularly the irrelevence of trucks is significant. Out of four types of trucks used by this study, three have petrol engines are non-existent for any of the trucks in our country. The maximum rated pay load of four trucks i.e 2,000 Lbs. 7,750 Lbs. 33,200 Lbs and 41,000 Lbs respectively is either far below or far above the pay load of our Bedford trucks (18,000 Lbs). Thus, the present day vehicle composition in our country is quite different from the vehicles covered in the World Bank Study. In our country, at present, excepting cars, all medium and heavy vehicles have

topography of the land whereas the area is flat in Pakistan. The study relevant to one country may not be applicable to other countries without qualifications.

In view of the above, there is need for a separate study relevant to vehicle composition and road conditions of each country. Accordingly, experiments of fuel consumption by vehicles most commonly found in the country have been carried out. The scope and methodology of the study are given in the following chapter.

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(1) De Weille, J. "Quantification of Road User Savings", World Bank Staff Occasional Paper No. 2 Baltimore 1966.

(2) H. Hide et al. "The Kenya Road Transport Study- Research on Vehicle Operating Costs", Transport and Road Research Laboratory U.K. Report No. 672 (1975).

(3) Hide, H., An improved data base for estimating vehicle operating costs in developing countries, TRRL Supplementary Report No. 2234 C, 1976.

(4) Hide,H, et al "The Kenya Road Transport Study: Research on vehicle operating costs" Overseas Unit, Transport and Road Research Laboratory, Crowthorne, Berkshire, 1975 (TRRL Report 672).

Chapter III

SCOPE AND METHODOLOGY

The study is aimed at providing reliable estimates of fuel consumption by various types of vehicles most commonly used in the country in varying traffic conditions. The most important factor which explains variations in fuel consumption is the speed of vehicles. Most of the other factors, e.g. road and traffic conditions, etc. exert their influence through charges in speed. Therefore, emphasis has been laid on finding relationships between speed and fuel consumption and speed for different types of vehicles.

Selection of Vehicles:

In order to make the results realistic, it would be desirable to have a sample of vehicles which is representative of country's fleet composition. One way of having such a sample would be to classify the vehicles according to main categories and as their each category, according to makes and models and to select several vehicles from each sub-graph. The resulting sample would be quite large and the resulting cost of the study would be beyond the scope of available time and budget. Besides, the selection of such a sample would not be possible at this stage due to lack of data as the information on number of vehicles of different makes and models is not available and there is no record of different makes and model is not available and there is no record of different makes and models of vehicles operating in the country either.

The alternative and more appropriate way of having a small representative sample would be to select one or a few typical vehicles in each of the main categories as may be permitted by the available time and money budgets. This course has been followed and only typical vehicles in each category was used for experiments. The problem of selection of vehicles has been made easy by the limited number of makes and models of commercial vehicles available in the country. For example most of the trucks and buses are of locally assembled Bedford make. In the medium and light vehicles categories, Ford Transit Wagon (Diesel), Suzuki Van are predominant.

The main categories of vehicles in our fleet composition and selection of vehicles for tests are briefly described below. The emphasis is on commercial vehicles which are more important for public policies. Private automobiles are not included.

Light Commercial Vehicles:

This category includes small vehicles having three cylenders of less than 600 c.c capacity. The number of such vehicles has rapidly grown all over the country. These vehicles are now commonly found in large numbers in cities, towns, rural areas and are used for passengers and goods traffic alike. These vehicle are replacing animal transport and taxis and are supplementing wagons in passenger transport.

The predominant make in this category is Suzuki Van. It is, rather, the only Make in its category.

As these vehicles have come into the market over the recent years, very little documented information concerning their performance is available. Hence the interest in tests on this vehicle.

One Suzuki Van of 1979 model was used for experiments. The vehicle belonged to the National Transport Research Centre and was in reasonably good maintenance condition.

Medium Size Vehicle (Petrol)

In the medium size category, two vehicles have been used for tests, one petrol vehicle and the other diesel. In the former category Toyota Hiace Wagon has been tested. The vehicle was a 1974 model and belonged to the National Transport Research Centre. This was quite popular Make in its category some year before. Quite a large number of these vehicles are used by commercial and industrial firms as well as by Government Departments. Lower initial capital costs seem to be the reason for owning such vehicles. These wagons are also found on short city route where reliability is not of significant importance. More than one forth of wagons in the city of Lahore are of this make.[1] Quite a good number of vehicles of this make are also being used in Karachi.

The production mix of diesel and petrol and their relative demand are such that petrol is surplus and exported. On the other hand, diesel falls short of require-

ments and is imported. The use of petrol vehicles is therefore of interest for policies concerning pricing and taxation of petrol and diesel and vehicles using two types of fuels.(2)

Medium Size (Diesel)

The medium size (Diesel) vehicles have grown fast in the country mainly for passenger transport in urban areas as well as on intercity routes. They have replaced petrol vehicles in this category due to lower operating costs as a result of lower price of diesel and higher mileage as compared to petrol for passenger transport in urban areas as well as on intercity routes.

The interest in the use of medium size vehicles (Mini Buses) in urban areas has recently grown in several countries and this has received the support of the World Bank as well. The main reason for this are persistent deficits of Urban Bus Services. This calls for detailed. Study about the performance of their categories of vehicles.

The most commonly used make in this category is Ford Transit. The same was used for one tests. The vehicle was a 1978 model belonging to the National Transport Research Centre, and in good maintenance condition.

Buses:

Majority of buses and trucks in the country are of Bedford Make which has two models, one is CJQ for trucks and the other is NJM for buses. The CJQ model is also used for buses with a seating capacity 42 passengers. The buses on NJM model are of relatively larger size having seating capacity of 52 passengers.

Tests were carried on both NMJ and CJQ Models are vehicle of each make was taken from private operations and Government Transport services. The result provided comparison between the two groups. The buses of private operators were in good maintenance condition and relatively of recent model, one 1978 and the other 1979. The Buses of Government Transport Services were relatively old 1974 and 1975 Models and in poor maintenance condition. Although it is difficult to find a bus other than Bedford in the private sector, Government Transport Services have several other makes including Isuzu of which quite a good number of vehicles exist, and Fiat 331 which is the most recent addition to the fleet of Punjab Urban Transport Corporations. Accordingly, Isuzu and Fiat 331-A buses were also included in the tests. The vehicles belonged to the Punjab Urban Transport Corporation, Rawalpindi. In addition a Ford 1011 Bus of the Punjab Road Transport Board, Rawalpindi Depot was also tested.

Trucks:

As in the case of Buses, majority of trucks in the country consist of Bedford CJQ model. The number of trucks of other makes are insignificant. Accordingly, main tests were made on Bedford CJQ Model. Which were readily available. Three water tankers 1979 Model belonging to the Capital Development Authority were used. Some tests were also made on FargoLeyland Model 1963 Model Tanker, also belonging to CDA were also made for comparison.

The main advantage for using water tankers was the ease of variation in load made possible by filling and draining off water as required. It was thus possible to test three load conditions for trucks, i.e. full load (2,000 gallons) half load (1,000 gallons and unloaded).

Technical specifications of vehicles used in the tests are given in the following table (Table III(1).

TABLE III (1)

SPECIFICATIONS OF TEST VEHICLES

Rehicle Type	Fuel	No. of Cylinder	Engine Capacity (Cubic Inch)	Wheel Base (Inch)	G.V.W. (Lbs.)	Pay Load/ Seating Capacity (Lbs.)	No.
Suzuki Van	Petrol	3	539 Cub.Inch.	72.4	2,921	1,320	4
Toyota Hiace	Petrol	4	1587 c.c.		5,070	-	12
Ford Transit	Diesel	4	2360 c.c.	106	5,630	-	13
Bedford CJQ	Diesel	6	330 Cub.Inch.	179	24,050	18,045	42
Bedford NJM	Diesel	6	330 "	216	21,952	-	52
Isuzu BF 500	Diesel	6	389 "	205	27,560	-	52
Fiat 331-A	Diesel	6		252	15,000 Kg	-	100
Ford R 1011	Diesel	6	380 "	192	26,100	-	55

Selection of Road Sections:

One of the important factors affecting operating costs including fuel consumption is type of the road, whether it is carpetted, surface treated, shingle or earth. The justification of highway improvement scheme is commonly based on savings in operating costs. The questions which most usually arise are: what are the vehicle operating costs on different categories of roads, e.g. earth, shingle, metalled? What would be the amount of road users' savings if a road is improved from if an earth road is shingled or a shingle road is metalled.

In view of the above, it would be desirable to test variations in fuel consumption according to type of road surface. The work would call for experiments for each vehicle on different types of roads. It was, however, not possible to find different types of roads, metalled, shingle, earth, etc. in one area. Moving to different areas for such experiments would have considerably increased costs and this was not permitted by budgetary constraints. Alternatively, test tracks can be built for such experiments. This would be more useful as fully controlled conditions can be obtained in this way. However, this was beyond the scope of this study.

Within the available time and budgetary constraints, it is sufficient to develop primary tabulations of fuel consumption on level tangent paved roads. Variations from

the base figures according to type of road, e.g. earth, shingle or paved, etc. can be estimated on the basis of data available from other studies.

Accordingly, a few paved road sections were selected for experiments around Islamabad and fuel consumption at different speed levels for each of the test vehicles were recorded.

The studies reviewed in the previous chapter give information on percentage increase in fuel consumption on gravel and earth roads over level tengent roads. The relevant Table is re-produced at Annexure-II. The data can be used in conjunction with our results for estimatinn of costs on gravel and earth roads.

Grade:

One of the important factors affecting speed and fuel consumption is the grade of the road. It would be desirable to have tests at various grades. However, as in the case of type of road sections of reasonable length of even grade were not available in the area. Although the study area is rolling type where one would expect to find roads of all grades, the road levels vary over small distances with the result that it was difficult to find road sections of reasonable length with uniform grade.

Besides, as most of the roads in the country are in flat areas, the information on grades is not of immediate importance either. Therefore, it appeared necessary to obtain basic data for level roads. Once this is done, the estimates of variations over level road can be made with the help of other studies.

It may be added that it was not possible to find any road with zero grade in the area. The most level road selected for tests had a grade of 0.4%. This was the nearest approximation to level tangent road and most of the experiments were made on this section. Some experiments were also made on road with a grade of 2.9%. However, as this section did not have sufficient length before and after for vehicles to pick up the required speed of larger vehicles on this section were not possible. The limited number of experiments have been used for analysis as far as possible for comparison with other studies.

Other studies reviewed in this report give percentage variations in fuel consumption over level tangent road at different grades. These ratios can be applied to primary data to arrive at estimate for different grades. It may also be noted in passing that increase in fuel consumption in upward direction is made up by less consumption in the downward direction. The average of both directions is taken as the value for a particular grade. The differences in values for different grades represent change according to grades.

Method of Measurement:

The fuel consumption measurements were made by means of an instrument specially designed for the purpose, viz. Fuel Flow Transducer with Digital Counter. The instrument measures fuel in milliliters (1/1000 Litres). The Transducer is inserted between the fuel tank and the engine. It generates a magnatic pulses for every c.c for fuel that passes through it. Digital Counter records the pulses displays the consumption. The Counter can be switched 'on', 'off' and 'held on'. The instrument operates on 12 Volt Battery. It can be plugged to vehicle battery.

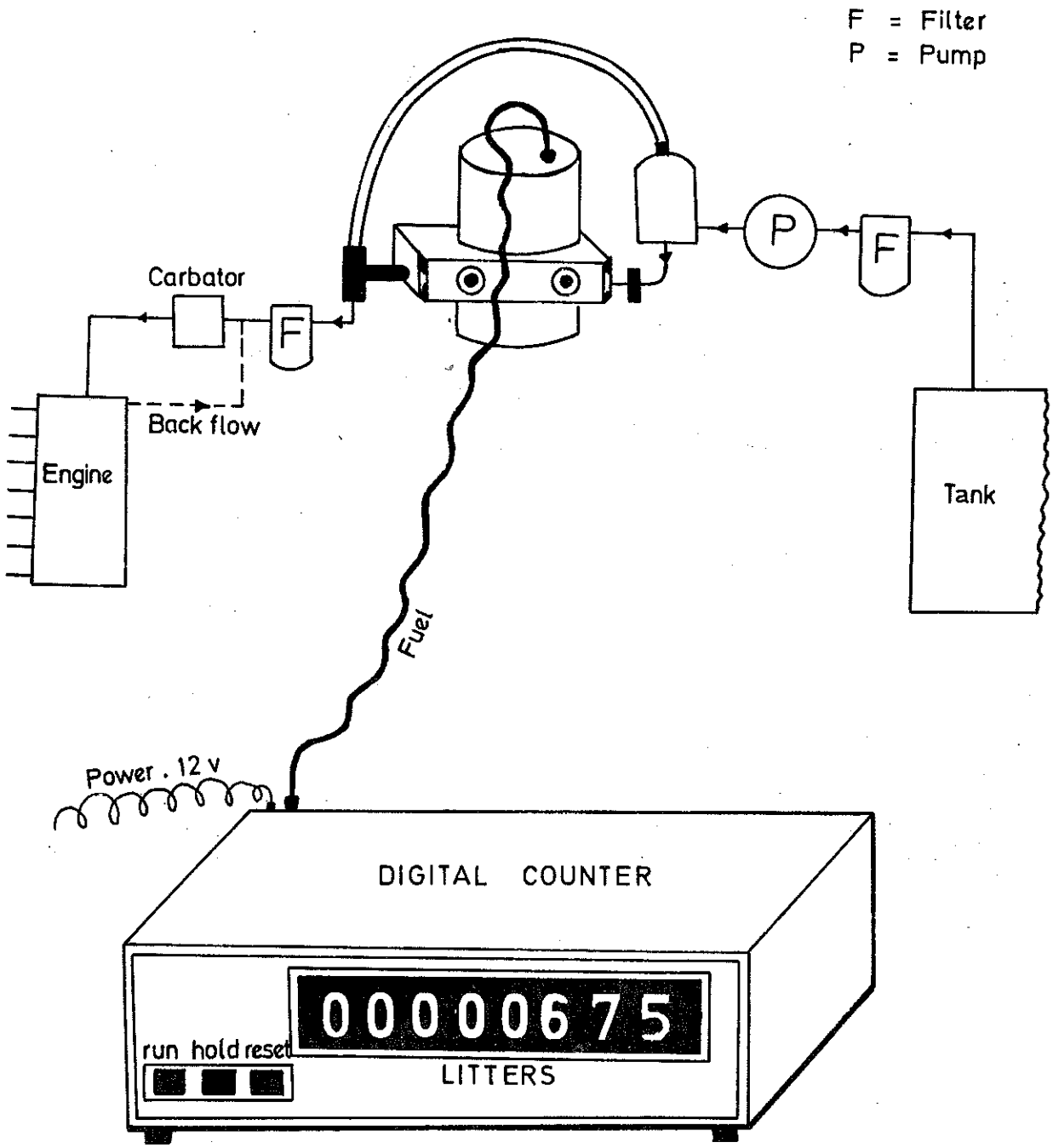
The instrument is designed for petrol engines but can also be used for diesel engines by minor changes in fuel connections for re-circulation of back flow to the engine.

The main advantage of the instrument is that it measures amount of fuel in minute quantities. This provides quite accurate estimates of fuel consumption by running the vehicle over very short distances. The study was covered only a limited area of fuel consumption. A number of other factors still remain to be tested. It is recommended that further experiments may be continued.

The instrument, through very efficient, did not prove enough sturdy. The digital counter failed twice. The lack of repair facilities and non-availability of parts delayed its repairs which took a long time to make as on one occasion some electronic parts had to be imported from

FUEL FLOW TRANSDUCER

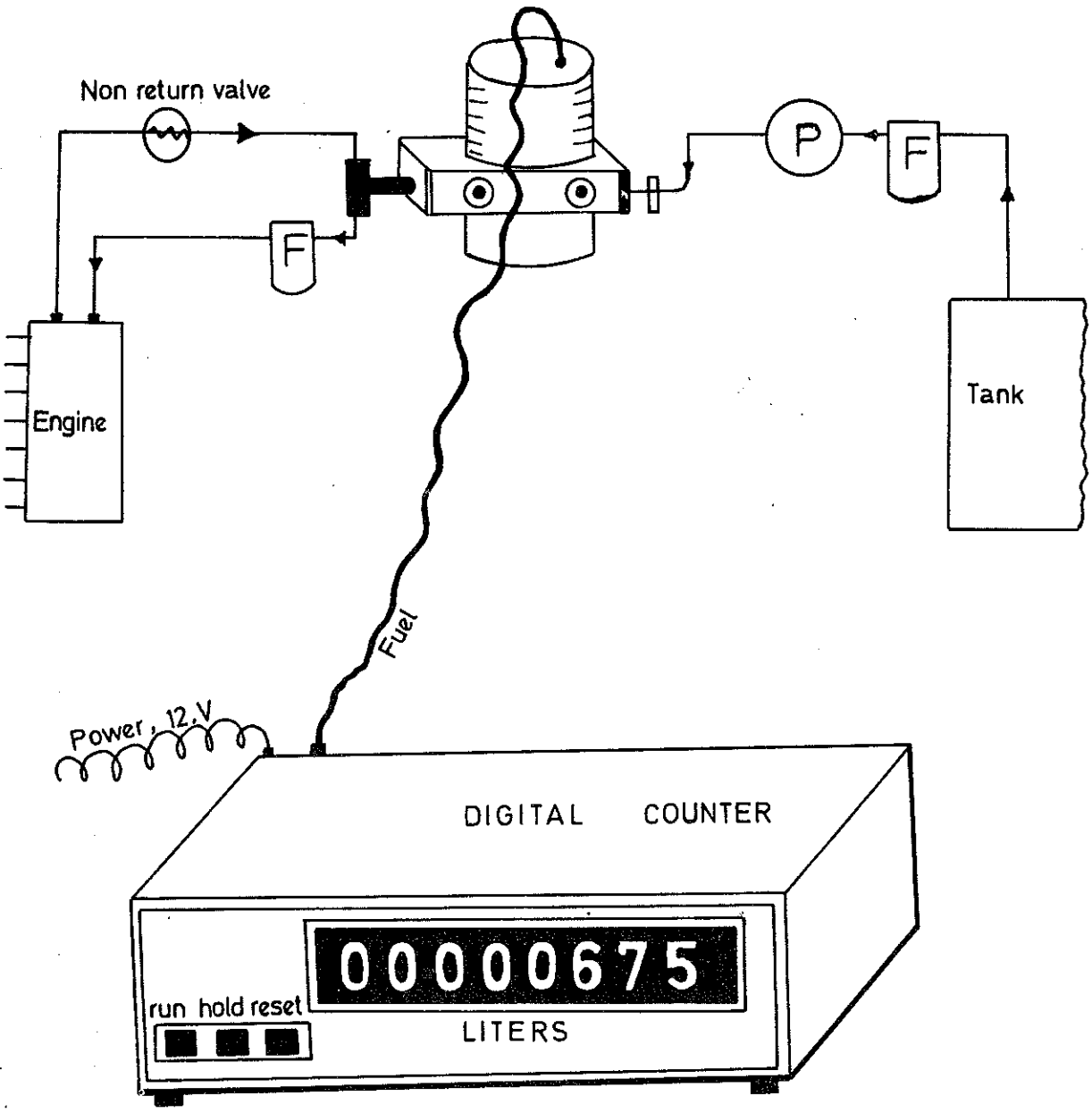
INSTALATION ON PETROL ENGINE



FUEL FLOW TRANSDUCER

INSTALATION ON DIESEL ENGINE WITH RETURN FLOW

F = Filter
P = Pump



abroad. The experiments were interrupted for long spells twice. Nevertheless, the teething troubles have been overcome and significant experience gained. The instrument can profitably be used for experiments after the completion of the study.

Length of Test Section:

Test runs were made mostly over a length of 1/2 Kilometer. This was quite sufficient with the type of instrument used. In certain cases longer runs of 1 Km were also made.

The distance of 1/2 Km on selected road sections was marked with white paint for ease of recording stopping and starting time.

Test Runs:

Test vehicles were run at the marked road sections at speeds ranging for 20 Km per hour to 90 Km per hour with 10 intervals. Information on time taken to traverse the fuel consumption was recorded. The time was measured by means of a stop watch to determine exact speed as opposed to the speed indicated by speedometers which not as correct particularly in extreme ranges.

The test section had sufficient length before and after the marked line. The test vehicles were run to attain the desired speed before the marked portion of test section. As soon as the vehicle reached the first marked line, the digital counter and stop watch were switched on by the operator. At the end of the marked portion, both were switched off and readings noted. Each experiment was repeated four to five time average fuel consumption was taken.The form used for recording the information is given at Annexure D.

(1) Volvo PUTC Model Urban Transport System, 1980

(2) For further discussion of the problem reference may be made to "Petrol vs Diesel Transport; An analysis of a policy option" Pakistan Development Review Vol. XVI No. 3 Autumn 1977.

Chapter IV

THE RESULTS

General Characteristics:

Before describing the results, their general form may be noted briefly. In the first instance, it may be noted that, as indicated before, one of the most significant variables affecting fuel consumption is the speed of vehicle. Other variables like road surface, grade, etc. exert their influence through changes in speed. Therefore, variations in fuel consumption in response to changes in speed are of primary importance. Accordingly, all tabulations give fuel consumption according to speed levels ranging between 30 and 90 Km per hour.

It will also be seen that the range of speed over which different vehicles were tested is not the same for all. Light and medium vehicles cover speed range upto 90 Km per hour. In the case of heavy vehicles viz. buses and trucks, tests extended upto 90 Km per hour for a few vehicles only. In other cases tests covered speed upto 80 and 70 Km per hour only. This was due to limitations of road, traffic and conditions of vehicles. Old vehicles were difficult to operate at higher speeds. As tests were made in the actual traffic conditions, it was often difficult to operate heavy vehicles at very high speeds even if vehicles were mechanically fit. In such conditions,

experiments were limited to lower speeds only. It may be noted tht maximum speed limit on rural roads is 65 Km per hour.

Relation Between Speed and Fuel Consumption:

As a general rule, the relation between speed and fuel consumption is 'U' shaped. At initial speed levels, starting the vehicle from stationary position using lower gears, the consumption is high. As the speed increases the rate of fuel consumption declines. After a certain level, the rate of consumption starts to rise with increase vehicle characteristics and varies from vehicle to vehicle. For example, the lowest consumption of Suzuki Van and Toyota Hiace is at speed of 40 Km per hour; for Ford Transit, 50 Km per hour; for Fiat 331-A Bus, 40 Km per hour; and for Isuzu Bus, 60 Km per hour. For Bedford buses the minimum consumption is at 70 Km per hour speed and for trucks 60 Km per hour. These speed levels may be regarded as optimum for fuel consumption purposes.

Fuel Consumption according to speed:

The detailed results of fuel consumption tests are given at Annexure A. Where Table A.I gives physical quantities of fuel consumption in c.c.'s per Kilometer at speeds ranging from 20 Km to 90 Km per hour for different types of vehicles. Table A-2 gives the same information in kilometers per litre which is the more general mode of expression and

might be better understood. The data has been generalized in Table A 3 which gives fuel consumption at different speed levels as percent of consumption at the minimum point. These values can be used for estimating fuel consumption for similar other vehicles at various speed levels once their consumption at a particular speed is known.

The data are supplemented by graphs at the end of chapter which show the relationships between fuel consumption and speed for different types of vehicles e.g. light and medium vehicles, Suzuki Van, Toyota Hiace and Ford Transit, Buses — Intercity Urban Public and private Buses and Trucks (Water Tankers) in loaded and empty condition.

The Summary of results indicating fuel consumption by selected vehicles at different speeds is given below:

Table I

Average Fuel Consumption on Level Tangent Road

Vehicle Type	c.c. per Km Speed Km per turn						
	30	40	50	60	70	80	90
Small Cars 1000/1200 c.c.	68	62	70	79	91	111	139
Suzuki Van L.C.V(Petrol)	45	43	45	48	52	60	69
Toyota Hiace M.C.V(Petrol)	101	98	102	108	115	124	137
Ford Transit M.C.V(Diesel)	87	75	67	75	86	98	106
Bus Intercity (Diesel) Bedford NJM	237	193	164	201	303	323	336
Bus Intercity (Diesel) Bedford CJQ	560	412	294	265	333	549	646
Truck(Diesel)	394	253	226	196	226	293	

In the above table, data concerning Bedford Buses relates to private buses only. The figures for trucks are average of three vehicles in three load conditions. Figures for individual vehicles are contained in table A.I to A.3.

The characteristics of fuel consumption by main vehicles categories are briefly described below:

Small Cars:

The vehicle tested in this category included two Morris 1000 c.c. and one Datsun 1200 c.c. Taxis.

The average minimum fuel consumption is 62 c.c. per Km or 16 Km per Litre (45 miles per gallon) at 40 Km per hour speed. At lower speed of 30 Km per hour, the consumption increased by 10% to 68 c.c. per Km or 14.7 Km per litre. At higher speeds the consumption by 13% at 50 Km per hour, 27% at 60 Km per hour, 47% at 70 Km per hour 79% at 80 Km per hour and 124% at 90 Km per hour.

Suzuki Van:

The minimum fuel consumption is 43 c.c. per Km or 23 Km per litre (or 65 miles per gallon) at 40 Km per hour speed. At lower speed of 30 Km per hour or higher speed of 50 Km per hour, consumption increases marginally to 45 c.c. per Km. Further increase in speed raises consumption at faster rates. For example, increase in speed from 40 Km to 60 Km per hour, increase consumption by about 12% from 43 c.c. to 48 c.c. Another increase of 20 Km from 60 Km to 80 Km per

hour results in an increase of 25% in fuel consumption. The variations in consumption over different speed ranges are not as much as for other larger vehicles. The maximum fuel consumption at 90 Km per hour speed is 160% of the minimum.

The difference in fuel consumption is not much significant over the speed range of 30 to 60 Km per hour. At speed levels of 70, 80 and 90 Km per hour the fuel consumption is 121%, 140% and 160% of the minimum consumption. It is evident that by operating the vehicle at lower speed levels, less than 60 Km per hour, more than 35% savings in fuel consumption can be made.

Toyota Hiace:

The pattern of fuel consumption is similar to that of light commercial vehicle. The minimum consumption is 98 c.c. per km at 10 per litre at 40 km per hour speed. At 30 km and 50 km per hour speed, the consumption is marginally higher at 101 c.c. and 102 cc. per km, respectively. At 60 km per hour, the consumption is 108 c.c. per km. Thus the variation in consumption between 30 and 60 km per hour speed is within 10% of the minimum. At higher speeds of 70 80 and 90 km per hour, the consumption is 117%, 127% and 140% of the minimum. The variation in consumption at different speed levels is smallest of all vehicles.

The consumption is more than twice the consumption of light commercial vehicle (Suzuki) at all speed levels while its seating capacity three times more.

Ford Transit:

The minimum level of consumption is 67 c.c. per km or 15 km per litre at 50 km per hour speed. The pattern of consumption forms a smooth 'U' shape curve. At 30 km per hour speed, consumption is 84 c.c. per hour km, declining to 75 c.c at 40 km per hour and 67 km at 50 km per hour, the lowest point. The consumption again increases to 75 c.c. and 86 c.c. at 60 and 70 km per hour speed respectively. At 80 and 90 km per hour speed, the consumption is 98 c.c. and 106 c.c. per km, respectively.

In percentage terms the fuel consumption at 30 and 40 km per hour speed is 125% and 112% of the minimum at 50 km per hour. On the other side of the minimum level, the consumption increases to 112%, 128%, 146% and 158% at speeds of 60, 70, 80 and 90 km per hour, respectively.

Petrol versus Diesel Transport:

The Toyota Hiace (Petrol) and Ford Transit(Diesel) are of similar size, having seating capacities of 12 and 13 persons respectively. The two vehicles can be substituted for one another. Capital cost of Diesel vehicle is more than petrol vehicle of comparable size. However, operating costs

of petrol vehicles are higher than diesel vehicles due to higher price of petrol which is mainly due to differences in taxes. This turns the balance in favour of d diesel vehicles, the capital cost of which is relatively higher. The effect of this on fuel supplies is also not favourable surplus in petrol and put and deficit in diesel are increased.

It is therefore interesting to compare operating costs of the two vehicles to find their relative economics. In such a study made earlier, capital and operating costs of Ford Transit and Toyota Hiace were compared. In this study, fuel consumption by the two vehicles was assumed equal at 20 Miles per gallons or 7 km per litre on the basis of manufacturers recommendations. The present tests indicate that diesel engines are more efficient in energy use. The average* mileage by the two vehicles is 9 km per hour by Toyota and 12 km per litre by the Ford Transit. Thus the output of Ford Transit per unit of fuel is 33% more than petrol vehicle. The results of the earlier study would need modifications to this extent.

Buses:

As indicated before, most of the buses and trucks in the country are of Bedford Make. There are two models in this make i.e. NJM and CJQ. The NJM Model has longer chasis (as compared to CJQ) and is designed for buses which have a

*Average for all speed levels.

seating capacity of 52 persons. The CJQ Model has shorter chasis and is desinged for trucks. However, the model is also used for buses which are of smaller size with a seating capacity of 42 persons. The results included in table IV (1) above relate to private buses which represent the most typical vehicles in their classes. Their performance is briefly described below:

Bedford NJM:

This is the most commonly used make of bus in the private sector. The vehicle used for tests was 1978 model in normal good maintenance condition.

The lowest consumption is 116 c.c. per km or 6.1 km per litre at 50 km per hour speed. At lower speed of 30 km per hour, consumption was 237 c.c.per km decling to 194 c.c. at 40 km per hour speed. At higher speeds of 60, 70, 80 and 90 km per hour, the consumption was 201 c.c. 303 c.c. 323 c.c and 336 c.c. per km respectively.

In percentage terms consumption at 30 km per hour speed was 144% of minimum, decreasing to 117% at 40 km per hour speed. At 60% per hour speed, the consumption was 122% of minimum. At 70, 80, and 90 km per hour, the cons-umption of this vehicle is lowest of all the bus makes considered and for all speed levels. CJQ Model which is a smaller size of the same make, the vehicle appears to be quite efficient in fuel consumption.

As compared to Ford Transit, the consumption of NJM Model at 50 km per hour is 2.4 times the consumption of Ford Transit. The average for all speeds is about 3 times the consumption of Ford. The seating capacity of the bus is 4 times the capacity of Ford Transit. The seat mile fuel consumption is therefore less for the buses as would be normally expected.

Bedford CJQ:

The vehicle tested was a 1979 Model Bus. The lowest fuel consumption was 233 c.c. per Km or 4.3 Km per litre at 70 Km per hour speed. At 30 Km per hour speed, consumption was 560 c.c. per Km declining to 412 c.c., 360 c.c. and 308 c.c. at 40 Km, 50 Km and 60 Km per hour speed respectively. At higher speed of 80 and 90 Km per hour the consumption was 549 c.c. and 646 c.c. per Km, respectively.

In percentage terms, the consumption at 30 Km per hour speed was 240% of minimum declining to 177%, 154% and 132% at 40 Km, 50 Km and 60 Km per hour speed. At 80 Km and 90 Km per hour speed, the consumption was 235% and 277% of minimum.

It will be evident from the above that level of minimum consumption is quite high, 70 Km per hour. The variation in consumption at speeds ranging between 50 and 70 Km per hour was moderate, about 25% above the minimum.

The increase in consumption at speeds lower than 50 Km per hour or higher than 70 Km per hour was very sharp.

A comparison of NJM and CJQ models indicates that consumption by CJQ model is higher than NJM Model at all speeds except at 70 Km per hour. Considering its seating capacity, the CJQ Model appears less efficient in fuel consumption in relation to NJM Model.

Trucks:

As indicated before, most of the trucks in the country are of Bedford CJQ Model. Accordingly,main tests in this category were on the same make. The test vehicles included three water tankers belonging to Capital Development Authority, Islamabad. All the three vehicles were Bedford CJQ 1979 Model in normally good maintenance condition. The advantage of using water tankers was the ease of varying load conditions. The vehicles were accordingly tested in three load conditions i.e. Full Load, Half Load and Un-loaded.

The figures presented in table IV(1) above represent average of three vehicles in three load conditions, of i.e. 9 elements.

It will be seen that minimum fuel consumption 196 c.c per km or 5.1 km per litre at 60 km per hour speed. With increase or decrease of 10 km per hour speed from 60 km per hour to 50 km or 70 km per hour,consumption

increases by 15% to 226 c.c. per km. At lower speed of 30 km and 40 km per hour, consumption is 394 c.c and 253 c.c per km. At higher speed of 80 Km per hour, consumption is 293 c.c. per Km.

In percentage terms, consumption at lower speed of 30 Km, 40 Km and 50 Km per hour is 201%, 129% and 115% of the minimum at 60 Km per hour. At higher speeds of 70 Km and 80 Km per hour, consumption is 115% and 149% of the minimum respectively.

Effect of Load on Fuel Consumption:

The effect of load on fuel consumptin has been examined for trucks only. The data covers all the three Bedford CJQ 1979 Model Water Tankers described above. Two of the three tankers had a capacity of 2000 gallons (9 tons) and the capacity of the third tanker 1800 gallons (8.16 tons) weight. Test runs were made with full load half load and unloaded conditions.

The average fuel consumption by the three vehicles in full load and empty condition is shown below:

Table 2

Average Fuel Consumption in Loaded and Empty Condition

Vehicle No. and Load Condition	Speed Km per hour 30	40	50	60	70	80	90
	C.C. Per Km						
1. Loaded	447	323	264	209	213	347	
Empty	410	273	226	183	164	280	
Loaded as % of empty	109	118	116	114	130	124	
2. Loaded	457	242	235	231	315	-	
Empty	388	213	206	199	242	-	
Loaded as % of Empty	118	114	114	116	130	-	
3. Loaded	342	240	220	185	220	275	
Empty	322	220	202	173	218	267	
Loaded as % of Empty	106	109	109	107	106	103	
4. Average:							
Loaded	415	268	240	208	252	311	
Empty	373	235	211	185	208	274	
	Consumption in Loaded Condition as % of unloaded Condition						
1.	109	118	116	114	130	124	
2.	118	114	114	116	130	-	
3.	106	109	109	107	106	103	
Average	111	114	114	112	121	114	
	Consumption as % of Minimum (Average for Loaded and Empty Condition)						
1.	227	158	130	106	100	166	
2.	197	106	103	100	130	-	
3.	185	128	123	100	125	151	
Average	201	128	115	100	117	150	

It will be seen from the above table that in full load condition, the average consumption is 415 c.c. per Km at 30 Km per hour declining to 208 c.c. per Km at 60 Km per hour and again rises to 311 c.c. per Km at 80 Km per hour speed. In unloaded condition, the figures are 8 to 12% less and vary from 373 c.c. per Km at 30 Km per hour declining to 185 c.c. per Km at 60 Km per hour and again rising to 274 c.c. at 80 Km per hour. The vehicles were not run beyond 80 Km per hour speed for safety consideration.

The minimum consumption in unloaded condition in one case is 164 c.c. per Km at 70 Km per hour speed. In the other two cases, the minimum consumption is 199 c.c. and 173 c.c. at 60 Km per hour speed, respectively. Taking average of the three vehicles, the minimum consumption is 185% c.c. at 60 Km per hour speed.

In percentage terms fuel consumption in loaded condition is 106% to 118% of unloaded condition for speed levels ranging from 30 Km to 60 Km per hour. However, at 70 Km per hour, the ratio of consumption is loaded and empty form for two trucks is 130% and that of the third trucks 106%. At 80 Km per hour speed, two of the three tankers were run. The ratio of one is 124% and of the other 103%. The values for 70 Km and 80 Km per hour speed are not consistent. Nevertheless, average consumption for all the three vehicles and all speed levels in loaded

condition is 114% of unloaded condition or consumption in loaded condition is 14% more than in unloaded condition.

Variations in fuel consumption according to speed have been examined before. It was observed that at lower speed of 30 Km per hour, the consumption was 200% of the minimum. On the other hand, at higher speed of 80 Km per hour, the consumption is 150% of minimum. Further examination of the phenomina indicated that the ratio is same for both loaded and empty conditions.

The above figures relate to average of these vehicles. However, there are differences between individual vehicles. For one vehicle the consumption at 30 Km per hour speed is 227% of the minimum while for the other vehicle it it 197% of the minimum. The minimum variation is for the third vehicle for which consumption at 30 Km per hour speed is 185% of the lowest point. In this case, absolute amount of fuel consumption and variation at different speeds is the minimum. The only variable different in this case is the capacity. The first two vehicles have a capacity of 2000 gallons. The rated capacity of the vehicles is 18000 lbs. which is roughly equal to 1800 gallons. Thus the two vehicles are overloaded. This can cause stress and relatively more consumption. The other reasons could be possible differences in the maintenance of vehicles, engine setting, etc. However, as the vehicles belong to the same organization and have smaller maintenance facilities, the difference appears due to no overloading.

The consumption by all the three tankers of CJQ Model is less than the Bus of the same make and model of Private Operator at speed levels from 30 to 60 Km per hour. However, at 70 Km per hour speed, the consumption of Bus is lower than two tankers and hgiher than one. This indicates that maintenance of CDA vehicles is comparable to Private Operators.

In addition to Bedford CJQ Model tankers, tests were also made on Fargo Leyland 1961 Model water tanker. The consumption of the vehicle was more than the other three tankers but less than PUTC Bus CJQ 1975 Model and Private Sector Bedford CJQ 1979 Model Bus.

The vehicle being very old, was not able to run safely at speeds exceeding 60 Km per hour. It was not necessary either as very few vehicles of this make will be operating in the country. The data is given in Table A.3 for purposes of illustration and has not been described in the text.

Part and Full Load Condition:

Experiments were also made in half load condition. The consumption was found midway between the full load and un-loaded condition. The variations between vehicles and speed levels were not significant.

The shaded area in Graph IV shows the difference in fuel consumption in fully loaded and unloaded form.

Government Transport Service Buses:

In addition to above, a number of Government Transport Services (GTS) Buses were tested specifically. These included Bedford NJM & CJQ Models, of Ford 1011, on intercity routes and Fiat and Isuzu on urban routes. The results are as follows:

Table 3

Fuel Consumption by G.T.S. Buses

Vehicle Type	c.c. per Km Speed Km per hour 30	40	50	60	70	80
Intercity						
Bedford NJM	1455	1180	883	710	620	-
" CJQ	675	640	577	550	500	-
Ford R 1011	300	210	194	200	270	330
Urban						
Fiat 331-A	234	200	222	242	290	-
Isuzu	300	268	198	175	238	300

Brief comments on the above results will be in order here and are given below for each vehicle separately.

Intercity Routes:

The Buses tested for Intercity Routes included Bedford NJM and CJQ and Ford R 1011. The Bedford NJM and CJQ Models are the same as used in the private operators. The results will provide comparison between public and private Transport.

Bedford NJM:

The Bus belonged to the Punjab Road Transport Board and was a 1974 Model. It was not in good maintenance condition. The average age of buses in Government Transport Service is hardly 6 years. The vehicle used was therefore considerably depreciated. Nevertheless, so long as the vehicle is in service, the performance is expected with reasonable limits. The Government Transport Services did not have latter models of this make. The private bus on the other hand was of 1978 model. The comprison is slightly blurred by differences in age of two buses. The minimum consumption was 620 c.c. per Km at 70 Km per hour speed. Which was the highest speed at which this vehicle could be tested. Consumption at lower speed at 30 Km per hour was 1455 c.c. per Km. This is the highest figures of all the vehicles tested.

In percentage terms, the increase in consumption at lower speeds of 60 Km, 50 Km, 40 Km and 30 Km per hour was 114%, 142%, 190%, 234% of minimum at 70 Km per hour. As compared to private bus, the consumption is 2 to 6 times highest as will be explained its next solution.

Bedford CJQ:

This Bus also belonged to the Punjab Road Transport Board and was a 1975 model, not in a very good maintenance condition.

The minimum fuel consumption was 500 c.c at 70 KM per hour the highest speed at which the vehicle could be run at lower speeds of 60 Km, 50 Km, 40 Km per hour consumption increased to 550 c.c, 577 c.c, 640 c.c and 675 c.c per Km. In percentage terms, consumption at 30 Km per hour speed was 135% of the minimum. The variation being much smaller than the NMJ Model.

The difference between the private and Government Bus of this make is not as large as of the NMJ Model which was perhaps a more depreciated vehicle.

Ford 1011:

This is an old bus with the Punjab Road Transport Board used on intercity routes. There are not many numbers of this make in the country. The results are of interest for comparison with the other makes.

Fuel consumption of this make compares well with Private Sector NJM Model. The consumption is much less than Bedford CJQ and NJM Models in the Public Sector. The difference in consumption at lower and higher speeds is also less.

The minimum consumption was 194 c.c. per Km at 50 Km per speed. At lower speeds of 40 and 30 Km per hour the consumption stands at 210 c.c and 300 c.c per Km respectively. At higher of 60, 70 and 80 Km per hour, the consumption rises to 200, 270 and 370 c.c per Km.

In percentage terms, the consumption at 30 Km and 40 Km per hour was 150% and 108% of the minimum. At higher speeds of 60 Km, 70 Km and 80 Km per hour, the consumption was 103%, 139% and 170% of the minimum. The variation in consumption is within 108% of minimum over 40-60 Km per hour speed range.

Although the vehicle appears quite efficient in fuel consumption, it may not be quite suitable for urban operations where operating speeds are quite low while the speed at which fuel consumption is minimum is quite high for urban areas 60 Km per hour.

Fiat 331-A:

This model is specifically designed for urban areas and the vehicle used was only one year old.

The lowest fuel consumption was 200 c.c. per Km at 40 Km per hour speed. If lower speed of 30 Km per hour, the consumption was 234 c.c. per Km and at higher speeds of 50 Km 60 Km and 70 Km per hour, the consumption increased to 222 c.c. 242 c.c and 290 c.c per Km.

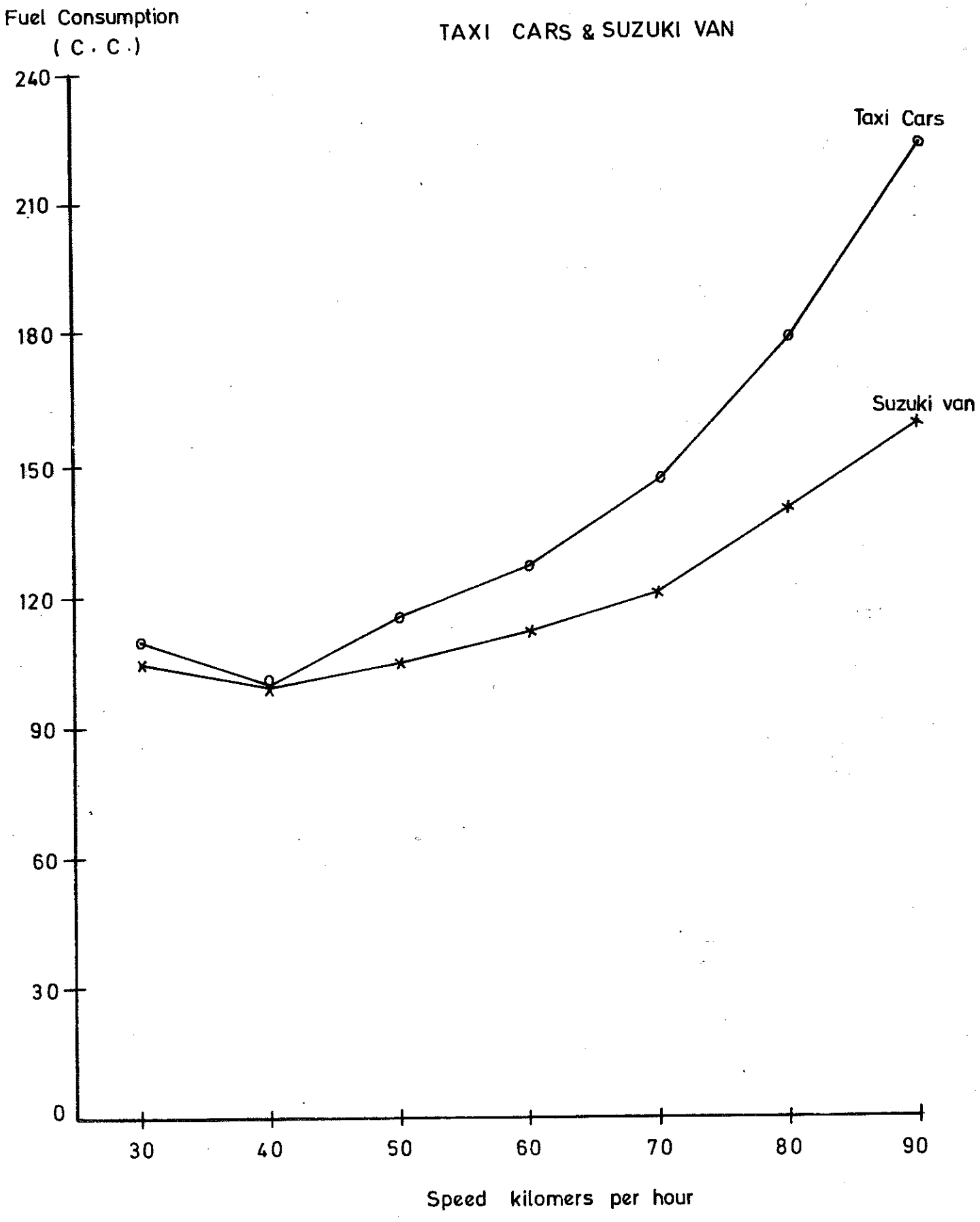
In percentage terms consumption at 30 Km per hour speeds was 117% of the minimum and at higher speeds of 50, 60 and 70 Km per hour, the consumption was 111%, 121% and 145% of the minimum. Variation in fuel consumption at other speeds levels are not as large as for other makes and are within 145% of the minimum.

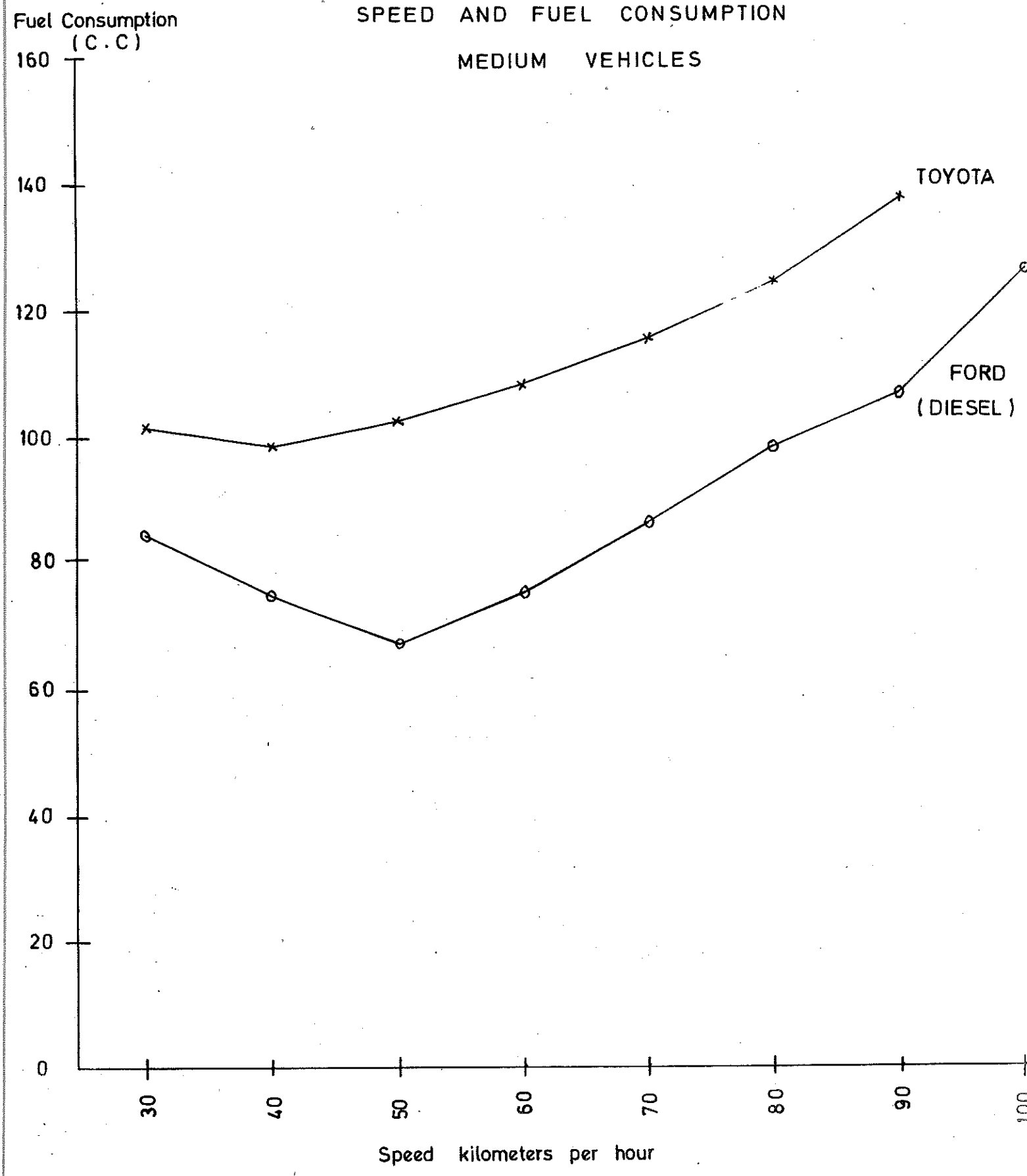
Less consumption at lower speeds is suitable for urban areas where there are frequent stops and low operatings speeds. A comparison of Fiat and Isuzu buses indicates that at lower speed levels, upto 40 Km per hour, Fiat has an advantage over Isuzu. However, for 50 Km per hour onwards, fuel consumption by Isuzu is less than Fiat.

The following graphs show the relationships between speed and fuel consumption for different types of vehicles viz light and medium vehicles - Suzuki Van, Toyota Hiace and Ford Transit, Buses — Intercity, Urban, Private and Public Sectors and Trucks - Loaded and empty condition.

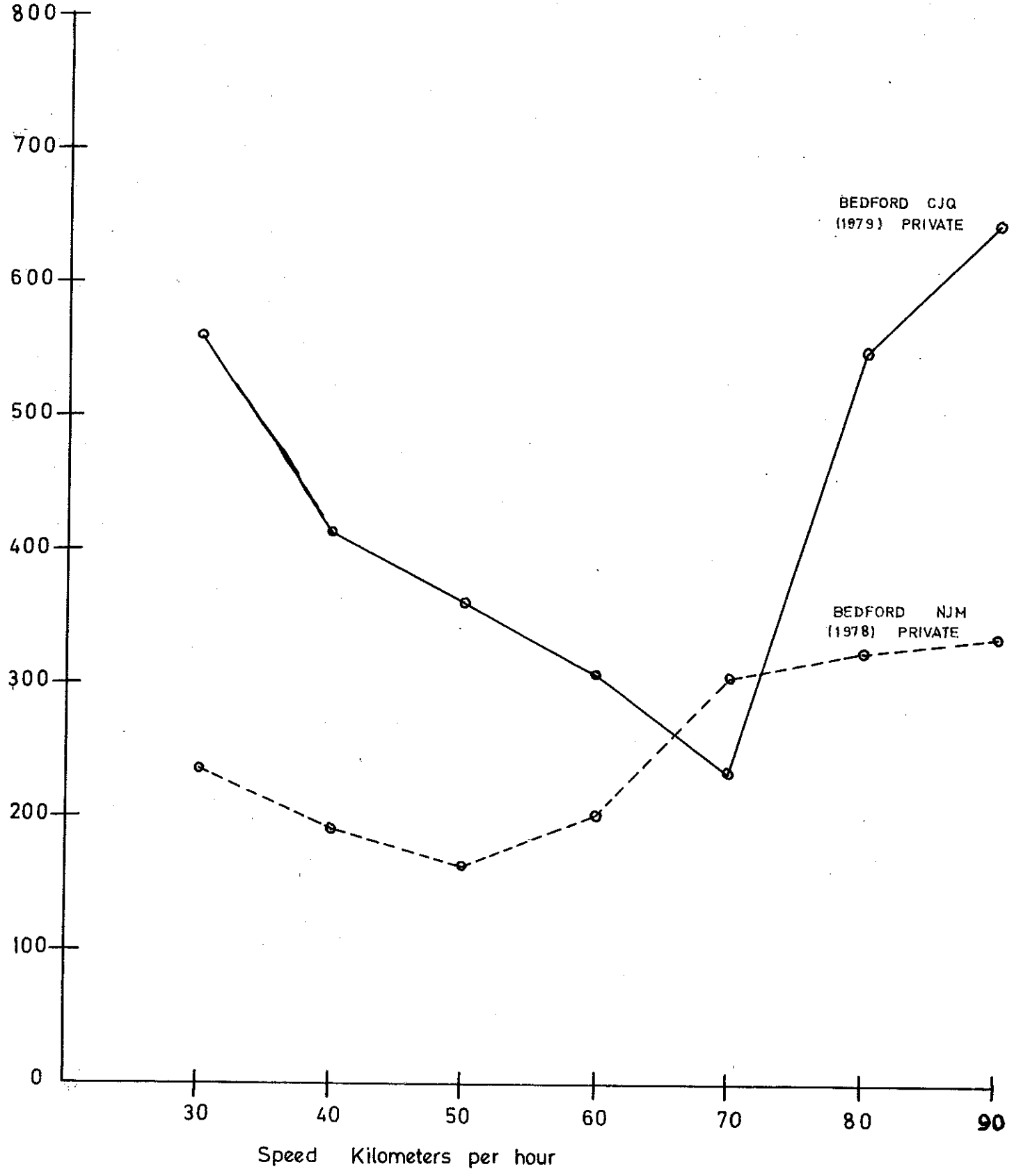
SPEED AND FUEL CONSUMPTION

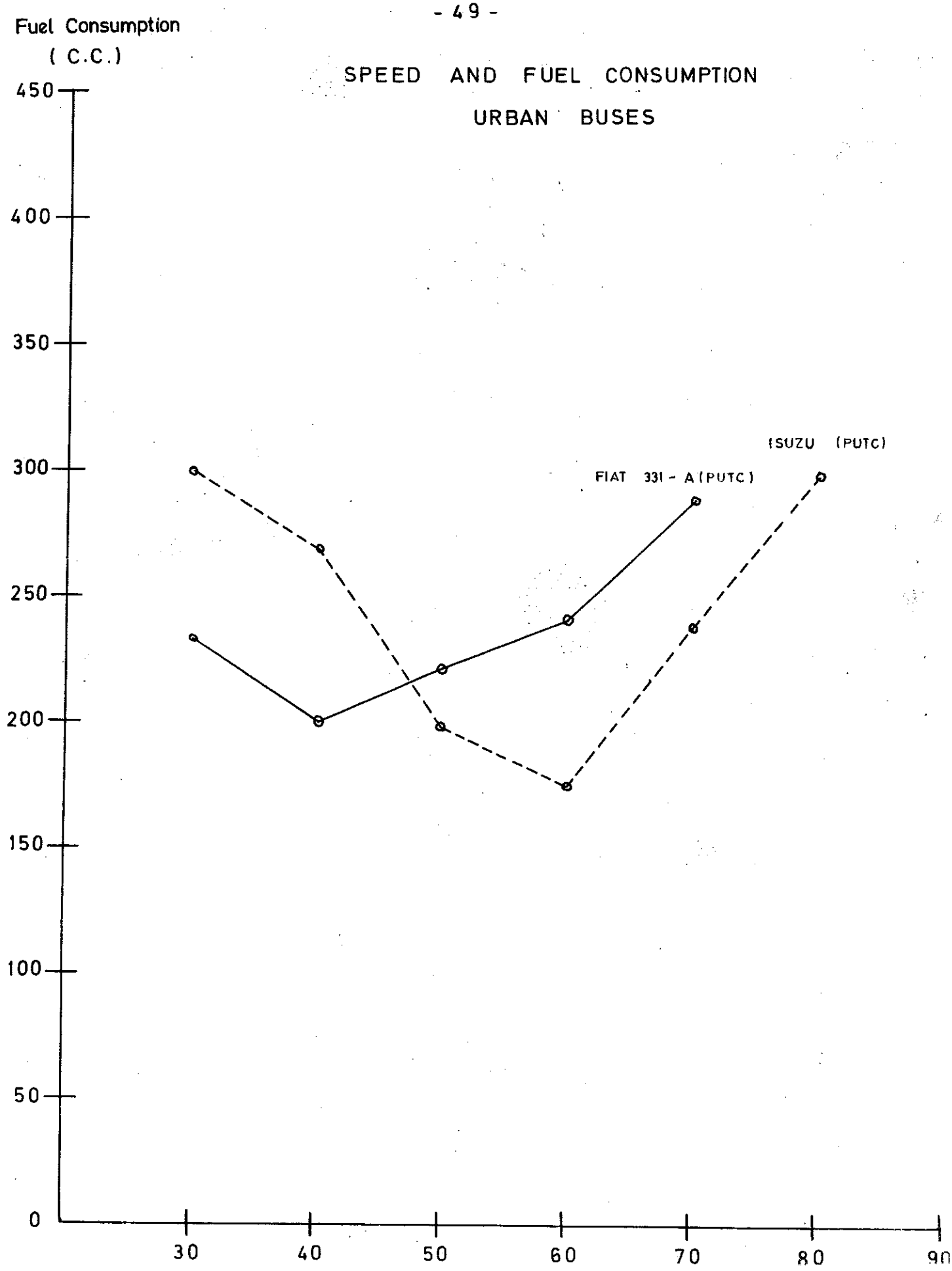
TAXI CARS & SUZUKI VAN

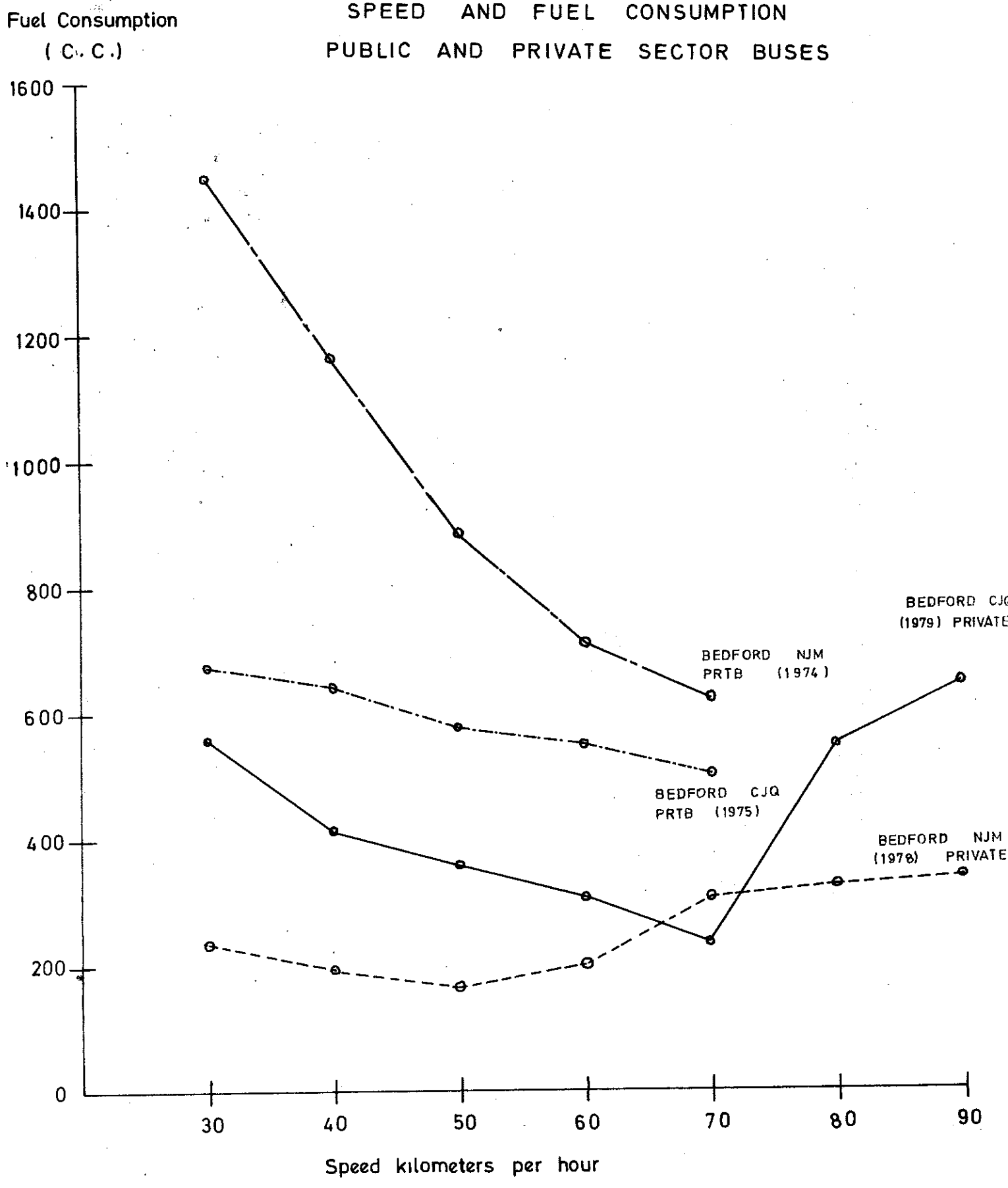


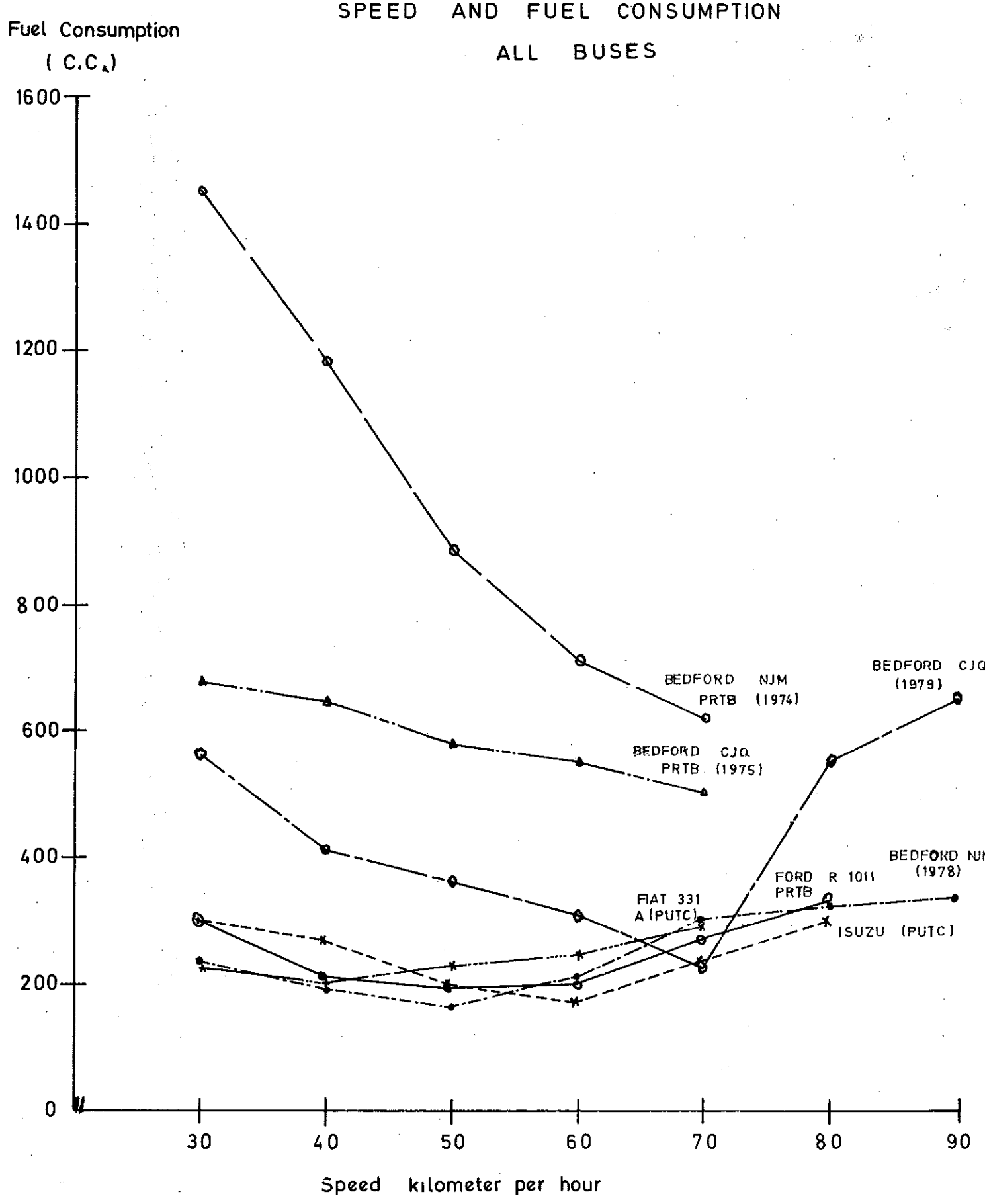

SPEED AND FUEL CONSUMPTION
MEDIUM VEHICLES
Fuel Consumption
(C . C)
160
140
120
100
80
60
40
20
0
TOYOTA
FORD
(DIESEL)
30
40
50
60
70
80
90
Speed kilometers per hour

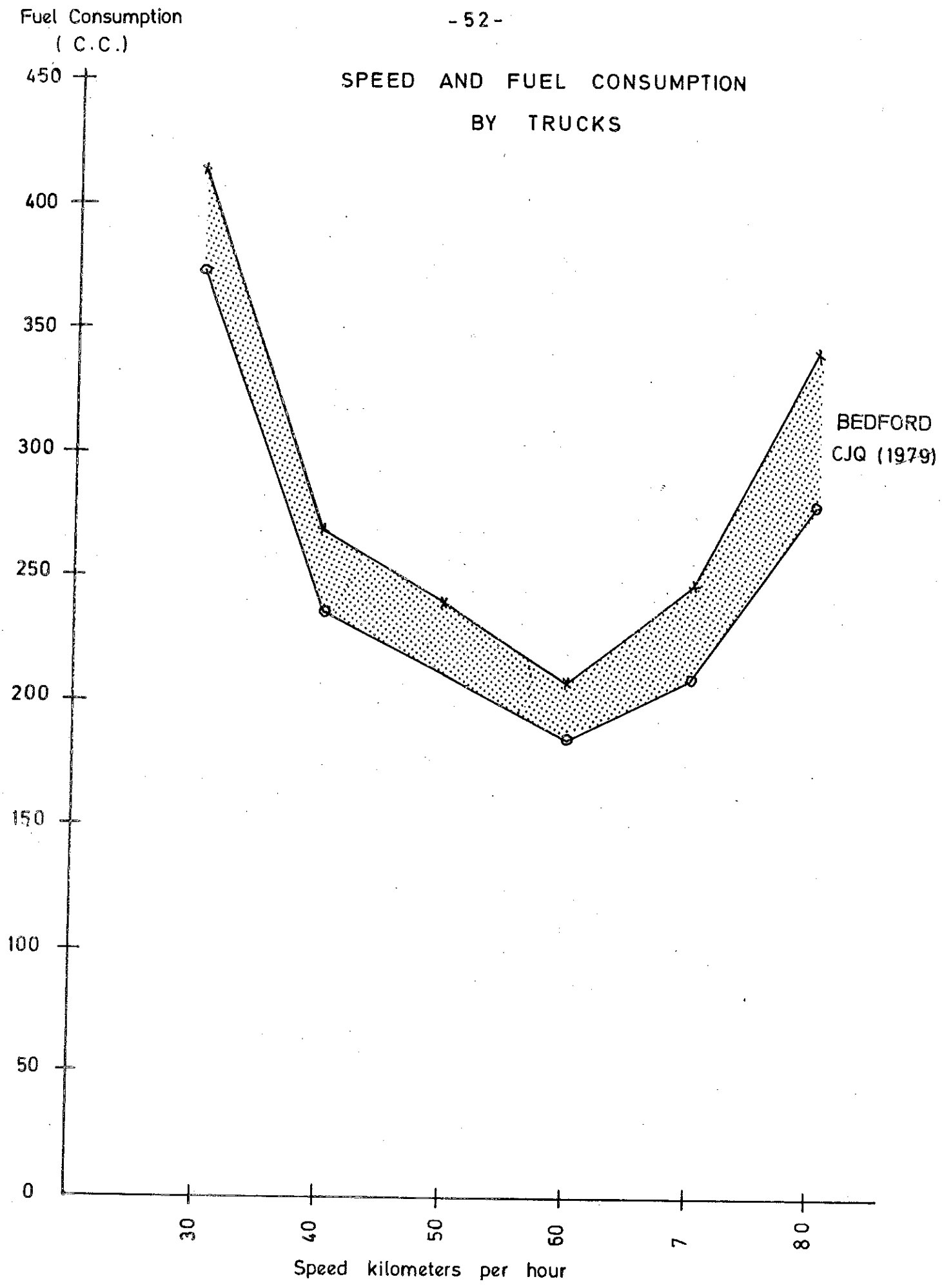
SPEED AND FUEL CONSUMPTION
INTERCITY PRIVATE BUSES BEDFORD
CJQ & NJM MODELS




SPEED AND FUEL CONSUMPTION
URBAN BUSES
Fuel Consumption
(C.C.)
450
400
350
300
250
200
150
100
50
0
30
40
50
60
70
80
90
ISUZU (PUTC)
FIAT 331 - A (PUTC)


SPEED AND FUEL CONSUMPTION
PUBLIC AND PRIVATE SECTOR BUSES
Fuel Consumption
(C. C.)
1600
1400
1200
1000
800
600
400
200
0
30
40
50
60
70
80
90
Speed kilometers per hour
BEDFORD NJM
PRTB (1974)
BEDFORD CJQ
PRTB (1975)
BEDFORD CJQ
(1979) PRIVATE
BEDFORD NJM
(1978) PRIVATE


SPEED AND FUEL CONSUMPTION
ALL BUSES
Fuel Consumption
(C.C.)
1600
1400
1200
1000
800
600
400
200
0
30
40
50
60
70
80
90
Speed kilometer per hour
BEDFORD NJM
PRTB (1974)
BEDFORD CJQ
PRTB (1975)
BEDFORD CJQ
(1979)
FIAT 331
A (PUTC)
FORD R 1011
PRTB
ISUZU (PUTC)
BEDFORD NJ
(1978)


Fuel Consumption
(C.C.)
SPEED AND FUEL CONSUMPTION
BY TRUCKS
450
400
350
300
250
200
150
100
50
0
BEDFORD
CJQ (1979)
30
40
50
60
7
80
Speed kilometers per hour

Chapter V

BUSES IN URBAN OPERATING CONDITIONS

The effect of actual operating conditions in urban areas were examined by testing the performance of two buses on urban routes viz Fiat and Isuzu Buses. These are the two makes in use with the Punjab Urban Transport Corporation in Rawalpindi - Islamabad Depots. The details are described in the following paragraphs.

Routes Examined:

The Fiat 331-A bus was operating on the route from Kohinoor Mills on Peshawar Road to Islamabad Secretariat and the Isuzu Bus was operating between Railway Station and Islamabad Secretariat. The length of route of Fiat 331-A Bus was 30 Km with 38 stops and of Isuzu 24 Km with 25 stops. The portion between Islamabad Secretariat and Rawalpindi Saddar was common for both the routes. The operating conditions on this part of the route were identical for the two buses and this covered major proportion of the routes. The portion from Saddar to terminal points of the two buses was slightly different. The route to Railway Station was shorter than the other. The number of stops were not less infrequent on both the routes.

Information Recorded:

Observations were made for five one way trips by the two buses on their respective routes. The information recorded included running and stopping times en-routes, fuel consumption at the stops and while running between stops. The details are shown in the main table at Annexure B. The summary of results are given below and briefly described in the following paragraph.

Table I

FUEL CONSUMPTION IN URBAN OPERATING CONDITIONS

	Fiat 331-A	Isuzu
1. Route Length Km	30	24
2. No. of stops enroute including signals, etc.	38	25
3. Average trip time(Minutes)	71.15	52.85
Running between stops	77%	71%
At stops	23%	29%
4. Average Speed Km per hour	25.3	27.2
5. Average time per stop	26 second	29
6. Average Fuel Consumption (c.c.):		
- Per stop	18.2	11.7
- Per Km running only	370	320
- Per Km including stops	394	333
7. Mileage Per Litre including Km stops	2.62	3.00

Running Time and Speeds:

About 1/4th of this trip time was spent at stops and 3/4th on routes by the two buses. The average time at stops was 26.4 seconds for Fiat and 28.8 seconds for Isuzu, although the Fiat Bus is larger having more seating capacity. Perhaps, its doors are larger and percent easy loading and alighting. The average speed on the two routes worked out to 25.3 Km and 27.2 Km per hour for Fiat and Isuzu respectively.

As compared to this, the average speed in congested areas in Lahore been found between 20-30 Km per hour. The average time spent at stops for 8 routes was 30 seconds, varying between routes from 18 seconds to 40 seconds.(1)

Fuel Consumption:

Fuel consumption for running between stops amounted to 370 c.c. per Km by Fiat as compared to 320 c.c. by Isuzu. Average consumption per stop was 18.3 c.c. for Fiat and 11.7 c.c. for Isuzu, respectively. Average fuel consumption, running and at stops amounted to 394 c.c. per Km or about 2.5 Km per litre by Fiat and 333 per Km or 3.00 Km per litre by Isuzu.

In relation to its weight and seating capacity, Fiat 331-A appears efficient in fuel consumption. The Gross Vehicle Weight of Fiat is 15000 Kg as compared to 12500 for Isuzu. Assuming passenger capacity according

to gross weight, the capacity of Fiat 331-A is 20% more than Isuzu whereas fuel consumption is only 18% more. Thus, consumption per seat or per Kg of weight is less for Fiat although the difference is not much. In any case, this dispels the doubt that Fiat being a heavier bus would consume relatively more fuel.

Comparison of fuel consumption in actual operating conditions/and at varying speed levels give in Table IV (3) (Table V(1)) indicate that fuel consumption in actual operating conditions is about twice the minimum consumption in most ideal conditions. The actual values for Fiat and Isuzu are 197% and 190% of minimum respectively.

The increase in fuel consumption in operating conditions is partly due to frequent stops and starts and partly due to deviations from the optimum speed. Nevertheless, awareness of optimum speed levels can result in savings in fuel consumption though such savings would not be significant for urban areas. However, on intercity routes, fuel savings could be significant.

(1) Volvo, "Model Urban Transport System Lahore, Traffic Conditions for Buses," 1980, IV Volvo.

Chapter VI

COMPARISON BETWEEN GOVERNMENT AND PRIVATE BUSES

It is generally believed that maintenance of Government Transport Service Vehicles is not as efficient as in the Private Sector. If it is so, the difference will be reflected in fuel consumption as well. Accordingly, the following table gives fuel consumption for Bedford NJM and CJQ Models Buses of Government Transport Services and private operators for comparison.

Table 2

IV(v) Fuel Consumption by Public & Private Sector Vehicles

Vehicle Type	Sector	c.c. per Km Speed Km per hour						
		30	40	50	60	70	80	90
Bedford NJM	i)Public	1455	1180	883	710	620	-	-
	ii)Private	237	193	164	201	303	322	336
	i)as ratio of ii)	6.14	6.11	5.38	3.53	2.04		
Bedford CJQ	i)Public	675	640	577	550	500	-	-
	ii)Private	560	412	360	308	233	549	646
	i)as ratio of ii)	1.20	1.55	1.00	1.78	2.14	-	-

Source: Annexure I Table I

It would be seen that consumption by the Government buses is higher than private buses. The difference is larger for Bedford NJM Model than for CJQ Model. The difference also varies with speed. However, the direction of change for the two vehicles is opposite to each other. In the case of NMJ Model, the difference decreases with increase in speed while

in the case of CJQ Model, the difference increase with speed as further described below.

Bedford NMJ:

Consumption by the Government bus is two to six times higher than private bus. At lower speed level of 30 Km per hour, the consumption by Government bus is 614% of private bus. The difference reduces to 538% at 50 Km per hour and to 204% at 70 Km per hour speed.

Bedford CJQ:

The difference in consumption between Government and private Bus is less than for NJM Model described above. The ratio of consumption by Government Bus is 120% at 30 Km per hour speed increasing to 214% at 70 Km per hour speed.

It may also be noted here that NJM Model in private Sector is very efficient in fuel whereas the same model is most inefficient in the Public Sector and has the highest amount of fuel consumption which is 4 to 5 time more than the Private Sector Bus of the same make. The difference CJQ Model is relatively less.

Although differences are partly due to the fact that public sector buses are relatively old and worn out and partly due to the fact that their maintenance and engine setting are not proper. The comparison is slightly blurred because of differences in age of vehicle. The age of Buses in the Public Sector 6 years. The two buses used

were six and seven years old and almost depreciated. However, it is expected that so long as a bus is in service it would be in a reasonable maintenance condition for being a road worthy vehicle.

The Governemnt Transport Services do not have a regular schedule of replacement and renewal of the buses. The addition of stock is very discontinuous. The buses of latter model in this make were not available with the local Depot.

The figures clearly indicate the difference in fuel costs which can arise due to proper maintenance of vehicles. It also shows the adverse operatint conditions of Government Transport Services in competition with Private Sector. Government Transport Services can achieve considerable savings on fuel costs by proper maintenance and up keep of their vehicles.

Chapter VII

EFFECT OF GRADE ON FUEL CONSUMPTION

Grade or level of the road is also one of the important variables affecting fuel consumption. On downward slopes, vehicles move with their own gravitational force and consume less fuel. The upward slopes cause more resistance and result in higher fuel consumption.

A rise in one direction is a fall from the other direction. A vehicle travelling in one direction at one time is likely to return back. The increase in fuel consumption in the rising direction will be off-set by the decrease in the downward grade. The variations according to grade are therefore measured from net change in grade taking upward and downward slopes together.

Detailed experiments of variations in fuel consumption according to grade were not made due to difficulties of finding suitable road sections of properly separated grades near the study area. In the study area which is mostly rolling, grades of roads change at small distances so that road sections of uniform grade over reasonable length are difficult to find. The time and budget constraints precluded the experiments at out-stations.

Nevertheless, some test runs were made with Suzuki Van and Ford Transit Wagon at a grade of 2.9%. Comparison of results with 0.4% grade used as level road

will give some indication of effect of grade on fuel consumption in the limited range. It was not possible to test larger vehicles on this section as sufficient space was not available for turning larger vehicler at the place. The results for the two vehicles tested are given below:

Table I

Fuel Consumption at Grades
Average of Upward and Downward
Movement c.c per Km

Vehicle Type	Speed KM.H	.4% Grade	2.9% Grade	Difference
Suzuki	30	45	36	(-) 20.0
	40	43	42	2.3
	50	45	47	4.4
	60	48	50	4.0
	70	52	56	7.7
	80	58	64	10.3
	90	65	73	12.3
Ford	30	62	63	1.6
	40	74	76	2.7
	50	92	102	10.9
	60	112	122	8.9

It would be seen that at lower speed levels of 30 Km and 40 Km per hour, the fuel consumption by Suzuki Van at 2.9% grade is less than at 0.4% grade. Technically this is quite possible as a vehicle can move on slopes without using fuel at lower speed upto a certain extent. However, when the speed increases, vehicle engine have to be used for controlling the vehicle at slopes.

Therefore, at higher speeds and sharp grades, fuel consumption increases. At 50 Km per hour speed, fuel consumption is 4.4% higher on 2.9% grade than 0.4% grade. The difference in consumption at 2.9% grade increases to 12.3% it is 90 Km per hour speed.

In the case of Ford Transit, difference in fuel consumption is 1.6% and 2.7% at 30 Km to 40 Km per hour speeds. At higher speeds of 50 and 60 Km, the increase is 10.9% and 8.9% respectively.

The decrease in fuel consumption for smaller vehicle at lower speed on higher grade is not comparable with other studies. However, increase at other speed levels and for Ford Transit is in line with the results of other studies.

It is difficult to draw general conclusions from a limited number of experiments.

The data on changes in fuel consumption according to grade can be obtained from other studies for use in conjunction with results of this study.

Kenya Study:

The Kenya Study has developed regression equations which include rates of rise and fall as independent variables. The difference of co-efficinets of rise and fall will indicate net change in consumption approximately.

Calculation of such differences indicates that 1% change in grade will result in .74% change in consumption for cars, 1.6% for medium size trucks and 25% for heavy vehicles. These results are more generalized and represent an average over a wide range. As the relationship between fuel consumption between fuel consumption and speed and other variables including grade is not liner in any case, the equation can only be used for estimating operating costs for certain stated conditions only. It is not suitable for estimating variations in costs according to grade. For this purpose, it would be appropriate to use data for each category of rise and fall and the World Bank Study would be more relevant.

The World Bank Study:

The World Bank Study gives % increase in consumption over level roads for grades of 1,2,4, 6 and 8%. The trends are briefly as follows.

Smaller vehicles are affected less by grade than heavier vehicles. The effect of grade upto 1.0% is insignificant for small and medium vehicles

The effect of grade also declines with increase in speed at lowergrades for smaller vehicles, but not for heavy vehicles or at very high grades.

For cars, the increase does not exceed 60% for the maximum grade of 8%. However, for heavy vehicles, the consumption increase even upto 200% for higher grades.

The relevant table of the World Bank Study is reprodeced in Annexure C.

Chapter VIII

COMPARISON WITH BUS MAKE STUDY

The Bus Make Study[1] carried out by the Centre some time before examined, among other things, fuel consumption by various makes of buses of Public Sector Corporations. The experiments on fuel consumption made now provide some data for comparison with the previous study. However, before making the comparison the difference in scope and methodology of the two studies may be noted so that the results could be appreciated in proper perspective.

In the Bus Make Study, the average fuel consumption expressed in terms Mile per Gallon (MPG) is based on management records concerning fuel supplied and estimates of mileage performed by individual vehicles. The data for both fuel and mileage was obtained from respective organizations. It expected records of fuel supplied to individual vehicles would be quite accurate as fuel is precisely measured and accounted for. However, the mileage performed by individual vehicles is not likely as accurate because in almost all cases, milometers of buses are not in working order. It is therefore not possible to determine the mileage performed. The estimates of mileage are made on the basis of length of route. Buses some times short circuit the route are sent on shuttle trips the length of which is not exactly known. The actual mileage therefore

differ from the calculated mileage. The error may not be large to warrant discurding the data.

On the other hand, the present study gives fuel consumption at speed levels ranging from 20/30 Km to 89/90 Km per hour. With interval of 10 Km. From this data, it is not possible to calculate average consumption as the distance a bus travels at various speed levels is not know so that weights to different speed levels cannot be assigned. Thus data of the two studies is strictly not comparable. Nevertheless an unweighted average of fuel consumption at different speed levels has been calculated. It gives a rough idea of average consumption.

Among the various makes considered by the two studies, Bedford and Isuzu are the two makes for which corresponding data is available in the two studies. However, as in the case of present experiments, the Bus Make Study, has not made distinction between CJQ and NJM Models of Bedford Buses. The results of experiments on NJM Model appeared closer to Bus Make Study and were therefore used for comparison.

The following table gives average fuel consumption indicated by the present experiments and Bus Make Study. The figures of present experiments are unweighted average of the Bus Make Study has been converted from Miles per Gallon is c.c's per Km the measure used in the present study.

1. Average Fuel Consumption by Buses

PRESENT STUDY

Private Buses		c.c.per Km
Bedford NJM	...	251
Bedford CJQ	...	428

BUS MAKE STUDY

Govt. Buses only

SRTC Bedford 1974	...	225
PUTC Bedford	...	231
NWFP Bedford	...	231
PUTC Izuzu 1975	...	233
PUTC Isuzu 1974	...	233

It will be seen from the above that average fuel consumption indicated by the Bus Make Study is quite consistant and varies within very narrow range between 226 c.c and 233 c.c per km. However, in the case of present study variations between vehicles are quite large. The consumption of Government vehicles Bedford NJM Model is exceptionally high. The vehicle was perhaps fully depreciated and in land maintenance condition. This may be ignored for comparison. In the case of CJQ the consumption of both private and public sector buses is higher than private NJM Model. As stated before, in the Bus Make Study,

distinction between NJM and CJQ models has not been made. However, fuel consumption indicated for Bedford Buses in the Bus Make Study is comparable with Bedford NJM Model of Private Operator only. The figure for Isuzu Buses are also comprable in the two studies. Accordingly, fuel consumption for these two vehicles only has been compared with Bus Make Study.

It would be evident that consumption of Bedford NJM Model (private) indicated by present experiments is about 10% more than the average of the Bus Make Study. In the case of Isuzu the consumption indicated by the present study is 5.5% higher only. The differences may be either due to method of averaging followed by the two studies or due to the fact that buses considered in the present study were of higher age and in relatively more worn out as compared to the period to which the data of the Bus Make Study relates. However, considering the type of data, the differences of 10% and 5% appear within reasonable limits.

The fuel consumption by Government Bus NJM Model is exceptionally high and appears due to poor maintenance and depreciation of vehicle. The figures for Bedford CJQ Model vehicles of Government and private operator are comparable with each other and both are higner than Bus Make Study. It appears that Bedford vehicles or CJQ Model are not included in the Bus Make Study. Therefore, comparison of figures for CJQ Model is not possible between the two studies.

(1) Farouk M.A. "Bus Make Study", National Transport Research Centre, Government of Pakistan, Islamabad, March, 1981.

Chapter IX

CONCLUSIONS AND RECOMMENDATIONS

The study has provided realistic estimates of fuel consumption by different types of commercial vehicles at different speed levels ranging from 20 Km to 90 Km per hour for paved tangent roads. This data may be used for estimating vehicle operating costs for various purposes including appraisal of highway projects, formulation of policies concerning pricing of road transport services, speed regulations, etc. The individual operations can use the information for minimizing operating costs as well.

The results have also shown the importance of proper maintenance of vehicle for economizing on fuel costs. The fuel consumption by old Government Transport Buses was more than twice the amount for private buses. The cost of maintenance provides quick devidends and the cost is paid off by savings in fuel consumption.

The present result provide only primary data on fuel consumption on level tangent roads. Variations according to type of road, grade, curvature, etc. Can be estimated by using ratios dervied in other studies some of which have been reproduced in the study for

ease of reference.

The equipment purchased for the study can profitably be used for further experiments. It is recommended that further work may be continued to further expand the range and scope the data.

The cost of continuing this work would be only marginal.

Annexure - A

RESULTS OF FUEL CONSUMPTION

A.I. Average Fuel Consumption by Motor Vehicles on level Tangent Road

(c.c. per Kilometer)

Vehicle Type	Speed Km per hour						
	30	40	50	60	70	80	90
Small Cars (Petrol)							
Morris 1000 c.c. Taxi I	65	55	64	73	88	114	143
Datsun 1200 c.c. Taxi II	76	70	69	79	95	120	150
Datsun 122 c.c.Taxi	62	62	78	85	91	99	124
Average	68	62	70	79	91	111	139
Zuzuki Van	45	43	45	48	52	60	69
Medium Vehicle							
Toyota Hiace(Petrol)	101	98	102	103	115	124	137
Ford Transit(Diesel)	84	75	67	75	86	98	106
Buses (Diesel)							
Bedford NJM,1978 Private(Diesel)	237	193	164	201	303	323	336
Bedford CJQ,1979 Private	560	412	360	308	23?	549	646
Bedford NJM PRTB (1974)	1455	1180	883	710	620	-	-
Bedford CJQ PRTB (1975)	675	640	577	550	500	-	-
Ford R 1011 PRTB	300	210	194	200	270	330	-
Isuzu(Diesel)PUTC	300	268	198	?75	2??	300	-
Fiat 331-A(PUTC)	234	200	222	242	290	-	-

Annexure - A

RESULTS OF FUEL CONSUMPTION

A.I. Average Fuel Consumption by Motor Vehicles on level Tangent Road.

(c.c. per Kilometer)

Vehicle Type	Speed Km per hour						
	30	40	50	60	70	80	90
Trucks							
Bedford CJQ 1979 Water Tankers							
1. Fully Loaded	447	323	264	209	213	347	-
Partly Loaded	444	307	253	195	177	319	-
Empty	410	273	226	183	164	280	-
2. Fully Loaded	457	242	235	231	315	-	
Partly Loaded	404	222	217	212	266	-	
Empty	388	213	206	199	242	-	
3. Fully Loaded	342	240	220	185	220	275	
Partly Loaded	332	230	211	179	219	271	
Empty	322	220	202	173	218	267	
Average(1 to 3)							
Fully Loaded	415	268	240	208	249	311	
Partly Loaded	393	253	227	195	221	295	
Unloaded	373	235	211	185	298	274	
Average of above	394	253	226	191	226	293	
Fargo Ley Land							
Loaded	581	500	404	480	-	-	
Partly Loaded	559	464	349	429	-	-	
Empty	359	318	240	326	-	-	

A.2. AVERAGE MILEAGE BY MOTOR VEHICLES ON LEVEL TANGENT ROADS.7

(Km per litre)

Vehicle Type	Speed Kilometers per hour 30	40	50	60	70	80	90
Small Cars (Petrol)							
Morris 1000 c.c.taxi I	15.4	18.2	15.6	13.7	11.4	8.8	7.0
Morris " " taxi II	13.2	14.3	14.5	12.6	10.5	8.3	6.7
Datsun 1200 c.c.	16.1	16.1	12.8	11.8	11.0	10.1	8.1
Average	14.7	16.1	14.3	12.7	11.0	9.0	7.2
Suzuki Van	22.2	23.2	22.2	20.8	19.2	16.6	14.5
Medium Vehicles							
Toyota Hiace(Petrol)	9.9	10.2	9.8	9.2	8.7	8.0	7.3
Ford Transit(Diesel)	11.9	13.3	14.9	13.3	11.6	10.2	9.4
Buses (Diesel):							
Bedford NJM(Private) (1978)	4.2	5.18	6.1	5.0	3.3	3.1	3.0
Bedford NJM(Private) (1979)	1.8	2.4	3.4	3.2	4.3	1.8	1.5
Bedford NJM(PRTB) (1974)	0.6	0.8	1.1	1.4	1.6		
Bedford CJQ(PRTB) (1975)	1.5	1.6	1.7	1.8	2.0		
Ford R-1011(PRTB)	3.3	4.7	5.2	5.0	3.7	3.0	
Isuzu(PUTC)	3.3	3.7	5.0	5.7	4.2	3.3	
331-A(PUTC)	4.3	5.0	4.5	4.1	3.4		
Trucks:							
Bedford CJQ 1979 Water Tankers							
1. Fully Loaded	2.24	3.10	3.78	4.78	4.63	2.88	-
Partly Loaded	2.35	3.25	3.95	5.13	5.65	3.13	-
Empty	2.44	3.46	4.42	5.46	6.10	3.57	-
2. Fully Loaded	2.19	4.13	4.25	4.32	3.17	-	-
Partly Loaded	2.47	4.50	4.60	4.71	3.76	-	-
Empty							

AVERAGE MILEAGE BY MOTOR VEHICLES
ON LEVEL TANGENT ROADS

(Km per litre)

Vehicle Type	Speed Kilometers per hour						
	30	40	50	60	70	80	90
3. Fully Loaded	2.92	4.16	4.54	5.40	4.50	1.75	-
Partly Loaded	3.01	4.35	4.74	5.58	4.56	3.69	-
Empty	3.10	4.54	4.95	5.78	4.58	3.74	-
Average							
Fully Loaded	2.41	3.73	4.16	4.80	4.01	3.21	-
Partly Loaded	2.54	3.95	4.40	5.13	4.52	3.38	-
Empty	2.68	4.25	4.74	5.40	3.35	3.65	-
Average	2.54	3.95	4.42	5.10	4.42	3.41	-
Fargo Lay Land							
Loaded	1.72	2.00	2.47	2.08	-	-	-
Unloaded	1.78	2.15	2.86	2.33	-	-	-
Empty	2.78	3.14	4.16	3.06	-	-	-

A.3. Fuel Consumption at Different Speed Levels on Level Tangent Road as Percent of Minimum Consumption = 100

Vehicle Type	Speed Kilometers Per Hour 30	40	50	60	70	80	90
Small Cars (Petrol):							
Morris 1000 Taxi I	118	100	116	133	160	207	260
Morris 1000 Taxi II	110	101	100	114	138	174	217
Datsun 1200 Taxi	100	100	125	137	147	160	200
Average	110	100	113	127	147	179	224
Suzuki Van	105	100	105	112	121	140	160
Medium Vehicles:							
Toyota Hiace(Petrol)	103	100	104	110	117	127	140
Ford Transit(Diesel)	125	112	100	112	128	146	158
Buses (Diesel)							
Fiat 331-A PUTC	117	100	111	121	145	-	-
Ford R-1011 PRTB	155	108	100	103	139	171	
Bedord CJQ PRTB(1975)	135	128	115	110	100	-	-
Bedford NJM PRTB	235	190	142	115	100	-	-
Bedford CJQ 1979(Private)	240	177	126	132	100	236	144
Bedford NJM (1978)(Private)	145	118	100	123	185	197	205
Trucks(Diesel): Bedford CJQ (1979) Water Tankers							
1.(a)Fully Loaded	214	155	126	100	102	166	
(b)Partly Loaded	250	177	199	110	100	180	
(c)Unloaded	250	166	138	112	100	170	
2.(a)Fully Loaded	198	105	102	100	136		
(b)Partly Loaded	191	105	102	100	125		
(c)Unloaded	195	107	104	100	122		
3.(a)Fully Loaded	185	130	119	100	130	149	
(b)Partly Loaded	185	128	118	100	128	151	
(c)Unloaded	186	127	117	100	126	154	
Av.(a)Fully Loaded	200	129	115	100	120	167	
(b)Partly Loaded	201	129	115	100	115	149	
(c)Unloaded	202	127	114	100	112	151	
Fargo Ley Land:							
(a)Fully Loaded	144	124	100	119	119		
(b)Unloaded	150	133	100	136	206		

ANNEXURE - B

B.I. BUS OPERATING CONDITIONS AND FUEL CONSUMPTION

	Fiat 331-A (RIH 4742)	Isuzu (RID 6615)
1. Gross Weight (Kg)	15,000	12,500
2. Route Length K	30	24
3. No. of trips observed	5	5
4. No. of stops enroute including signals, etc.	38	25
5. Average trip time (Minutes)	71.15	52.85
- Of which running between stops	54.45	40.85
- Standing at stops	16.75	12.00
6. Average Speed Km per hour	25.3	27.2
7. Average time per stop (seconds)	26	29
8. Fuel consumption litres per trip	11.819	7.981
- Of which running between stops	11.122	7.688
- Standing at stops	0.697	0.293
Total:	11.819	7.981
9. Average Fuel Consumption(c.c.):		
- Per stop	18.2	11.7
- Per Km running only	370	320
- Per Km including stops	394	333
10. Mileage Kilometers per litre including stops Km	2.54	3.0
11. Fuel Consumption per Km per 100 Kg gross weight c.c.	2.62	2.66

ANNEXURE - C

World Bank Study

Fuel Consumption and Rate of Rise and Fall* — Passenger, Car, Trucks (on tangent paved road)

(%increase from consumption on level road)

Rate of rise and fall (meter per 100 meters)	Speed (Kilometer per hour)											
	24	32	40	48	56	64	72	80	88	97	105	113
1	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	3	3	3	3	3	-	-	-	-	-
4	10	10	9	8	8	8	6	5	2	-	-	-
6	30	32	32	30	27	22	18	13	11	9	6	-
8	54	59	61	60	56	51	48	40	34	28	-	

*Based on a fifty-fifty distribution of up grades and down grades.
Source (48 ch. 20, pp. 32-33)

TRUCK - I

1	-	-	-	-	-	-	-	-	-	-	-
2	2	3	3	4	4	4	4	4	3	2	2
4	11	11	11	13	13	13	12	11	9	-	-
6	36	39	40	39	37	35	32	29	-		
8	71	79	82	82	81	79	76	76	-		

TRUCK - II

1	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	4	-	-	-	3	2	-
4	5	7	8	9	13	11	12	14	-	-	-
6	22	23	24	25	37	29	31	-			
8	47	51	52	53	81	50	-				

TRUCK - III

1	-	-	-	-	4	11	20	30	34	-	-
2	-	-	-	6	20	36	54	70	-		
4	8	25	52	89	-	-		-			
6	52	96	-	-	-	-					
8	-	-	-	-	-	-					

TRUCK - IV

1	6	10	12	14	15	16	15
2	21	24	44	40	44	47	48
4	59	85	108	127	145	-	-
6	109	154	196	-	-	-	
8	155						

*Based on a fifty-fifty distribution of up grades and down grades.
Source : (48, Ch. 20, p.p. 36-49)