CHAPTER 3 - ROAD USER COSTS SURVEYS

INTRODUCTION

Road user costs are of primary importance in this study, and a major portion of the total study resources will be directed towards determining these costs. Some elements of user costs can best be determined by experiment as discussed in Chapter 4. However, major effort must go into surveys of real operating costs since some factors can only be developed from real world operating conditions.

No vehicle cost Survey of this size and complexity has been attempted before. The nearest related study, TRRL's Kenya Study (Ref.9), was fairly limited in extent and in the applicability of its results. Certainly no formal methodology has yet been established for this kind of survey and questions about the methodology outlined here remain to be answered in pilot studies.

Extensive resources have already been allocated to the survey portion of the Project in terms of technical assistance from survey experts, statisticians and economists. They helped in devising and detailing the methodology, and we expect to complete the task of survey design by June 1976 after analysis of pilot survey data.

Within the road users costs surveys, emphasis is also being placed upon depreciation and vehicle maintenance costs. These are the items about which least is presently known and a significant effort in these areas should produce results more valid than the judgemental values historically used.

OBJECTIVES AND SCOPE

The overall objective of the user costs surveys is to establish relationships between various components of vehicle operating costs and road design variables, surface roughness, vertical and horizontal alignment, and for essentially low-volume rural roads. In order to do this it will be necessary to determine user costs for measurable road conditions so that cost differentials can be determined.

The components of vehicle operating costs being considered are 1) fuel 2) oil 3) tyres 4) maintenance parts 5) labour and 6) depreciation. Maintenance and depreciation together comprise about 50% of operating costs (see Table 3) and a major task of the Survey is to establish sound relationships for these components. Fuel consumption will be addressed in the user experiments and the results calibrated using survey data. Tyre costs comprise overall an estimated 10% of operating costs, but become a major item in heavy vehicles (see Table 2) and thus an important part of the Survey, particularly for buses and trucks.

In addition to the vehicle operating costs listed above there are several other important costs. These consist of 1) crew costs, 2) interest on capital, 3) insurance, 4) licenses and other fees, and 5) company overheads. These costs cannot be directly related to the primary independent variables of surface type, roughness, and geometry. Although cost items, they will receive only minor attention during the Survey.

Initially the Survey will be conducted in the states of Goiás and Minas Gerais and the Federal District of Brasilia. These areas should satisfy Survey needs in terms of extremes of roughness and geometry. Studies in other states may be required to determine the effects of traffic congestion on gravel roads or to obtain a wider range of depreciation data. Therefore additional satellite studies will be undertaken later to fill any gaps in the Survey as required.

During preliminary evaluations it was established that the cost of data collection must be a primary input to the survey design. Thus an evaluation must be made of the importance, or priority, of all data items, to control costs and maximize benefits. An evaluation of data collection costs will be made during the pilot study (March-June 1976) and by June a fairly objective estimate of the scope of the Survey in terms of numbers of vehicles will be available.

TABLE 3 - IMPACT OF COSTS BY COST ELEMENT AND VEHICLE CLASS, INCLUDING TAXES, ON THE VEHICLE POPULATION OF MINAS GERAIS AND GOIÁS, EXCLUDING VEHICLES IN THE URBAN AREAS OF BELO HORIZONTE AND GOIÂNIA. ANNUAL COSTS IN MILLIONS OF CRUZEIROS, DECEMBER 1975

VEHICLE CLASS	FUEL	OIL	TYRES	MAINTENANCE	DEPRECIATION	TOTAL
CAR	726	58	57	265	468	1574
UTILITY	1045	73	79	564	653	2414
BUS	176	37	69	184	180	646
TRUCK	1040	219	756	1089	792	3896
TOTAL	2987	387	961	2102	2093	8530
PERCENTAGE	35.0	4.5	11.3	24.6	24.5	100

Source - 16,17,18

Note: Figures are rounded.

TABLE 4 - AVERAGE OPERATING COSTS FOR TYPICAL VEHICLES IN FOUR MAIN CLASSES, BY COST ELEMENT. COSTS IN CRUZEIROS PER KILOMETRE INCLUDING TAXES AT DECEMBER 1975

VEHICLE CLASS	FUEL	OIL	TYRES	MAINTENANCE	DEPRECIATION	TOTAL Cr$ PER KM
CAR (4 pass.)	.3102	.0250	.0242	.1135	.2000	0.6729
VW 1300 Sedan	46	4	3.5	17	29.5	100%
UTILITY (LIGHT)	.4653	.0324	.0350	.2510	.2905	1.0742
Chevrolet C 10	43	3	4	23	27	100%
BUS (36 pass.)	.4762	.1004	.1850	.4985	.4861	1.7462
Mercedes 0-362	27	6	10.5	28.5	28	100%
TRUCK - 3 axle	.4762	.1004	.3462	.4985	.3625	1.7838
Mercedes 1113	27	5.5	19.5	28	20	100%

Sources 17,18

MAJOR COSTS ELEMENTS

Before describing the Survey design being considered for use in the Project it is appropriate to discuss the various elements of vehicle operating costs and examine their impact from information already available. This is done below with particular attention to Brazil.

Vehicle Depreciation

It seems logical to assume that vehicles which are driven primarily on rough, unpaved roads will wear out, physically deteriorate, and therefore depreciate in value more rapidly than those vehicles used primarily on smooth, paved roads. Many logical assumptions are wrong, however. If prospective buyers had perfect information about the vehicles they were considering for purchase, they might indeed be less willing to buy vehicles which had been driven on rough roads, thus forcing a lowering of their prices.

If prospective buyers do not know the history of the vehicles they consider for purchase, having been driven on rough roads may not affect the price of these vehicles at all. It is an empirical question. Since we are working in a market economy and in general accepting the price (market value) of each commodity as its value, it would be inconsistent to try to find some "real" or intrinsic depreciation of these vehicles. We must accept their market value as their true value, and the reduction in market value as the depreciation.

Thus there are two steps in the process of measuring depreciation. 1) Obtain a measure of depreciation for each class of vehicle. 2) Obtain a measure of the difference in resale value attributable to each vehicle class having been used under different highway conditions.

For the first item Table 5 shows calculations based on industry data for used vehicle sales in Rio and São Paulo as of September, 1975. More data sources are being sought and similar calculations will be made. In most countries, automobiles seem to lose a fixed percentage of their current value each year. In Brazil, inflation complicates these calcula -

TABLE 5 - PERCENT OF 1975 MODEL VALUE MAINTAINED BY EARLIER YEAR MODELS, FOR BRAZILIAN AUTOS

	1975	1974	1973	1972	1971	1970	1969	1968
FORD								
Corcel	100	85.2	75.0	63.2	54.4	46.3	39.2	-
Belina	100	85.4	74.4	64.5	55.6	47.1	-	-
Maverick	100	86.4	72.4	-	-	-	-	-
Galaxie 500	100	79.0	65.3	47.2	37.9	30.3	25.0	20.5
Rural	100	82.5	68.5	59.1	51.6	45.9	38.2	33.6
Jeep	100	86.0	75.0	63.8	55.0	47.4	42.0	38.8
CHRYSLER								
Dodge Dart	100	81.8	68.3	54.0	43.7	36.7	30.2	-
Dodge Charger	100	76.9	64.8	49.7	40.7	-	-	-
G.M.								
Opala 4 cyl.	100	83.7	70.8	58.9	50.6	43.1	36.5	-
Opala 6 cyl.	100	78.2	57.4	54.8	57.4	39.5	33.4	-
Veraneio	100	81.7	67.0	57.0	48.8	41.1	35.2	31.6
PUMA								
Puma GTE	100	81.2	71.2	62.6	53.8	48.3	41.8	35.5
V.W.								
Brasília	100	89.3	81.1	-	-	-	-	-
Kombi	100	87.1	77.0	65.3	57.3	50.9	43.7	38.5
VW 1300	100	89.9	79.9	70.6	62.0	55.9	50.3	44.4
VW 1500	100	86.2	74.4	65.3	57.4	50.9	-	-
Average Percentage	100	83.8	71.4	59.9	51.9	44.9	37.8	34.7
15% Depreciation	100	85.0	72.3	61.4	52.2	44.4	37.7	32.1

Data from Quatro Rodas "Automobile Market" report based on sales prices in São Paulo and Rio de Janeiro. October 1975.

tions, but for automobile models which have been produced for several years without major design changes, the prices as of September 1975 have been used to calculate the price on that date of each preceding model year as a percentage of the 1975 price. The data seem to indicate that autos have a resale value approximately given by the formula

$$RV = B\ (0.85)^n$$

where RV = resale value
B = the base price of the 1975 model in September 1975
n = age of auto in September 1975, in years, given by:
n = (1975 - model year)

Similar data and calculations are needed for trucks and buses.

The second step in the analysis of depreciation will involve obtaining information from dealers as to the difference in resale value of vehicles which have been driven largely on smooth, paved roads. This may be done through the Delphi process of getting groups of dealers together and seeking a consensus estimate, or it may be done by administering questionnaires to dealers.

It is proposed to attempt the Delphi method, making preliminary investigations amongst dealers in Brasilia, before organization of a wide-spread survey, covering several areas of Brazil. Information on depreciation will be sought from the vehicles in the main survey, but it is considered likely, as in the Kenya study, that relying on these alone for our sample will yield insufficient data.

Vehicle Maintenance

Vehicle maintenance (parts and labour) is a major component of operating costs for all vehicles (see Table 4). It is necessary to separate the elements of parts and labour since the relative unit costs of these items varies from time to time and more importantly, from region to region. The ratio of part costs to labour costs also varies for different maintenance operations. This is illustrated in Table 6 for a city bus fleet in Bradford, England.

Maintenance consumption, unlike fuel, oil, and tyres, does not vary uniformly with distance travelled, and this makes measurement more difficult. The numerous different parts must wear out or fail in service and be replaced before consumption can be measured. Thus for study purposes a long period of time is required to measure true consumption rates. These rates vary considerably over the life of the vehicle since different items require replacement or attention at different time or accumulated travel intervals.

Possible relationships between highway characteristics and vehicle maintenance costs follow.

Vertical Geometry - the number and steepness of grades contributes to engine, clutch, gearbox and differential wear. Wear is greatest on up or plus grades but is also affected on down or minus grades. In addition, minus grades affect brake wear.

Horizontal Curvature - affects engine and gearbox wear through required speed changes. Steering gear, springs and shock absorbers are affected by sideways forces.

Surface Type and Roughness - affects every part of the vehicle in some degree, but particularly steering and suspension, electrical parts, chassis and body.

Other related factors contributing to overall maintenance costs during the life of the vehicles are a)driver behaviour, b) vehicle use, and c) owner's maintenance policies.

a) driver behaviour - may affect maintenance cost per km much as it does fuel consumption. Excessive speed and acceleration contribute to engine wear, hard braking to brake wear;
b) vehicle use - conditions of use affect maintenance costs. Traffic congestion, frequent loading and unloading for commercial vehicles, causing engine and brake wear, and bodywork damage, respectively.

TABLE 6 MAINTENANCE AND REPAIRS - LABOUR COST AS A PERCENT OF TOTAL COSTS FOR A FLEET OF BUSES IN BRADFORD, UK

Item	Labour as a Percent of Total
Painting	94
Bodywork	83
Electrical	71
Chassis and Brakes	67
Engine	60
Transmission	27

Source - R. Travers Morgan and Partners, London "Costing of Bus Operations" Interim Report July 1974.

c) maintenance policy - poor maintenance and irregular servicing causes premature failure of parts, and shortens the vehicle's effective life, thus adding to depreciation cost as well as to parts consumption. Vehicle "downtime" is an important consideration for commercial vehicle operators, and it is often difficult to select an optimal maintenance policy. Decisions required include 1) when to remove the vehicle from operation for inspection and preventive maintenance, 2) how frequent should servicing intervals be to avoid costly breakdowns, and 3) should new or reconditioned spare parts be used etc. Operators usually arrive at such decisions by trial and error and such policies vary to suit their own opinions and peculiar circumstances.

Fuel Consumption

Fuel is a major cost element in all vehicle classes, and remains so whether considering commercial prices or economic or shadow prices. It is particularly important for cars and other gasoline vehicles when considering the commercial price, since this class (mainly private vehicles), often subsidizes diesel vehicles (mainly commercial vehicles) through a higher rate of fuel tax.

From a survey point of view, fuel consumption has the following characteristics:

1) varies directly with distance travelled
2) is the simplest cost item to measure
3) variation in consumption rates reveal themselves quickly
4) can be used to calibrate experimental data
5) most operators keep records
6) can be used to check data on other costs items (in fuel consumption data is suspect, so is other data)

Tyres

Highway surface characteristics have a direct and obvious effect on tyre wear since the vehicles tyres are in direct contact with the road. Surface roughness on both paved and unpaved roads is therefore a major factor in tyre wear. However vertical and horizontal geometry are also known to have effects on tyre wear, in association with vehicle speed and direction changes causing abrasion or sloppage. Another factor, particularly important for heavy vehicles, is weight carried per axle.

Oil Consumption

Oil consumption is a relatively minor item of operating cost in all vehicles, usually representing less than 2% of total operating costs. It is probable that engine and gearbox oil consumption is much more directly related to engine wear than conditions of vehicles use.

Other Costs

a) Crew Costs - This information may be derived from operators, organizations such as National Highway Freight Transportation Association (NTC), and official sources. In general, crew costs increase with the size of the vehicle, particularly for freight vehicles but also to some extent for buses.

b) Interest on Capital - In most estimates of vehicle operating costs, an interest or finance charge is included, often lumped together, or hidden within, depreciation costs. In the present study it is hoped to derive reliable estimates for vehicle depreciation and capital on interest charges in each year of vehicle life, and a set of age spectra for each vehicle class.

c) Insurance - In most countries some form of insurance coverage is compulsory and is included as a component of vehicle operating cost. Tariffs issued by insurance companies and amounts paid by vehicle operators usually reflect the claims experience in the preceding year or few years.

d) Licences and Other Fees - Annual vehicle licences for each vehicle class can be calculated easily by reference to TRU (Taxa Rodoviária Única) tables for any year.

e) Company Overheads - This item covers all other essential items of expenditure connected with vehicle operations not already listed above. Overheads typically include rental costs for offices and workshops, clerical and management salaries, insurance (other than vehicle insurance), accountancy fees, power light and heat, telephones, stationery and postage, and may include other items, such as advertising.

SURVEY DESIGN AND METHODOLOGY

Many questions remain to be answered regarding sample design and survey methodology. This section summarizes the current state of the problem and accomplishments. An intensive study of the survey approach and its strengths and limitations is currently underway as outlined with our sponsors and the Expert Working Group (EWG) in December.

Preliminary proposals for the survey design for buses, trucks, utility vehicles and cars are also presented in this section. These proposals will be refined and revised in the next three months through the inputs of the experts mentioned later and the survey group.

To effectively design a survey a wide variety of information is required, as follows:

1) the exact objectives of the survey stated in terms of data inputs
2) data on the vehicle population
3) data on route characteristics used by the vehicle population
4) knowledge of problems likely to be encountered during data collection.

At the present time three major activities are underway to gain this required information. These three activities will assist in developing an effective final survey design for use in the road user costs surveys.

1) Gathering background information in pre-pilot studies
2) Consultation with survey design experts
3) Testing survey instruments in "pilot studies."

Background Data Collection Techniques and Sources

In the initial interviews, many items of information will be recorded. Field personnel will first assess the operator's willingness to cooperate and secondly, his ability to do so. The following types of information will be investigated in pilot studies.

Does he keep records?
What items are recorded and how?
What items are missing?
Is information compiled separately for each vehicle?
Are routes and vehicle arrival and departure times noted?
Are tachographs used?
Are loads and passengers recorded for each trip?
Are all invoices, vouchers and receipts kept to support cost control summaries?
Will the field team have access to all supporting documents?
What checks does the operator himself carry out to ensure accurate records?
If formal records are incomplete, can they be compiled from invoices and other documents?
Can the team assist the operator to establish a reliable information system?

Where formal records are not kept, the operator will be encouraged to begin doing so and the team will assist him in setting up a cost control system, monitored by senior project personnel. Original evidence, particularly invoices, will then be checked wherever possible, rather than relying on the summary totals produced by the operator himself. Where records are kept by the operator, data will normally be taken directly from them, but only after checking the recording system for accuracy and reliability.

Data collection will consist primarily of repeated visits with the operators of sample vehicles. Project personnel will visit each operator at least once per month to complete a set of forms designed to obtain all the information shown in Table 7 for "Interviews - Vehicle Operator's Records."

Often during the regular data collection phase the operator's goodwill will be tested to the utmost by requests for "this document," "that ledger," "those invoices," etc. Tact and patience will be required from the field team to avoid pushing too far on the one hand and to recognize on the other, the appropriate moments to make requests.

In survey terminology the field personnel must be extremely skilled at building and maintaining "rapport" with the operators, since the nature of the data sought, as well as the number of visits required for collection, will require such skills.

In addition to the vehicle operators, information will be sought from a variety of other sources. These include vehicle and tyre distributors, repair shops, NTC (National Highway Freight Transportation Association - Associação Nacional de Empresas de Transporte Rodoviário de Carga), DNER and DER's.

Physical measurements of roughness, and vertical and horizontal geometry, are extremely important to the road user costs surveys and are covered in detail in Chapter 6.

Table 7 summarizes the variables for which data will be collected and identifies for each the sources which the research team will access to obtain the data.

Consultation - Survey Design Experts

Several experts have been contacted to assist the survey team in the design and development of the survey. Presently, Mr. Paul Moore, formerly of Research Triangle Institute (RTI) and now a sampling statistician for USAID with Instituto Brasileiro de Geografia e Estatística (IBGE) in Rio de Janeiro, is contributing time and giving useful ideas under an informal exchange agreements with TRDF.

In late December 1975, Messrs. Wyatt, Odilon, Hudson and

TABLE 7 - DATA COLLECTION ITEMS AND SOURCES

Item / Source	Independent Variables	Dependent Variables	Other information
Interviews - Vehicle Operator's Records	1. Age of Vehicle 2. Payloads, Freight and Passengers 3. Distance Travelled 4. Time Spent on Route 5. Number of Stops on Route and Time Loading and Unloading 6. Traffic Delays and Congestion 7. Vehicle Speed	Consumption & Cost of - 1. Fuel 2. Oil and Greese 3. Tyres 4. Maintenance Parts 5. Maintenance Labour 6. Accident Costs 7. Crew Time	1. Fleet Size 2. Nature of Business 3. Bus Tariffs 4. Haulage Rates 5. Vehicle Specifications 6. Other backgroung, e. g. growth, 7. Labour Hourly Rates
Physical Measurements Mays Meter Inclinometer Traffic Counters Maps	1. Traffic Volume and Composition 2. Road Surface Type 3. Roughness 4. Vertical Geometry Meters of Rise and Fall by Surface Type 5. Horizontal Geometry Degrees of Curvature by Surface Type		(Continued)

TABLE 7 - (Continued)

Item / Source	Independent Variables	Dependent Variables	Other Information
Other Sources - DNER DER's Vehicle Distributors Repair Shops Tyre Distributors IPR NTC	1. Traffic Volume and Composition 2. Bus Passenger Counts	1. Depreciation from Interviews and Delphi Surveys 2. Parts and Labour Costs	1. Blading frequencies for unpaved routes 2. Taxes and Duties on Fuel, Tyres, Spare Parts.

Moser, of the project staff, and Professor Anderson, consultant, spent four days discussing with Mr. Moore possible approaches for the survey. Other meeting and telephone conversations have taken place since that time and additional working sessions are planned.

In addition, Dr. Wade Clifton joined the staff in early February and has begun a study of the problems. Dr. Clifton, a survey research economist from University of Texas, will remain to assist the staff here until mid-April and can be available subsequently. Prior to that time, Professors A. A. Walters and Cheshire, consultants to the World Bank and Dr. Rob Harrison of the University of Aston in Birmingham, England, will arrive for discussions in late March 1976 to assist with finalizing the survey designs.

Pre-Pilot Studies

In order to obtain necessary information for planning the Surveys, pre-pilot and pilot study activities were planned in December 1975. A list of the tasks for these studies is given below. These are followed by the preliminary survey designs for buses, trucks, utility vehicles, and cars.

Pre-Pilot Study Tasks October 1975 - February 1976

1) Interview fleet owners, NTC, vehicle distributors and "autônomos" unions to obtain background information on a) vehicle types, b) operating costs, c) the structure of the bus and freight industry, and d) trends in the industry;
2) Contact others likely to have an interest in the survey: IBGE and Instituto de Pesquisas Rodoviárias (IPR);
3) Obtain vehicle population data from various agencies including DNER, DER-GO, SUTEG, DER-MG, DER-DF, SERPRO headquarters and regional offices, and NTC;
4) Visit DNER, DER-GO, DER-MG and DER-DF for information on characteristics of selected routes;
5) Appraise the data collection problems likely to be encountered from further interviews with vehicle owners;

6) Design and pre-test the data collection documents.

Tasks 1-5 have been completed except for item 3 where negotiations are currently in progress with SERPRO to supply TRU records of vehicle population, fleet sizes and addresses of owners in Minas Gerais, Goiâs and the Federal District. Task 6, the initial design of the documents has been completed (see Figures 7, 8, and 9) and pre-testing will commence on 9th March in a short data collection exercise.

Pilot Studies

The primary objective of the pilot studies as outlined below is to test the practicality of the survey designs for efficient selection of vehicles whose routes have the required discrimination in the independent variables 1) surface type, 2) roughness, 3) vertical geometry and 4) horizontal geometry. The number of companies and vehicles selected for actual data collection will be small, probably four or five companies, one or two "autônomos", and a total of 30 or 40 vehicles. Because of the short time span, 3 months, the data collected is unlikely to yield positive results for prediction equations. However the data collected will be sufficient to fulfill the second major objective, to provide the team with experience in data collection, coding and analysis, and evaluation of data collection costs, as an input to the main survey design.

Pilot Study Tasks March-June 1976

1) Assemble vehicle population data for buses, trucks, utility vehicles and cars and array with corresponding available data on route characteristics;
2) Select pilot-study participant companies in a first-stage sample (see below under section "Preliminary Survey Designs");
3) Obtain more detailed information on road characteristics for the companies' routes;
4) Select a second-stage sample of participants and check routes with the Maysmeter;

CONTROLE MENSAL DE DESPESAS

MÊS ___ ANO ___

NOME DA EMPRESA

VEÍCULO NÚMERO — MARCA

TIPO DO VEÍCULO — MODELO

PLACA — ANO FABRICAÇÃO

ROTA USADA — CÓDIGO

CONSUMO DE COMBUSTIVEL

VELOCÍMETRO	DIA	CONSUMO		VELOCÍMETRO	DIA	CONSUMO	
		LTS	Cr $			LTS	Cr $
					TOTAIS		

ÓLEO DO MOTOR

VELOCÍMETRO	DIA	CONSUMO		VELOCÍMETRO	DIA	CONSUMO	
		LTS	Cr $			LTS	Cr $
					TOTAIS		

GRAXAS

VELOCÍMETRO	DIA	CONSUMO	
		KG	Cr $
	TOTAIS		

OBSERVAÇÕES

OUTROS ÓLEOS

ABREV. ÓLEO	VELOCÍMETRO	DIA	CONSUMO	
			LTS	Cr $
		TOTAIS		

Figure 7 Data Collection Document for Fuel, Oil and Grease. Note. Actual Size is 18 x 28 cm.

CONTROLE DE PNEUS

NOME DA EMPRESA: ______________________ MÊS: ______ ANO: ______

VEÍCULO Nº: ______________ PLACA: ______________ MARCA: ______________

TIPO DO VEÍCULO: ______________ MODELO: ______________ ANO FABRICACÃO: ______________

ROTA USADA:

NÚMERO	ESTADO DO PNEU	INSTALAÇÃO		RETIRADA		OBSERVAÇÕES
		VELOCÍMETRO	DATA	VELOCÍMETRO	DATA	

CÓDIGOS:

ESTADO DO PNEU
- NOVO
- RECAPADO

OBSERVAÇÕES
- PARA OUTRO VEÍCULO
- PARA RECAPAGEM
- INUTILIZADO

Figure 8 Data Collection Document for Tyres Note.
Actual size is 21 cm x 26 cm.

CONTROLE DE SERVIÇO DE OFICINA

NOME DA EMPRESA | MÊS | ANO
VEÍCULO NÚMERO | MARCA | PLACA
TIPO DO VEÍCULO | MODELO | ANO FABRICAÇÃO
ROTA USADA | CÓDIGO

VELOCÍMETRO	DIA	CAUSA DO SERVIÇO	CÓDIGO SERVIÇO	REFERÊNCIA	MÃO DE OBRA		VALOR PEÇAS	CUSTO TOTAL
					Nº HORAS	Cr $		
				TOTAIS				

OBSERVAÇÕES

Figure 9 Data Collection Document for Maintenance Parts and Labour.
Note. Actual Size is 17 x 29 cm.

5) Conduct initial interviews on routes, vehicles and records available;
6) Arrange programme of visits and commence data collection;
7) Code data inputs;
8) Develop specifications for output programmes;
9) Analyze data;
10) Conduct progress checks and monitor data collection costs;
11) Develop pilot study report including final proposals on survey design.

PRELIMINARY SURVEY DESIGNS

The States of Goiás and Minas Gerais together have a population of approximately 3,455 intercity buses, owned by 375 companies and operating on 1,300 lines, totalling about 100,000 kilometers in route length (Ref. DER-GO and DER-MG). The distribution of bus company fleet sizes is shown in Figures 10 and 11. In addition, there are approximately 2,500 buses operating on urban routes which will not be considered for purposes of this study. In these two states there are also 258,000 cars, 98,100 utility vehicles, and 48,500 trucks (Ref. 16).

Given vehicle populations of these sizes, which for all classes represent about 10% of the Brazilian total, we hope to be able to locate sufficient numbers of vehicles operating on extreme route conditions.

Preliminary Survey Design - Buses

There is a probability that if a company has a large number of routes then for operational reasons the buses will change routes quite frequently. In general, the larger the number of routes and buses, the greater the likelihood of frequent route changes for any vehicle. This mixing of the effects of route characteristics will make it difficult to find vehicles operating consistently under extreme route conditions of roughness or geometry during the 30-month data collection period. Therefore companies will be stratified on programme of roughness measurements. Additional companies will be selected if the initial sample routes do not adequately cover the expected range of roughness.

A final selection of buses will be made by contacting the companies to request their cooperation in data collection. An initial questionnaire will be completed to check route data, and compile details of each fleet, checking vehicle age spectra. Companies will be oversampled to allow for non-cooperation, or inadequate cost records, and vehicles over-sampled to allow for accidents and vehicle disposals.

Preliminary Survey Design - Trucks, Utility Vehicles, and Cars

Unlike buses, where much useful information has been made available from the records of DNER and other agencies, far less initial information is available for trucks, utility vehicles and cars. While most buses, or bus companies, have defined routes, the majority of trucks, utilities, and cars, do not. Furthermore, no published information is available on those who may operate regular trips on defined routes. Thus the task of finding vehicles traversing mostly routes of a homogeneous nature becomes difficult.

Geographic stratification will be used to classify road usage as mostly paved, unpaved or mixed. Centers of population will be classified by size, and grouped in a number of geographic areas according to distance from the main paved road networks. Large population centers are normally closer to paved roads. However a number of towns in northern Minas Gerais have already been noted which are up to 200 km from the nearest paved roads. Four centres of between 5 and 10 thousand people and one between 10 and 50 thousand have been identified.

Estimates based on vehicle ownership (see Table 8) indicate perhaps 500 cars, 250 utilities, 40 buses and 130 trucks as the vehicle universe in this "mostly unpaved" region.

A register of the vehicle universe, at least for the main study area, is considered essential and is being obtained through DNER, from TRU records held by SERPRO on magnetic tapes. From the TRU records, owners names and

TABLE 8 - VEHICLE OWNERSHIP

VEHICLE PER 1,000 OF POPULATION					
	GOIÁS	MINAS GERAIS	FEDERAL DISTRICT	BRASIL	KENYA
CARS	12.9	17.0	73.0	31.0	6.4
UTILITIES	5.4	6.4	13.4	8.4	4.1
BUSES	0.25	0.45	1.5	0.55	0.30
TRUCKS	2.1	3.3	3.9	4.8	1.6

Notes:

1) Vehicle figures TRU 1974. Population figures for Brazil from the 1970 census plus 10%.

2) Kenya population estimated as 10 million. Vehicles figures for 1973 from TRRL Report 672.

3) Cars - Compare:

Western Europe - 1970, 228 per 1000
U.S.A. - 1970, 434 per 1000

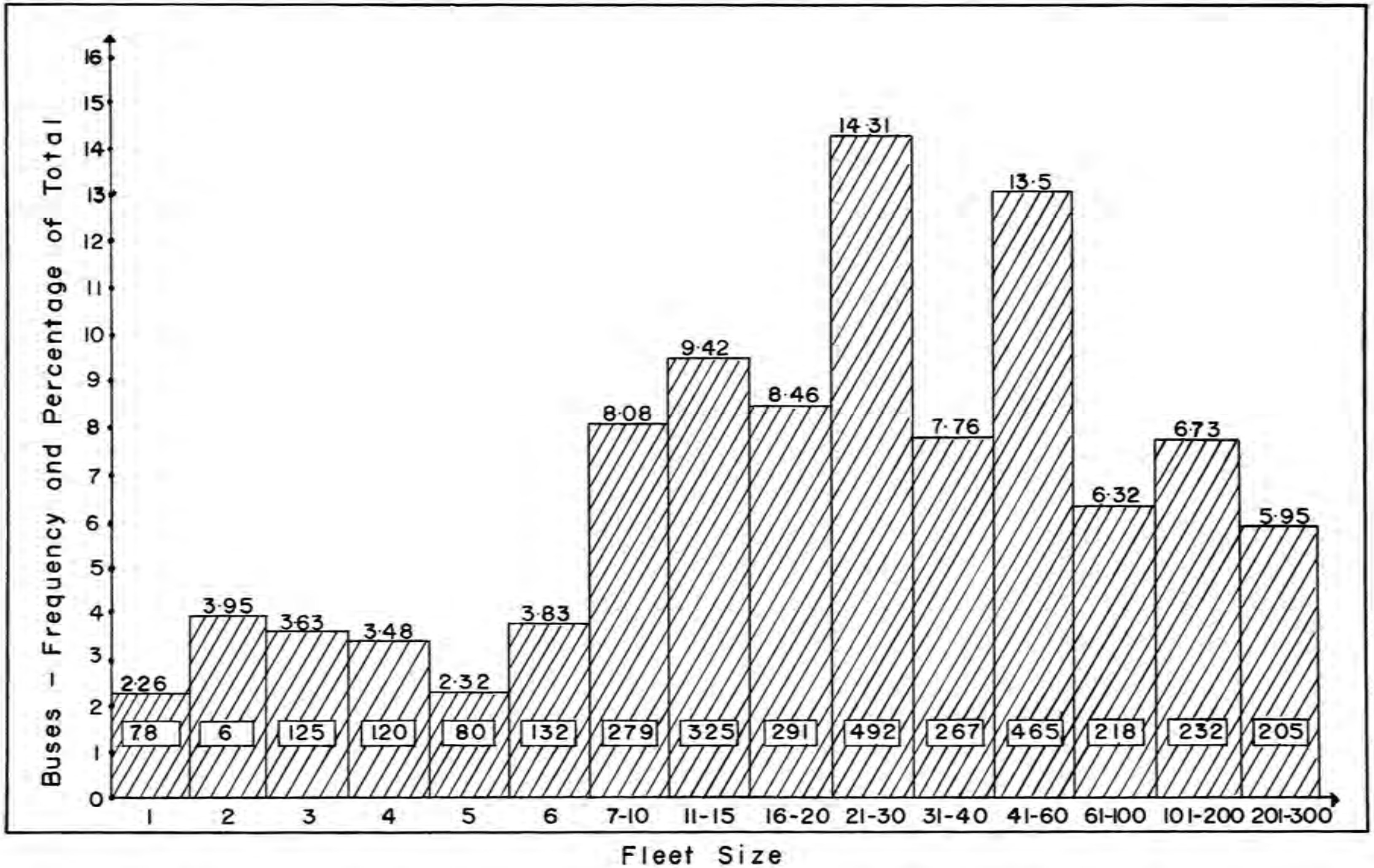

Figure 10 - Percentage and Frequency Distribution of Bus and Fleet Size for Intermunicipal Companies in the States of Goiás and Minas Gerais.

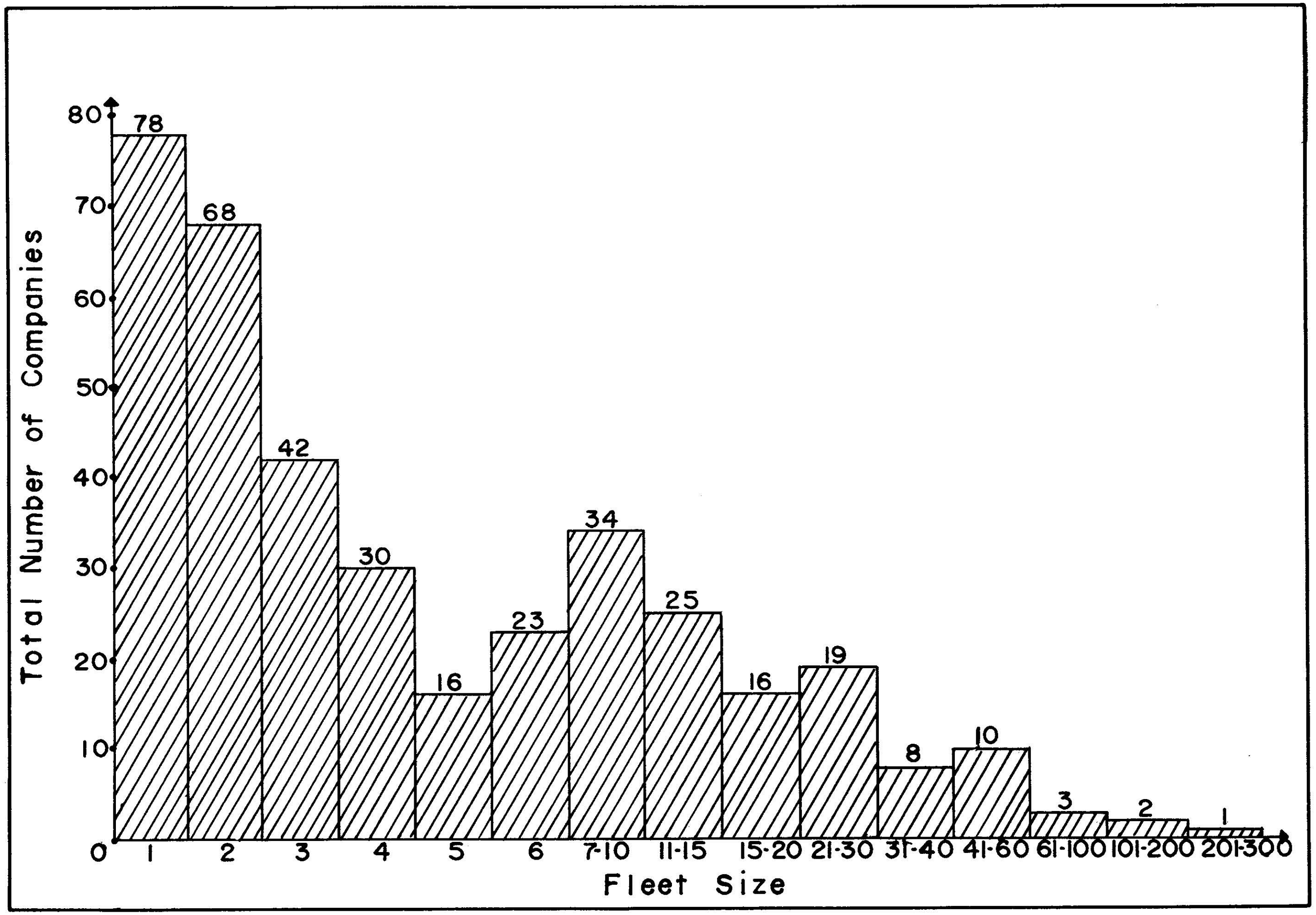

Figure 11 - Frequency Distribution of Fleet Sizes for Interminucipal Bus Companies in the States of Goiâs and Minas Gerais.

the basis of whether their routes in general are "mostly paved", "mixed", or "mostly unpaved". The total length of each route will be divided into paved and unpaved. These totals will be summed for all routes and the total route length of each company expressed as total kilometers and percentage unpaved. Paved and unpaved sections of each route will be multiplied by trip frequency (number of buses per week) and the totals of paved and unpaved for all routes summed again. The total vehicle distance travelled will be expressed as total kilometers and percentage unpaved. This may be a more useful figure than total route length since it characterizes the average amounts of paved and unpaved travel for any vehicle. We can now stratify each company into "mostly paved," "mixed" and "mostly unpaved" on the basis of vehicle distance travelled.

The companies will be stratified based on operating locations into geographic regions characterized as mostly hilly or mostly flat, so that the first stage of sampling will have a better chance of including hilly and flat routes. The proposed strata are shown in Figure 12.

From each stratum a sample of companies will be chosen, taking medium or larger companies where possible. This will be done to obtain as many buses as possible on different route types and to reduce the number of companies to be visited during the pilot survey. A higher proportion of companies will be selected from the "mostly paved" and "mostly unpaved" strata since they represent the extreme characteristics of the routes.

The actual hilliness of the routes of each company chosen will be investigated in detail, from road profiles where available or from the 40-metre interval contour maps. The sample companies will then be stratified on the basis of "steep," "medium" or "flat" routes. At this stage a check will be made to ensure that an adequate range of vertical geometry has been obtained. The strata are illustrated in Figure 13. An initial sample of unpaved routes will be measured in different geographic areas using the Maysmeter, prior to the full

Geographic Areas		Mostly Paved		Middle		Mostly Unpaved	
		Companies	Nº of Buses	Companies	Nº of Buses	Companies	Nº of Buses
	Mostly Flat						
	Middle						
	Mostly Hilly						

Figure 12 - 1st Stratification of Bus Companies by Vehicle Miles of Travel and Geographic Area.

Vertical Geometry of Routes		Mostly paved		Middle		Mostly unpaved	
		Companies	Nº of Buses	Companies	Nº of Buses	Companies	Nº of Buses
	Flat						
	Medium						
	Steep						

Figure 13 - 2nd Stratification of Bus Companies by Vehicles Miles of Travel and Measured Vertical-Geometry.

addresses and vehicle fleet details being stratified into "mostly unpaved," "mostly paved" and "mixed" regions.

Fleet Size Stratification - The maintenance policies and thus total operating costs of the"autônomo" class and large companies ("empresas") may be significantly different regardless of what type of roads they use. Therefore although from previous experience it seems easier to collect data from large companies, for prediction purposes"autônomos" should be included. However, from a sample of about 200 roadside interviews undertaken by DNER in Goiãs it appears that the overhelming majority of "autônomos" routes cover very large areas of Brazil and are of such a mixed character as to make them useless for survey purposes. A very small percentage of the sample appeared to operate regularly on the same routes for short periods. It is probable that such operators have sub-contract agreements with large companies and thus information about"autônomos" on regular routes may best be obtained from large companies.

Initially 6 strata will be identified, except for cars, where there is no fleet size distinction.

1. Empresas - Mostly Paved
2. Autônomos - Mostly Paved
3. Empresas - Mixed Routes
4. Autônomos - Mixed Routes
5. Empresas - Mostly Unpaved
6. Autônomos - Mostly Unpaved

From these strata, samples will be chosen. The extremes will be oversampled particularly on "mostly unpaved," where both fleet sizes and the range of vehicle types are likely to be smaller. At this first stage we will ensure that vehicle classes and types are covered.

Direct Contact with Owners - Unlike the bus survey, no information about routes is known. Therefore the sample owners will be interviewd using a questionnaire. They will be asked to give details of vehicles routes and frequency of use, and to give ratings along a scale for roughness, hilliness, and curviness. The questionnaire will assist in giving owners a feeling that their opinion is worthwhile and may encourage a willingness to cooperate in the research when subsequent contacts are made for data collection.

Second-State Sample - From the analysis of the questionnaire a second-stage sample will be taken, stratified by route classification. It is likely at this point that some owners may change from the strata in the first-stage, geographic stratification. This is more likely for long distance operators. In any event long distance routes may be dropped because of measurement difficulties and because they are far less likely to be of a homogeneous nature.

Final Sample - Based on the previous stratification and the questionnaire results, final sampling would proceed in the same way as for buses. Many trucks may have routes in common with buses so that information from route measurements with the Maysmeter may be available, together with additional measurements taken as required.

SAMPLE DESIGN - DISCUSSION OF ALTERNATIVE SAMPLING APPROACHES

Any survey effort consists of five sequential phases: 1) sampling selection; 2) questionnaire design; 3) field work; 4) coding; 5) analysis. This effort is still on phases 1 & 2. Decisions made at each phase limit the options at all future phases, so the analysis required must be anticipated before making decisions about any previous phase. This is now being done on this Project. Presently a choice must be made between alternative sampling techniques, and the choice has serious implications for future analysis plans. Although many sample designs are possible, preliminary calculations and discussions have focused attention on three alternatives: 1) a probability sample of vehicles; 2) a quota sample of vehicle-route patterns; 3) a combination of these two. Below is a cursory discussion of each with the major attendant implications described briefly.

However, one central point needs to be understood. There is no such thing as one "best" sampling design unless the study has one single objective. If the study has multiple objectives, as most do, then value judgements must be made about what weight to attach to each objective. The design effect (DEFF) is a measure of the increase in sampling error obtained in a particular type of sample over and above that obtained from a simple random sample (SRS) of equal size. Simple random samples set the standard for excellence in samples, but they are almost always too expensive to conduct. Clustered samples, are vastly more economical to draw and to use.

It is possible to calculate, <u>post hoc</u>, the sampling error (and hence the DEFF) for any variable obtained in a probabilistic sample. Such DEFFs have been known to range from 1.04 (very good) to 18.0 (very bad) for different variables within the same study. In this case, the first variable was the most important variable in the study, and the sample was designed to minimize its variance. It succeeded, but obviously at the expense of some of the other variables. The point of this discussion is to give some content to the statement that there is no such thing as one "best" sample design unless the study has a single objective.

What is needed in this study, then, is the establishment of a hierarchy of objectives. The overall objectives of the road user cost survey are given and discussed in the second section of this chapter under OBJECTIVES AND SCOPE. They are multiple. One class of objectives - those involving the estimation or validation of costs for such items as fuel, oil, tyres, etc.-is in conflict with another, establishing the relationships of the various components of vehicle operating costs to the main road design variables.

It is in this context that the following alternatives should be reviewed and considered.

<u>Probability Sample of Vehicles</u>

A probability sample of vehicles is the most conventional approach. A sampling frame is available from Serviço de Processamento de Dados (SERPRO) in the form of a computer tape listing all vehicles which have paid their Road Tax (Taxa Rodoviária Única - TRU) for 1975. There are uncertainties concerning physical access to the tapes and processing them, but these problems can be resolved. This type of information provides an excellent sampling frame permitting stratification of the vehicles by age or type of vehicle, geographic area, number of vehicles owned by the potential respondent, etc.

If a sample of vehicles were drawn from this frame and interviews taken with their owners, it would yield a representative sample of all the vehicles registered in any state. To increase the efficiency of the data collection effort, owners of multiple vehicles could be oversampled; or buses and trucks could be oversampled; or clusters of vehicles could be selected from a geographically-ordered list to prevent their being thinly spread all over the 2-state area.

Such a sample would provide excellent population estimates of all variables measured with easily calculated confidence intervals. It is not clear whether it would provide a very useful estimation of the impact of road types on vehicle operating costs, however. This depends upon the distribution of vehicle travel among road types. If the sample vehicles are fairly similarly distributed in their travel over all the different road types, then little can be learned from them about the impact of road type on operating costs. For example, if all vehicles did half their travel on flat, smooth, straight, paved roads, then one could never learn anything about the impact of such roads on vehicle operating costs. If some spent a great deal more and others a great deal less on such roads, then there is a good chance of relating variations in their operating costs to variation in the types of roads they operate on.

A major problem with using such a sample is the unknown but probably unsurmountable difficulty of sending project measurement vehicles over all the routes that a representative sample of vehicles would travel. Measures of roughness, horizontal and vertical geometry are needed, and surface type for all roads travelled on by all vehicles in the sample if these road characteristics are to be used to explain varia - tions in vehicle operating costs.

A sampling approach seems ideal for providing estimates of vehicle operating costs. It is not attractive for estimating the impact of road characteristics on vehicle operating costs.

Quota Sample of Vehicles

A quota sample of vehicles with fixed, homogeneous routes is the most efficient way to estimate the impact of road characteristics on vehicle operating costs. Before defining the cells, each of which will be assigned a quota of vehicle owners, it will be helpful to review the condition under which quota samples can be useful. If enough is known about the dependent variable of interest to specify all its major determinants and if one knows how these determinants are distributed throughout the population and can classify a potential respondent readily on these major determinants, then quota sampling may be useful. It can only be useful in terms of predicting the dependent variable, and never allows one to put confidence intervals around his predicted value for that variable. Since not every element in the population being "represented" by the sample has known, non-zero proba- bility of selection, the quota sample doesn't even meet the minimum requirements for a probability sample. One searches until he fills his quota for a cell, then accepts no more respondents in that cell Order of encounter determines probability of selection, and that probability drops from 1 to zero when the cell is filled.

Quota sampling is normally used only in political polling and marketing research but it provides a way here of filling the cells of an experimental design which was developed to estimate the impact of road characteristics on vehicle operating costs, and yields the additional benefit of allowing us to accept into our sample only those vehicles which operate on fixed as well as homogeneous routes. This option to exclude vehicles which run all over the country virtually guarantees the ability to send project survey vehicles to measure all the roads used by sample vehicles, thus ensuring a full complement of the major independent variables whose effects on operating costs are the purpose of the user costs survey.

By giving up legitimate probabilistic estimates of the population characteristics, one gains the kind and quantity of data he must have to use the experimental design developed to test the impact of road characteristics on vehicle operating costs. Essentially, while enough may not be known to satisfy all the criteria for using a quota sample, if the assumption that vehicle operating costs depend upon road characteristics is not borne out by the data collected to measure the nature of this dependency, then we know the assumption was wrong. If the data do show a dependency, then measures of how much and in what way each road characteristics determines user costs will emerge from the analysis which shows the dependency.

The cells will be defined by the intersection of five vehicle types with sixteen road types. Eighty cells will be defined by such intersections, but some of these cells may not exist in the real world. If no vehicles can be found operating on mainly "rough-paved-straight-hilly" routes, then that cell's allocation of sample cases will be redistributed among the other cells.

Before moving on to the third alternative, it should be emphasized that we do not now know enough about how vehicle travel is distributed across all the road types to apply weights to the vehicle operating cost estimates obtained from all the cells and obtain a weighted estimate of the population mean for vehicle operating costs. We do not know enough about our study population to follow the lead of the political pollsters in this technique. Using a quota sample means giving up good estimates of the mean vehicle operating costs in favor of better estimates of the impact of road characteristics on these costs. It is a clear, but not a simple choice.

A Mixed Sample

The third alternative is a mixture of the previous two. Actually, it is simply combining a smaller version of the probability sample and a smaller version of the quota sample. It is an awkward compromise, but if population estimates are necessary and measuring the impact of road characteristics upon vehicle operating costs is vital, then some such compromise may be necessary.

Other Considerations

Quota samples don't provide reliable estimates of population means or distributions. Further, studying only vehicles which operate on fixed homogeneous routes, may bias the findings. Speculation about the nature and direction of such biases can be raised, but without a probability sample, nothing can really be known about them.

Consider driver behaviour. On a very familiar route it's surely different from what it would be on an unfamiliar one. Selecting vehicles operating on fixed routes may minimize the impact of surface roughness on vehicle repair costs if, for example, the driver who makes his route daily learns exactly where major bumps in the road are and avoids them.

Cumulative impact of certain kinds of stress on vehicles, if it exists, will work to bias the results in the opposite direction. One can hypothesize, for example, that the suspension system of a vehicle doesn't begin to suffer from road roughness until the shock absorbers have worn out. For the vehicle subjected to rough roads infrequently, its engine, brakes, drive train and other parts may wear out before its frame suffers any damage from its infrequent encounters with rough roads. For the vehicle which runs every day on rough roads, the suspension system may be the first part of the vehicle to need repairs. Parallel arguments could be made for the impact of other road characteristics on other vehicle parts.

But this may not be misleading. If the model is developed and implemented, the kinds of roads found most efficient in the model will, over time, become more and more common. Thus vehicle exposure to these kinds of roads will grow, and it is probably just as well to start with a measure of impact under conditions of extreme exposure.

In conclusion, the decision between quota sampling and probability sampling must be a value judgement about what the most important goals of the study are. It might be better not to think of quota sampling as sampling at all. Just calling it a process of finding real world examples of vehicle use sufficiently homogeneous to fill cells in an experimental design might be a better description. Quota sampling is a term which is almost pejorative among sampling experts, and it promises more of the benefits of probability sampling than it delivers to the uninitiated. Nevertheless, it is an accurate and brief description of one option.

WORK PLAN AND SCHEDULE

The work plan shown in Figure 14 divides the road user costs surveys into 18 separate activities within the 3 1/2 year period of the project.

In late 1978 a final report will be prepared for this study; however it is proposed that survey activities should continue in some form to provide additional long term verification of the results.

Referring to the schedule, there are some major milestone dates which mark the start or end of key activities.

1) June 1976 marks the end of pre-pilot and pilot studies and finalization of survey design and methodology;
2) In July 1976 the main survey is initiated along with data analysis;
3) In December 1976 the build up to full survey size will be completed;
4) January 1977 marks the completion of initial measurements of vehicle routes and when full definition of the range of route characteristics can be made;
5) July 1978 shows the commencement of final data analysis phase;
6) The Final Report is due in late 1978.

TASK NUMBER	ACTIVITY
01	Obtain vehicle user information to guide the selection of survey participants and to establish user population statistics
02	Interview selected users & identify the vehicles, the amount of travel & vehicle routings for all potential survey participants
03	Contact vehicle manufacturers to develop replacement frequency information on vehicle parts
04	Establish the information required from the user survey participants, draft & print recording documents
05	Select tentative pilot study participants and routes based on surface type travel and check geometry of routes before finalyzing pilot study participants
06	Draft specifications for computer programs to summarize user survey data
07	Implement the pilot study for the user survey and debug the data collection process during the initial phase
08	Visit pilot study participants at intervals to collect data
09	Identify companies having effective operational cost control and collect their historical data including tachographic data when available for comparison with user survey data
10	Test procedures for obtaining geometric & roughness information using pilot routes
11	Evaluate and revise user survey procedures based on a review of pilot study procedures, data forms, computer summaries & the results of the factorial analysis on the pilot data
12	Establish the final user survey design & develop an implementation schedule
13	Contact user survey participants & initiate data collection process
14	Data collection and follow up throughout the study period
15	Data Processing and Analysis
16	Develop geometric information on user routes from construction plans and field measurements
17	Obtain periodic roughness measures on user survey routes using a Mays Meter
18	FINAL ANALYSIS & REPORT PREPARATION

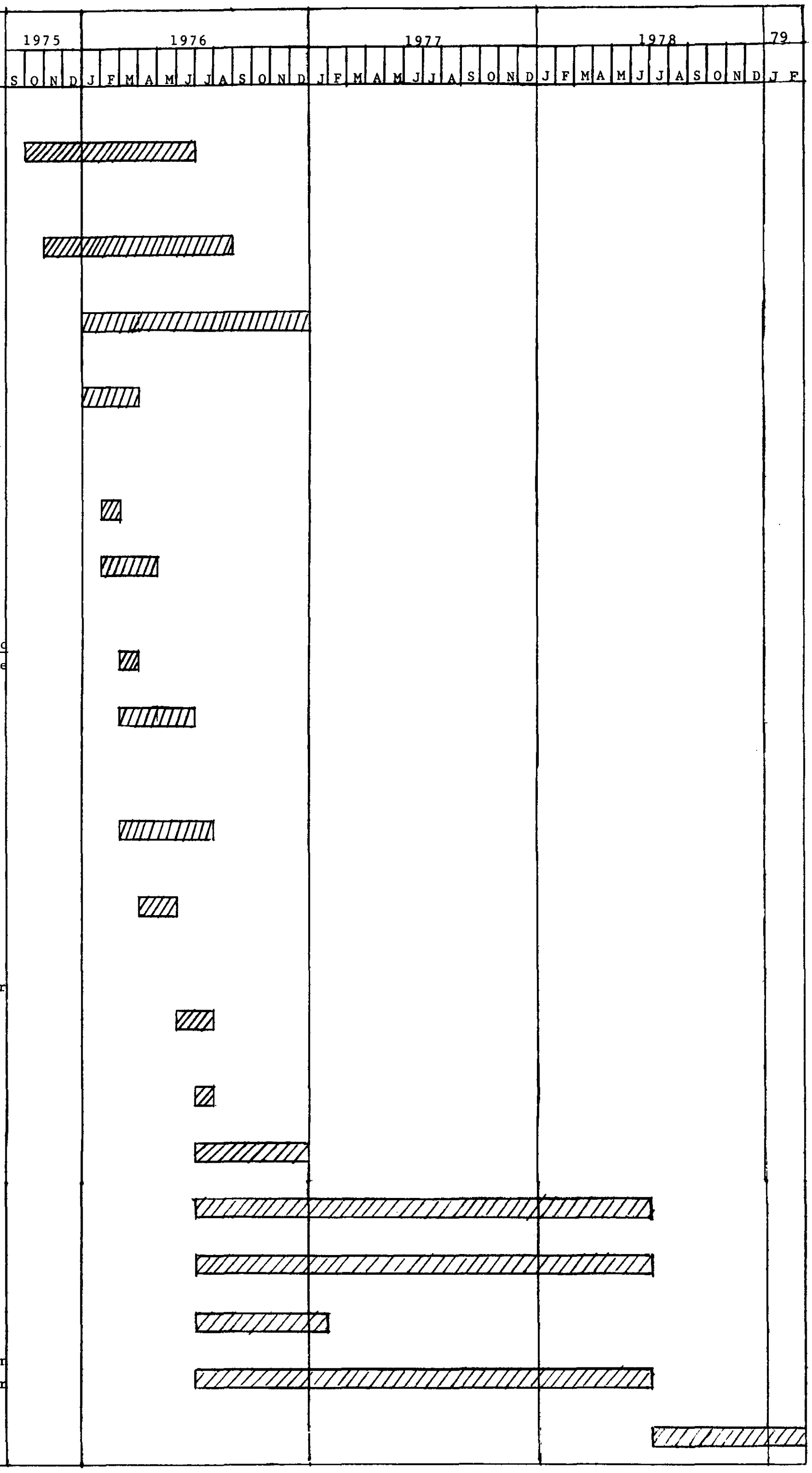

Figure 14 - Road User Survey Work Plan and Schedule