CHAPTER C

ROAD USER COSTS SURVEYS

1 *OBJECTIVES*

The overall objectives of the User Costs Surveys remain those stated in the Inception Report (Ref. 1). The surveys are to establish relationships between various components of vehicle roughness and vertical and horizontal alignment, for essentially low-volume rural roads. The major components of vehicle operating costs being collected by the surveys are:

- Fuel;
- Oil;
- Tires;
- Maintenance parts;
- Labor;
- Depreciation.

The Surveys have retained the basic format developed in the Inception Report, but several refinements have been incorporated as a result of field experience, pilot studies and advice from the Expert Working Group.

The data items which will be examined to establish and corroborate the relationships between vehicle operating costs and road design variables are given in Table C.1. The table lists each data item, gives its survey number and identifies the general analytical category to which it has been assigned. Each data item collected by the User Surveys Group is identified by a unique combination of prefix and number. The prefix specifies the survey or survey area responsible for its collection, and the number locates the data item within that survey data. The prefixes are defined as MS (Main Survey), MSC (Main Survey Continuous), RS (Route Survey) and SS (Supplementary Surveys).

A majority of the surveys directly address the problem of identifying the relationship between the consumption of user cost items and road geometry and surface characteristics. It is of considerable importance for the analyst to have a good range of observations, and so a number of factorial designs have been considered to ensure that extremes would be covered by the surveys.

The route surveys have only recently generated sufficient data to give adequate descriptions of routes traveled by user vehicles. The original factorial, as shown in Table C.2. was therefore qualita-

TABLE C.1 - USER COST SURVEYS DATA ITEMS

Data Item	Survey Number	Category
Fuel	MSC 1	Dependent Variables
Oil and Grease	MSC 2	
Tire Life	MSC 3	
Tire Tread Measurements	SS 1	
Maintenance Parts	MSC 4	
Maintenance Labor	MSC 5	
Maintenance Standard Labor Hours	SS 2	
Accident Costs	MSC 6	
Crew Time	MSC 7	
Depreciation	MS 1	
Age	MS 2	Independent Variables: Vehicle
Payloads, Freight and Passengers	MSC 8 SS 3	
Distance Travelled	MSC 9	
Time Spent on Route	MSC 7	
Number of Stops, Loading and Unloading	MSC 10 MSC 7	
Vehicle Speed	MSC 9	
Vehicle Specifications	MS 3	
Pavement Type	RS 1 MS 4	Independent Variables: Route
Roughness	RS 2	
Vertical Geometry	RS 3	
Horizontal Geometry	RS 4	
Pavement Width	RS 5	
Land Use	RS 6	
Traffic Vol/Composition	SS 4	Additional Factors/ Variables
Tacograph Studies	SS 5	
Taxes and Duties	SS 6	
Inflation Indices	SS 7	
Labor Rates	SS 8	
Bus Tariffs	SS 9	
Haulage Rates	SS 10	
Fleet Size	MS 5	
Nature of Business	MS 6	

TABLE C.2 - QUALITATIVE FACTORIAL DESIGN FOR MAIN SURVEY

	Paved	Mixed	Unpaved
Flat			
Rolling			
Hilly			

tive in nature. The preliminary analysis has enabled us to produce a quantitative factorial, shown in Table C.3, which will be tested over the next three months by positioning all surveyed routes into appropriate cells and evaluating the dispersion.

2 *ORGANIZATION*

The organization of the User Surveys Group is designed to perform two major activities:

- Collection of vehicle cost data;
- Measurement of route characteristics.

These are completely different in terms of methodology, techniques, equipment, management and personnel. However, in terms of the Group's primary objectives, these activities must be closely coordinated from the stage of initial data collection until the final analysis.

The organization chart shown in Figure 7 presents the structure and current staffing of the group. As indicated, vehicle-cost data collection activities are split into two main geographic areas:

- The Federal District, Southern Goiás, *Triângulo Mineiro* and Mato Grosso, with researchers based in Goiânia and Brasília; and

- Minas Gerais, with researchers based in the DER-MG headquarters in Belo Horizonte.

There are several main centers of data-collection activity within both areas, where visits are made at least once per month. These are shown on the map indicating the geographical scope of the Surveys (Figure 1, chapter A).

The route survey team is in the process of measuring approximately 50,000 km of operator routes located within the survey area. The survey vehicles are instrumented, serviced and based at the GEIPOT garage and workshop. At the moment, there is no field capability to repair or calibrate survey vehicles, and any serious problems, therefore, force them to return to Brasília. It may be necessary to make some small organizational changes to support the survey programs in Mato Grosso.

TABLE C.3 - QUANTITATIVE FACTORIAL DESIGN FOR MAIN SURVEY

ROUGHNESS	HORIZONTAL	VERTICAL: FLAT <4.5	ROLLING 4.5 - 7	HILLY 7+
SMOOTH 0 - 50	0 - .3			
	.3+			
MIXED 50 - 90	0 - .3			
	.3+			
ROUGH 90+	0 - .3			
	.3+			

Units

Vertical and Horizontal = Algorithmic values
Roughness = QI counts per km.

MT-GEIPOT

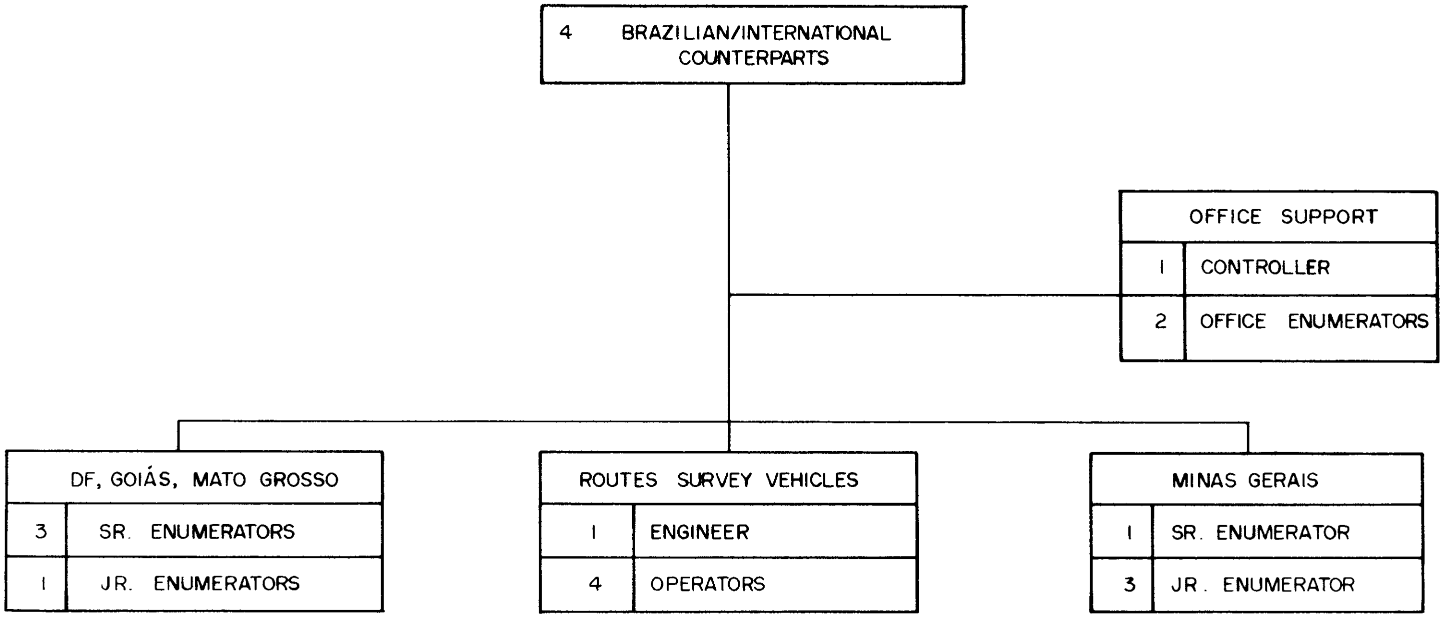

FIG. 7

USER COSTS SURVEY ORGANIZATION CHART

3 COSTS SURVEYS

No formal methodology was available for planning and managing surveys of the size and complexity planned for Brazil. There were a number of important unknown factors to address before the surveys could begin to generate good analytical data. These were:

- The response rate of vehicle operators and willingness to supply operating data;
- Availability and quality of operating data, particularly on vehicle parts consumption;
- The frequency with which vehicles remained on known routes;
- The position of these routes in the fatorial of road characteristics.

Vehicle operators were interviewed to gain information on the response rates, data quality and type of routes likely to be identified by the Surveys. Pilot studies were conducted to test vehicle selection, with respect to route type, data collection, documentation, computer coding and analysis procedures, assess data collection costs and train field enumerators. Only recently, all these objectives have been attained, together with the realization that good Surveys management depends on fast, summary output from the computer files.

a *Methodology*

Since the study began, a variety of data-collection documents have been tried and continued efforts made to standardize the format of the information, to expedite its transfer to computer files for analysis. This standardization has not proved possible because the record-keeping practices of companies vary tremendously. It has been necessary in almost every situation to custom design the methodology to be used for each user survey participant. This process has required the continued presence of senior survey personnel at the user's offices during the establishment of procedures and to train the field enumerator.

There are two basic approaches that have been implemented. One is to make maximum use of the companies' own records, where the field enumerator is required to tabulate data in a manner suitable for later standardization. The second approach involves self-administered questionnaires designed to generate data where records are non-existent or inadequate.

(1) *Companies' Own Records*

This method is reliable and efficient, once experience has been gained in the use and interpretation of the companies' material. The methodology has evolved through the study of photocopied company records or of information tabulated from them. The first approach involves extensive use of local photocopy shops to duplicate original company records. These are then brought to our offices and the data are transferred directly to keypunch documents by the field enumerator himself. This process requires skill and frequent assistance from senior researchers because some element of transformation is always involved. The data are normally compiled on a monthly basis by the vehicle operators, but sometimes also on a weekly basis. All photocopied records are labeled with the company's identification number and carefully preserved as original documents in the appropriate company file.

The second approach is used when photocopying is not possible. Special field forms are designed or adapted for use by the field enumerators in tabulating information from company records. This first requires a detailed examination of the various records the operator is using. A document is drawn up which very closely follows the format of the operator's own documents. It is designed to facilitate, to the maximum extent possible, the task of copying the information, on the theory that the simpler the task, the less the possibility of errors. This special field document is then returned to our offices where it is transferred to a keypunch document in the same manner as original records, and stored in the same way. This second method involves spending more time at the company's premises.

(2) *Self-administered Questionnaires*

This method has never been considered very satisfactory because:

- It presupposes inadequate records;

- The response rate is very low, with only a faithful minority continuing to fill them out;
- It is practically impossible to make cross-checks on the data, so they must be considered unreliable.

Self-administered questionnaires, mainly those distributed, to *autonomos* (owner operators), continue to be used, since this is the best method we have found to extract data from this important class. Whenever possible, the *autonomo* is persuaded to retain invoices and receipts for parts purchases, so that the information given may be checked.

b *Survey Scope and Size*

The present geographic scope of the surveys, and the main centers of data collection are shown in Figure 1. This represents an area of approximately one million square kilometers (386,000 square miles), or more than 10% of the total area of Brazil. The principal study area includes Minas Gerais, the Federal District and Goiás. Satellite studies were to be extended to other parts of Brazil, as necessary. In order to obtain a sufficient range of road geometric conditions, it was found necessary to collect data in Mato Grosso, a predominantly flat region. This area has been developed into more than a satellite study area, owing to the importance of flat routes in the survey factorial.

c *Data Collection*

In recent months, our data-collection efforts and the quality of fieldwork in general have improved considerably. This is due in large measure to further concentration on training of newly hired field enumerators, but also to the greater familiarity the users now have with the objectives and methods of the research.

Access to company records is freer now than in the early stages of full-scale field work and our people have a better idea of where to look for useful data. The users, for their part, have more confidence in our ability to interpret their material correctly.

Since the beginning of our survey effort, we have identified 66 companies and 237 *autonomos* to participate in the study. For each of these panel members we have established a file showing the member's name, address, fleet size and commercial activities, among other items needed for future evaluations of the member.

Every vehicle considered suitable for inclusion in the study, also must be appropriately identified in considerable detail and placed on file. In establishing this file it has been necessary to make repeated calls on the members. At present we have a detailed description of 1261 vehicles on this file.

A number of our members have dropped out because they have disposed of their vehicles or we have not been able to maintain their interest. Also, where it has not been possible to establish reliable data, the member has been dropped. Currently, members are being screened to see where they fall in our factorial requirements. They are being dropped when the cost involved in collecting data from them is both high and they fall in cells already covered.

As a result of dropouts or of our elimination of some participants, we now have 41 companies and 59 *autonomos*, from whom we are currently collecting data. This reflects a response rate of 62% and 25% for the companies and *autonomos*, respectively. The vehicles still included encompass 285 buses, 166 trucks and 103 cars from companies, and 67 medium and light trucks from the *autonomos*, which represent about half our current vehicle file.

A substantial amount of detailed user costs data has been collected from the survey participants. This information encompasses all of the items classified as MSC in Table C.1. Since March of 1977, a concentrated effort was made to incorporate those data into computer files, where they could be structured for analysis. In the process, it has been established that the existing data-processing system is not efficient in handling a large part of these vehicle-cost data. First, the data needed to be carefully checked for consistency and accuracy. We find that initial computer editing rejects approximately 10% of the punched cards as being in error, and manual checking is revealing many more errors. For these reasons, more pre-checking of data was indicated, and this is now being done. Early in 1977, our office staff was understrength, although this situation has now improved with the hiring of two more clerks who have now been trained. Table C.4 shows that a considerable quantity of data has accumulated in the past few months, which has not been handled satisfactorily by the existing data-processing system. It also shows that important data items, par-

TABLE C.4 - USER COST SURVEYS - PROGRESS TO AUGUST 1977

Data Items	Collected	Processed	Checked and Analyzed
	Vehicle	- Months of Data	
Fuel	7760	1840	1221
Motor Oil	7650	1750	1199
Oil changes	7650	1750	1147
Other oils	7320	1580	995
Grease	7480	1620	1029
Tire changes	6810	1340	933
Parts Costs	6550	1090	-
Labor Hours	3010	250	-
Loads	1900	1120	945

ticularly parts costs and labor hours, must be given special attention immediately. Information that is classified as collected means that it falls between being a copy of the user's documents and being coded and ready for keypunching. Processed material is keypunched and on file, but not yet rechecked and cleared for analysis. To date, only 13% of all data collected have been checked and those were the data used in the preliminary analysis. A second preliminary analysis is planned for the earliest possible date.

Nearly half of the information that must be processed is in a monthly rather than a daily form. A monthly data system has been designed which will enable the group to process these data. This system is in the final stages of programming, and it is hoped that the backlog of data will be cleared by the end of September. Shortly after that time, we will be able to access the data files to obtain details of the exact disposition of vehicle data items across the factorial cells.

In determining vehicles to be added to the survey in the future, it is now of much greater importance to consider the value of any given vehicle remaining in the survey, and the marginal value of potential new entries. To do this, we need to know, as exactly as possible, the position of the vehicles in the factorial cell design. Where cells are filled, the value of additional vehicles to the cell is negligible, as may be the value of existing vehicles in the cell if it is already overcrowded.

In contrast, the value of having vehicles in certain other cells, for example, heavy trucks on hilly, unpaved routes, will be very great, possibly more than ten times the present average data-collection cost per vehicle.

At this time, all the information we need to aid in decisions on survey membership is not yet available from the computer files, but the problem is being worked on and has been given top priority, as an essential element in guidance of future field work.

4 *ROUTE SURVEYS*

The Inception Report did not address in detail the issue of appropriate surveying procedures for user routes identified by the user costs surveys. It took over six months to develop:

- An efficient management structure for the survey team;
- The best instruments to measure highway characteristics for survey analysis;
- A numerical format for the measurement and analysis of routes;
- A training program for survey vehicle drivers and operators;
- Effective documentation for the recording and processing of route data.

The most important development was the transfer of all procedures, except vehicle servicing and instrument performance, to the User Surveys Group, making it responsible for the collection of both dependent and independent data items.

a Survey Vehicle Performance

Two fully instrumented survey vehicles with trained crews began work in December 1976, and a breakdown of performance this year is given in Table C.5. It is interesting to note that over 20% of the available time for both vehicles is spent in calibrating the Maysmeters and verifying their calibration. This highlights the importance placed on the reliability of roughness measurements in our survey program. Results to date indicate a productivity figure of appromimately 180 km of combined geometry and roughness data per working day. It is not felt that this figure will be improved, because travelling, as opposed to actually measuring, will increase as routes in Mato Grosso and southern Minas Gerais are identified.

It is estimated that since the start of the program the vehicles have measured over half of all routes giving good user-cost data, which suggests that all routes should be surveyed by May 1978.

b Data Processing

Routes identified for analysis are given a unique number and described using nodes which are three-digit numbers representing a specific geographic location. The route number and node sequence are then recorded on File 27, and an example of its output is given in Exhibit 1. No cost data are accepted unless the route codes assigned to those

TABLE C.5 - SURVEY VEHICLES ACTIVITIES JANUARY-JUNE 1977

	Vehicle 653	Vehicle 282	Both
Vehicle Repair	3	5	4
Defective DMI	2	5	3
Defective Maysmeter	15	2	9
Training Staff	0	2	1
Vehicle Maintenance	3	8	6
Adding Instruments	0	2	1
Verifying Calibration	6	12	9
Calibration Maysmeter	11	12	12
Administrative Problems	4	5	4
Total	44	53	49
Working	56	47	51

Note: Units in percentage of available time

ROTA	QUANTIDADE NOS	NOS
4176	17	305 303 316 477 326 335 329 332 333 332 329 335 326 477 316 303 305
4177	11	305 302 301 341 386 387 386 341 301 302 305
4178	15	305 302 301 327 306 307 308 334 308 307 306 327 301 302 305
4179	15	305 303 316 477 326 335 329 332 329 335 326 477 316 303 305
4180	11	305 304 319 352 320 321 320 352 319 304 305
4181	11	305 303 316 477 326 335 326 477 316 303 305
4182	13	305 302 301 341 386 387 336 387 386 341 301 302 305
4185	15	305 303 316 477 326 335 329 330 329 335 326 477 316 303 305
4186	31	305 302 301 327 328 323 324 479 561 480 481 482 398 397 396 395 396 397 398 482 481 480 561 479 324 323 328 327 301 302 305
4187	43	305 302 301 341 386 417 416 412 411 410 409 421 422 423 424 425 426 431 432 433 435 436 435 433 432 431 426 425 424 423 422 421 409 410 411 412 416 417 386 341 301 302 305
4188	15	305 304 337 344 345 346 347 484 347 346 345 344 337 304 305
4189	29	305 304 337 344 345 346 347 484 485 486 487 488 490 491 492 491 490 488 487 486 485 484 347 346 345 344 337 304 305
4191	05	323 496 497 496 323
4194	15	388 409 421 440 442 443 511 445 511 443 442 440 421 409 388
4195	13	388 409 421 440 442 506 507 506 442 440 421 409 388
4196	15	388 389 390 391 392 393 394 508 394 393 392 391 390 389 388
4197	17	388 389 390 391 392 393 394 395 396 395 394 393 392 391 390 389 388
4198	11	388 389 390 563 564 446 564 563 390 389 388
4200	13	388 409 410 411 412 414 415 414 412 411 410 409 388
4201	15	388 409 410 411 412 416 417 418 417 416 412 411 410 409 388
4202	15	388 409 410 411 412 416 418 325 418 416 412 411 410 409 388
4203	23	388 409 421 422 423 424 425 426 431 432 433 434 433 432 431 426 425 424 423 422 421 409 388
4204	15	388 409 421 422 423 424 425 426 425 424 423 422 421 409 388

EXHIBIT 1 - Example of the Route Link File

data are described on this file. Two hundred routes located in DF, Goiás and Minas Gerais are presently held on the file, and routes in Mato Grosso and southern Minas Gerais will be added in the next three months.

The geometry file* contains about 12000 km of data, and examples of the output from the vertical and horizontal link geometry program accessing this file are given in Tables C.6 and C.7. The roughness file has 14020 km of combined paved and unpaved route data, and exceeds the size of the geometry file because of replicate route sections. The file has been designed to accept replicates so that a time series analysis can be conducted on unpaved routes to capture the range of roughness and ensure more accurate independent data for analysis. This replicate program is scheduled to start in 1978, after all routes have been surveyed once for geometry and roughness data.

c *Roughness and Geometry Algorithms*

Survey vehicles produce a flow of data on geometry and roughness characteristics which must be transformed into a single route statistic for each independent variable. Each statistic must produce a suitable range for analysis and at the same time preserve the key characteristics of the variable being measured. Small but very rough sections, for example, within a moderately rough route need to be captured by the statistic so that the full impact of roughness on user costs is retained for analysis.

Geometry and roughness algorithms were developed as initial attempts to quantify these important route variables. Output from the geometry algorithms, by link, are given in Exhibit 2 and links are combined into appropriate routes for analysis. A priori, a link with a steep positive grade in one direction and therefore a steep negative grade in the other, should impose different costs on a vehicle, depending on its direction of travel. The geometry statistics for each link produced by the algorithm reflects the direction of travel of any vehicle by following its route description on the route file. We believe this represents an improvement over the rise-plus-fall statistic.

Roughness output shown in Exhibit 3 is part of the program to calculate this independent statistic. It can be seen that sections or bands of roughness within a link are calculated, where roughness is not uni-

*The current status of route files is given in Table C.8

TABLE C.6 - OUTPUT FROM LINK GEOMETRY FILE: VERTICAL DATA

LINK 260292

NUMERO DO GREIDE	COMPRIMENTO METROS	VALOR DO GREIDE
1	270	4.0 %
2	720	-5.0 %
3	530	6.0 %
4	290	-1.0 %
5	790	-2.0 %
6	470	-4.0 %
7	740	6.0 %
8	590	1.0 %
9	510	-2.0 %
10	520	-6.0 %
11	770	5.0 %
12	1190	-2.0 %
13	570	-5.0 %
14	930	6.0 %
15	1050	1.0 %
16	740	3.0 %
17	610	-3.0 %
18	1110	0.0 %
19	1350	-5.0 %
20	470	5.0 %
21	540	-1.0 %
22	610	3.0 %
23	630	-5.0 %
24	420	2.0 %
25	480	-4.0 %
26	420	4.0 %
27	890	-2.0 %
28	500	2.0 %
29	510	1.0 %

TABLE C.7 - OUTPUT FROM LINK GEOMETRY FILE: HORIZONTAL DATA

LINK 260292

NUMERO DA SECAO	TIPO DA SECAO	RAIO (METROS)	ANGULO SUBTENDIDO	DIRECAO	COMPRIMENTO (METROS)	PAVIMENTO
1	T				1570	P
2	C	720	23	E	290	P
3	T				790	P
4	C	700	38	D	470	P
5	T				430	P
6	C	630	28	E	310	P
7	T				3680	P
8	C	850	12	D	180	P
9	T				5760	P
10	C	1140	9	E	180	P
11	T				1250	P
12	C	600	20	E	210	P
13	T				160	P
14	C	550	38	E	370	P
15	T				600	P
16	C	550	33	D	320	P
17	T				1210	P
18	C	1030	5	E	90	P
19	T				790	P
20	C	1140	10	D	200	P
21	T				510	P

LINK	% PAV	CLASS 1 NUMERATOR HORIZONTAL	VERTICAL	COMPLIMENTS (KMS)
409388	1.00	12.56	105.54	18.28
388409	1.00	12.33	106.86	18.28
409421	1.00	7.66	92.37	17.77
421409	1.00	7.31	100.64	17.77
410409	1.00	1.52	21.84	3.94
409410	1.00	1.56	15.86	3.94
410420	1.00	2.76	38.62	6.53
420410	1.00	2.65	37.26	6.53
411410	1.00	13.80	149.32	30.37
410411	1.00	13.54	134.73	30.37
412411	1.00	13.84	224.45	36.11
411412	1.00	13.79	196.39	36.11
412414	1.00	6.57	143.64	17.78
414412	1.00	7.45	138.40	17.78
414415	1.00	12.25	146.30	20.91
415414	1.00	11.74	177.79	20.91
416412	1.00	4.32	52.40	10.93
412416	1.00	4.26	59.45	10.93
417416	1.00	10.78	189.23	27.36
416417	1.00	10.77	195.18	27.36
417418	1.00	12.89	111.29	20.54
418417	1.00	11.95	172.10	20.54
417419	1.00	1.06	22.93	1.72
419417	1.00	1.57	7.55	1.72
421422	1.00	3.23	34.30	6.89
422421	1.00	3.19	41.94	6.89
421440	1.00	10.62	134.08	21.84
440421	1.00	11.19	95.54	21.84
422423	1.00	6.78	52.34	11.85
423422	1.00	6.07	91.99	11.85
423424	1.00	5.55	39.00	9.13
424423	1.00	4.64	91.07	9.13
424425	1.00	6.93	108.94	17.24
425424	1.00	6.35	116.38	17.24
425426	1.00	11.31	156.12	23.34
426425	1.00	10.94	157.23	23.34
426431	1.00	14.87	198.12	23.93
431426	1.00	14.96	151.76	23.93
431430	1.00	7.58	61.23	11.67
430431	1.00	7.39	72.76	11.67
431432	1.00	5.70	52.44	8.18
432431	1.00	5.00	97.96	8.18
432433	1.00	6.19	62.60	9.83
433432	1.00	5.85	68.30	9.83
433434	1.00	3.41	29.15	7.95
434433	1.00	3.19	46.16	7.95
433435	1.00	4.21	29.21	4.76
435433	1.00	4.34	37.79	4.76
435436	1.00	7.42	51.29	12.38
436435	1.00	6.28	101.58	12.38
440441	1.00	1.06	24.57	2.37
441440	1.00	1.10	25.55	2.37

EXHIBIT 2 - Horizontal and Vertical Link Statistics Generated, in Both Directions, by the Geometry Algorithm Program for Paved and Unpaved User Routes

LINK	EST.	PROCEDENCIA	DESTINO	PAV	VEIC	DATA DE TESTE	NO. DA SECAO	IRR MEDIA CONV	DESVIO PADRAO	DISTANCIA (KMS)
							4	225	31.5	4.18
510400	MG-184	CARMO RIO CLARO	ENT CCNC APAR	P	C653	18/04/77	1	261	119.5	0.64
							2	145	47.4	0.64
							3	166	35.5	13.20
							4	254	27.0	0.64
402388	BR-167	ENT TRES PONTAS	ENT VARGINHA	P	C653	17/04/77	1	269	159.8	0.64
							2	154	17.2	3.22
							3	271	11.1	1.28
							4	188	29.1	1.61
							5	209	72.8	0.65
							6	220	26.9	0.64
							7	133	22.6	2.56
							8	216	22.6	1.28
							9	157	33.7	4.19
							10	227	66.6	0.64
							11	136	31.1	7.73
351350	BR-262	STA BARBARA	B COCAIS	P	C282	25/04/77	1	103	15.3	10.94
354356	BR-356	ENT MARIANA	ENT ALCAN	P	C282	23/04/77	1	144	17.2	14.16
562316	BR-356	OURO PRETO	ENT C/ BR-040	P	C282	23/04/77	1	61	14.9	61.15
549384	BR-262	CHETE BH	B HORIZONTE	N	C282	25/04/77	1	292	107.5	36.69
021022	MG-223	MG223ENT.M.CARM	MG-223ENTCASC.R	P	C282	17/02/77	1	74	15.3	49.24
017025	MG.190	E.BR352 MG190	MG190 M CARMELO	N	C282	17/02/77	1	483	85.0	22.20
480561	MG-446	ENT PASSOS	ENT ALFINOPOLIS	P	C282	05/04/77	1	97	23.4	25.17
526310	BR-262	ENT BR-354	ENT P/BARUI	P	C282	29/03/77	1	60	17.9	11.90
310309	BR-262	ENT BARUI	ENT LUZ	P	C282	29/03/77	1	91	23.0	42.40
359356	BR-365	BR365TREVOPATOS	BR-365PATROCINI	P	C282	15/02/77	1	74	20.1	64.69
273272		PETROLINA	NEROPOLIS	P	C282	30/01/77	1	118	34.6	10.94
							2	104	25.7	27.03
035037	BR-153	ENT GOIATUBA	ENT BURIT ALEGR	P	C282	01/02/77	1	64	33.0	6.75
035057	BR-153	ENT GOIATUBA	ENT BURITI ALEG	P	0436	17/11/76	1	86	19.9	6.75
036037		ENT ITUMBIARA	ITUMBIARA	P	0436	17/11/76	1	59	13.9	1.60
254226	GO-174	MONTIVIDIU	AMORINOPOLIS	N	0436	09/12/76	1	428	116.7	0.64
							2	262	126.9	2.57
							3	247	91.6	115.67
043244	BR-060	ENT STA HELENA	BR060ENT GO 407	P	0436	02/12/76	1	69	13.0	21.66
042545	BR-060	BR060ENTJANDAIA	BR060ENTPARAUNA	P	0436	02/12/76	1	59	12.5	51.49
045046	BR-060	BR060ENTPARAUNA	ENT STA HELENA	P	0436	02/12/76	1	57	22.6	25.49
299040	BR-060	GOIANIA	ENT. PALMEIRAS	P	0436	01/12/76	1	57	13.1	56.90
542541	BR-050	ITUVERAVA CENT	ITUVERAVA ENT	P	C282	11/03/77	1	136	22.4	1.93
							2	51	6.2	0.64
534533		UBERABA-CENTRO	ENTRADA-UBERABA	P	C282	10/03/77	1	121	15.7	1.73
364365	BR-365	TREVO-CAMPINOP	ENT-ITUIUT	P	0436	03/02/77	1	125	21.9	0.64
							2	75	9.0	0.64
170182		BRASILIA	UNAI	N	0436	03/11/76	1	383	109.5	65.01
157142		DOIS IRMAOS	BARRO ALTO	N	0436	05/11/76	1	225	97.2	37.65
181182		CABECEIRAS	UNAI	N	0436	10/11/76	1	555	115.1	76.92

EXHIBIT 3 - Link Roughness, in Maysmeter Counts per .2 Mile, Converted to a Measurement Speed of 80 kph and Grouped, where Roughness is not Uniform, into Sections of Roughness within each Link

TABLE C.8 - STATUS OF ROUTE FILES: AUGUST 1977

	File Number	Status
Route Link File	F27	200 routes coded
Roughness File	F73	9070 km paved 5950 km unpaved
Geometry File	F25	12000 km

form, as part of the algorithm. The roughness values are converted from the measurement speed, where necessary, to 80 km/h, and the program gives mean and standard deviation values for each section of roughness at that speed. These data are then converted to QI counts per km by referencing the car, the date of measurement and the relevant calibration equation.

The roughness and geometry programs now enable the team to evaluate the importance of a route in terms of its position in the analytical factorial, where the route links have been surveyed. This will provide an important management, as well as analytical, procedure of the project.

5 PRELIMINARY RESULTS

A preliminary analysis of the user-costs data was made to test our complete study program and to see if it was suitably designed to produce the desired quantitative relationships between user cost and highway design characteristics. The data-processing system to handle the survey data has not yet been totaly programmed and therefore many of the data files are incomplete. Nevertheless, it was possible to perform an analysis for a portion of the companies and their routes. The probability of obtaining meaningful relationships from this analysis was small, but it was recognized that the main benefits would center on testing the effectiveness of the collection and processing systems. These results were considered vital in ensuring the efficient management of the surveys in the second half of the project. Accordingly, 19 companies that were expected to produce good cost data and whose routes had been surveyed were selected for this analysis. Operating-cost and vehicle-characteristics data were manually prepared from summary reports of various vehicle files. Single statistics for vertical and horizontal geometry by user route were produced by manually summarizing data that had been produced at a link level. A QI (quarter car simulator base system roughness measurement) was developed for each route using the file modification and manipulation capabilities of SAS. The cost and route characteristic values, by vehicle type, were then keypunched and SAS used to analyze the data.

a Analysis of Data

The operating-cost data compiled from 19 companies comprised of 165 vehicles: 87 2-axle trucks, 39 3-axle trucks and 39 buses.

The routes of these companies exhibited high correlations between the major independent variables. Table C.9 shows the spread of the vehicles across the various factorial cells. The distribution of vehicles within the factorial cells reflects the high correlations that existed between the horizontal and vertical components. Buses, in particular, are almost entirely confined to the rolling geometry level. Of all the vehicles, 56% are located in the rolling, straight and smooth factorial cell. These high correlations made it impossible to separate the effects of the various route components.

b The Data-Processing Systems

The data-processing system that was designed to edit and place survey vehicle measurements from the user survey routes on computer files, consolidate this information to produce a single statistic of geometry and roughness, and associate this information with operating-costs data by vehicle, works very well and no changes are recommended for this processing system.

The data-processing system designed to handle the flow of vehicle operating-cost data did not work as planned and is considered unsuitable to the needs of the field enumerators. The existing system is designed to develop information on a daily basis. The problem is that daily records do not reveal discrepancies in the data which are obvious when that same information is summarized monthly. Also, the daily records have created a workload burden that has overwhelmed our office clerical staff with the consequence that the records have not been diligently screened, and many errors are detected by program edits. The data rejected by the edits must be corrected before they are stored on a computer file. This file is then processed for consistency and the generation of summary outputs where data are again screened. These latter summaries are revealing discrepancies that must be resolved at the field level.

Frequently, three to four months pass before all data on user vehicles are collected and processed. Field enumerators find it

TABLE C.9 - MIDTERM ANALYSIS - VEHICLES IN FACTORIAL

ROUGHNESS	HORIZONTAL \ VERTICAL	ROLLING 4.5-7	HILLY 7 +
SMOOTH 0 - 50	0 - 0.3	42 2-axle trucks 23 3-axle trucks 28 Buses	
	0.3 +		8 2- axle trucks 13 3- axle trucks
MEDIUM 50 - 90	0 - 0.3		
	0.3 +		
ROUGH 90 +	0 - 0.3	8 Buses (Note: No Roughness Statistic available for 6 Buses)	
	0.3 +		37 2- axle trucks 3 3- axle trucks 3 Buses (Note: No Roughness Statistic available for 1 Bus)

difficult to correct errors that are identified as having occurred four months in the past. The system is currently being modified so that the field enumerators collect monthly rather than daily information. The forms to implement these changes had already been developed to handle the monthly summary data available historically from many of the users. Therefore, the changes currently being made in the system are expected to be smoothly implemented.

c *Route Statistics Algorithms*

The roughness algorithm produced values ranging from 23.9 to 177.7 (QI counts per km) which corresponded with subjective assessments of what constituted the best and worst route. The tentative boundaries for this independent variable range from 0 to 49 (smooth), 50 to 90 (medium rough), and 90 + (rough), with these intervals expressed as QI/km. A route which incorporated a long section of the smoothest route, but then went on to a very rough final section had a QI value of 49.8 counts per km with a standard deviation of 50.1, which is what one would have expected. The roughness algorithm seems to be very satisfactory and QI values by route type are given in Table C.10.

The range of vertical geometry for complete routes (two-way) was from 4.3 to 12.1. The latter (12.1) route had a one-way value of 19, which is likely to be as extreme as will be found in Brazil. The tentative boundaries for vertical geometry are: less than 4.5, flat; 4.5 to 7, rolling; 7 and above, hilly. Flat routes, however, have not yet been placed in the analytical factorial for lack of data, which will only be obtained from surveys to be conducted in Mato Grosso. The definite analytical factorial will be the same as shown in Table C.9, with flat route results included. It is considered that the vertical geometry algorithm gives adequate discrimination for statistical analysis, although changes may be made after further analysis.

The horizontal algorithm produced values from 0.10 to 0.84, and was considered to have achieved an adequate range of values. The tentative boundaries for this item range from 0 to 0.3 (relatively tangent) and more than 0.3 (relatively curvilinear). Traffic data were produced for each route and ranged from 181 to 8279 ADT, and although they were not finally utilized in the analysis, the team has shown a capability of producing route traffic data.

TABLE C.10 - ROUTE FACTORIAL AND ROUGHNESS (QI) VALUES

M = Mean

S = Standard Deviation

	ROLLING						HILLY		
PAVED	1.	M	23.9	7.	M	34.6	1.	M	37.9
		S	8.4		S	5.3		S	8.6
	2.	M	25.8	8.	M	35.9	2.	M	43.7
		S	14.6		S	12.5		S	21.8
	3.	M	22.9	9.	M	31.3	3.	M	37.2
		S	24.2		S	9.4		S	2.0
	4.	M	43.8	10.	M	40.1	4.	M	36.3
		S	11.9		S	15.3		S	2.8
	5.	M	33.3						
		S	7.8						
	6.	M	43.2	11.	M	27.5			
		S	4.9		S	1.5			
MIXED	1.	M	49.8				1.	M	177.7
		S	50.1					S	52.4
	2.	M	36.8				2.	M	138.2
		S	4.9					S	76.0
	3.	M	42.3				3.	M	100.0
		S	28.9					S	69.0
UNPAVED	1.	M	132.6	4.	M	146.5			
		S	32.2		S	40.9			
	2.	M	94.9	5.	M	138.3			
		S	38.6		S	30.4			
	3.	M	105.3	6.	M	151.9			
		S	27.4		S	49.1			

The subjective assessments of geometry and roughness used by the team in placing routes into factorial cells correlated well with the statistics produced by the algorithms used in the preliminary analysis.

However, the limited number of routes analyzed did not produce the spread across the factorial required for a good statistical analysis. Routes which were hilly were also generally rough and curvy. This problem is highlighted by the most extreme vertical route (12.1), which also had the highest roughness (177.7) and horizontal (8.84) values.

d *Summary of Preliminary Analysis*

This preliminary examination of a portion of the surveys data did not produce any meaningful relationships. It did, however, stimulate thought on how the independent data should be utilized to direct the field team efforts towards critical factorial cells. One such procedure would involve calculating all algorithmic values for all routes presently surveyed and guiding the field teams toward key routes for analysis.

The trade-off between what can be most efficiently collected, with given resources, against what is desirable from the analysis viewpoint, remains the key to the success of the project. The statistical exercise has resulted in the development of a meaningful analytical factorial, which can be filled by the Surveys Group and appears effective for the project statisticians. In this respect alone, the statistical analysis was a constructive exercise since it quantified the previous qualitative factorial for vertical, horizontal and roughness values.

It is proposed to evaluate the resultant factorial by conducting a further analysis including vehicle parts costs data, in November or December 1977, when all the necessary computer programs and files are completed. In the meantime, the computer program for route-characteristic data will be run on all existing route data, so that routes of special interest to the analyst can be given a priority in the field cost-collection activities. It remains our intention to "attempt to initially obtain equal cell sizes in the factorial and to have the biggest sample size our resources will permit, consistent with data quality" (Ref. 2).

6 SUMMARY

A work program for the remainder of the project is given in Figure 8 and this shows that a closely coordinated series of activities are required to produce the user-cost input relationships for the Model, by July 1978. Preliminary analysis has revealed the need to change certain procedures so that data can be processed and analyzed on a routine basis. No organizational changes are considered necessary at this point in time. If it becomes obvious that specific factorial cells are underpopulated, some relocation of field staff will be made to search for the relevant cost data.

7 PROCEDURES

All route data on file are being analyzed so that routes can be positioned in the quantitative factorial. All vehicles on the vehicle-data file will be assigned to their routes in this factorial, and an examination will be undertaken of data quality per cell, particularly parts-cost data. This procedure will allow the team to focus on those areas of the analytical factorial not yielding good data.

Field staff will not be permitted to recruit new survey members unless they can show that good data are available. Good data mean accurate values for fuel, oil, tires, parts and labor, collected from routes with a wide variety of geometry and roughness characteristics. If this results in a smaller survey, field staff can spend more time checking data quality.

The preliminary analysis showed that some fully surveyed routes were not being used by vehicles on the vehicle-data file. In the future, only those routes yielding good cost data will be surveyed. It is also thought that the route network will begin to stabilize towards the end of 1977, as fewer new routes are identified. This will allow the survey vehicles to begin a program of replicate roughness measurements.

A monthly system of user-cost data collection is now being implemented. It will enable a more thorough check on data quality to be made by the researchers and also significantly reduce the volume of cards, and hence the load, for data processing. The computer programs for this system must carry the highest priority within the User Surveys Group.

GEIPOT

Empresa Brasileira de Planejamento de Transportes

WORK PLAN AND SCHEDULE

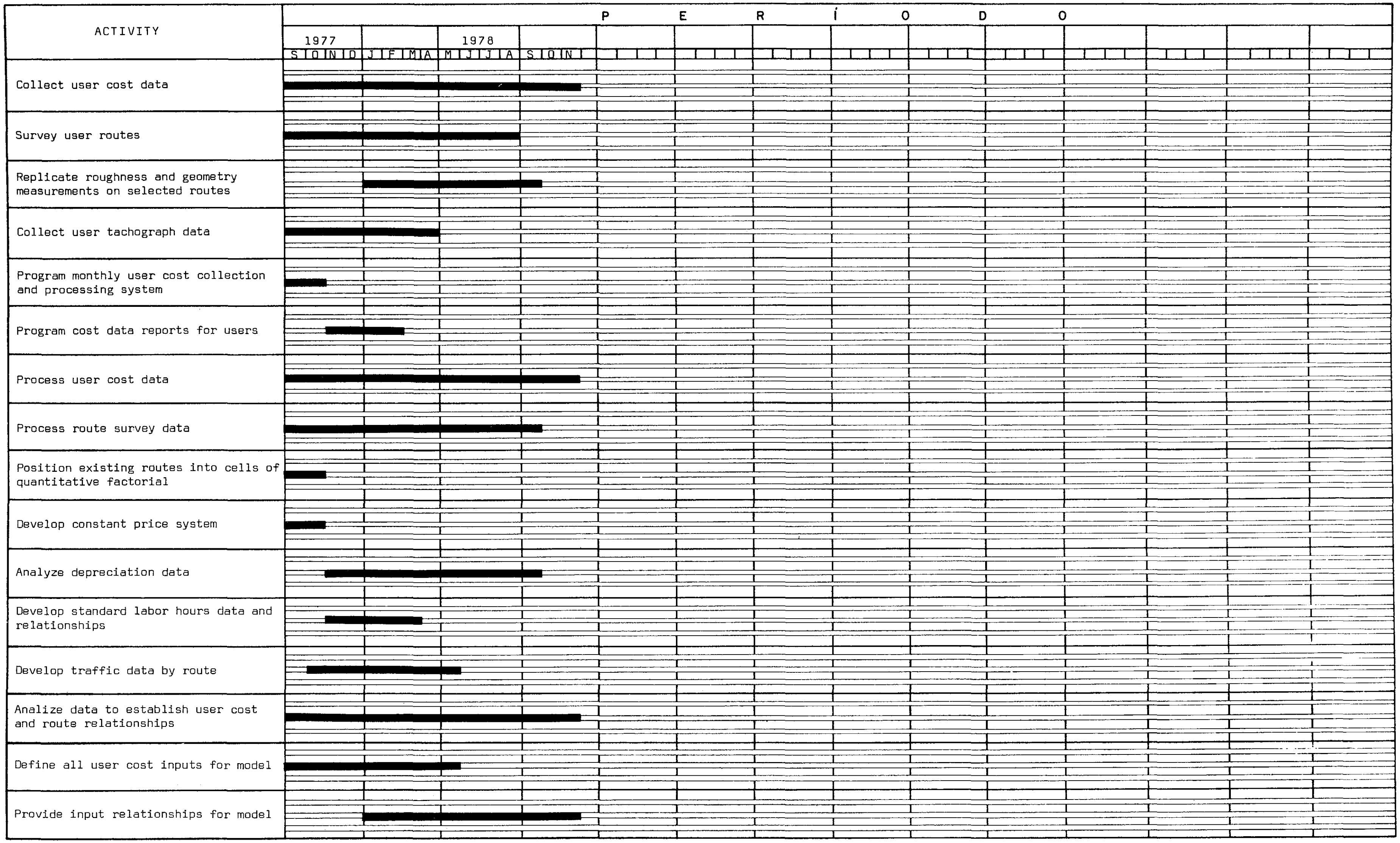

FIG. 8

GEIPOT

Empresa Brasileira de Planejamento de Transportes

WORK PLAN AND SCHEDULE

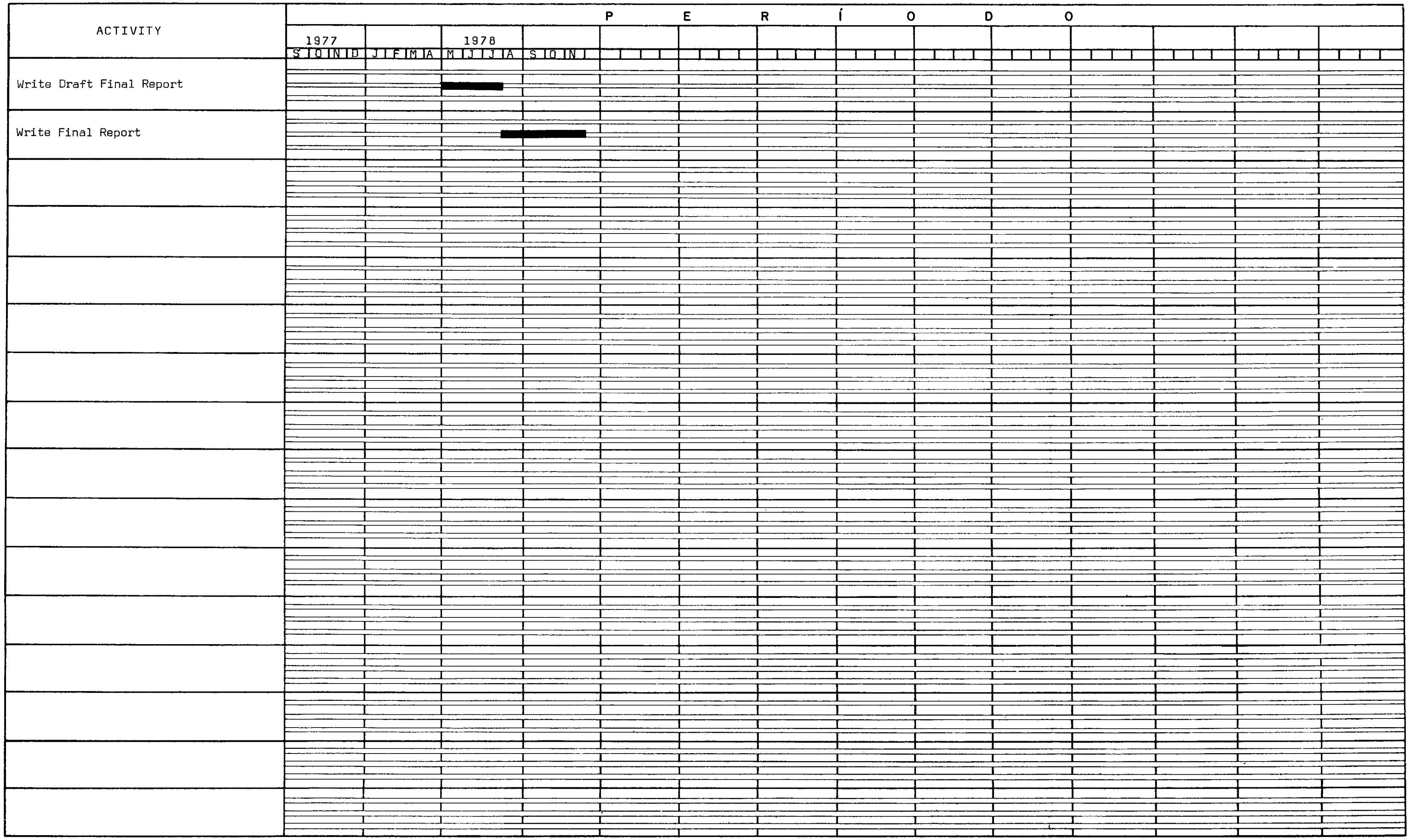

FIG. 8 (CONT.)

8 COMPUTER SUPPORT

The main implication arising from the preliminary analysis is that unless data preparation, processing and analysis can be quickly brought up to date, and thereafter kept current, it will be impossible to provide the necessary data for the final analysis to develop relationships for the model by July 1978.

An estimated average of 28,000 keypunched cards must be handled per month until April or May 1978, when survey-car activities begin to diminish. It is essential that computer support for our group be geared to handle the keypunching, verifying, processing, editing, correcting, and updating of the group's three major computer files and five smaller ones, on a routine monthly basis.

9 DATA COLLECTION

A long lead time is required from first contact with a vehicle operator to the time when a sufficient quantity of accurate data is on a clean file. This lead time is often three to six months, and both hard work and good fortune are necessary to find good contacts. Therefore, search activities for new users must cease in March 1978. Further, only users with good-quality data extending for a minimum period of 12 months will be accepted as survey respondents. This means that it may not be possible to fill some factorial cells for final analysis starting in June 1978.

10 THE COMPUTER MODEL

In the present study, data are being collected to derive relationships for use within the model.

When the model itself is finally ready for use, the model user will find that more data collection in the operational-cost area is necessary. The model user must provide the following inputs in order to use the model:

- Unit costs of petrol, diesel fuel, oils, maintenance labor, new vehicles, tires, driver's and passenger's time;
- Information on standing or fixed costs both for private

cars and commercial vehicles;

- Information on taxes of all items used in vehicle operation and other transfer charges, such as annual licence fees, since the model may be used in either the "financial" or "economic" mode;
- Foreign exchange components of costs, particularly those for fuel, oils and tires.