CHAPTER E

PAVEMENT AND MAINTENANCE STUDIES

1 OBJECTIVES

The pavement and maintenance studies are directed towards understanding pavement performance in Brazil, i.e., how pavements constructed with different materials and at different times perform under different traffic loadings. Concurrently, the influence of alternate maintenance standards on the pavement's performance is being studied, which is a very important aspect since very little information is available on the impact of alternate maintenance levels on the pavement's future performance.

The primary objective of the studies of this Group will be to quantify a model of pavement performance which predicts the condition of a roadway as a function of:

- Structural variables such as material properties and layer thicknesses;
- Traffic volume and composition;
- Climate;
- Maintenance;
- Age and rehabilitation for paved roads.

The model will be applicable to paved as well as unpaved roads.

There is an identified need to establish rehabilitation policies through an evaluation of the tradeoffs among different designs and stage-construction strategies for a variety of maintenance standards. The pavement and maintenance studies are expected to produce some of the relationships needed for this evaluation. They can also from the basis for a continued and expanded study encompassing a wider range of pavement designs and materials over an extended time period. It will be difficult to develop complete pavement performance relationships for pavements with ten to 20-year life spans within the study period. The experimental designs adopted permit the analysis of roads of different ages in cross sectional analysis. However,equally important is the formulation of a sound basis for continued research in the future. The construction of the special maintenance and rehabilitation experiments clearly fall into this latter category. It will be impossible to evaluate these sections to destruction in the remaining 15 months of the project because the asphaltic concrete sections, for example, could have a life of up to 10 years:

2 ORGANIZATION AND STUDY PROCEDURES

The approach being used for determining a pavement deterioration relationship is to monitor a number of variables describing pavement behavior, distress and performance on a number of test locations selected on existing roads. Each test location is divided into two sub-sections which will receive different maintenance levels. The sub-sections are 320m in length, with an 80m transition between the sub-sections. In some cases, the section lengths are reduced on unpaved roads where the sub-sections on curves are only 80m in length. This is because extreme geometric conditions need to be investigated and curves with radii of less than 250m seldom have a length of more than 240m. Besides monitoring pavement behavior, distress and performance, the characteristics of the pavement materials, traffic distributions and vehicle weights are being determined.

A variety of activities need to be performed in fulfilment of the stated objectives. During the initial term of the project, a functional organization was developed to perform these activities. This organization structure is illustrated in Figure 38, but because of the graphic deficiency of this type of diagram, all the interrelationships between the different engineers and field crews cannot be shown. Because of the varied nature of the work, the field crews travel independently, and this makes organization, programming and control extremely time consuming.

The characterization and determination of the properties of the materials used on each of the test sections comprise an important part of the study. Since the project does not possess the capability of carrying out the field material testing, a consultant was hired to perform this work. The project maintains a full-time supervisor with the consultant's team, besides the regular visits of the supervising engineer. To control the work, a soils laboratory was set up which is capable of executing all the laboratory tests necessary, including such sophisticated tests as the determination of the resilient modulus of undisturbed subgrade samples and bituminous surfacing samples.

3 SCOPE OF THE STUDIES

The pavement and maintenance studies are basically proceeding as was envisaged in the Inception Report with various refinements

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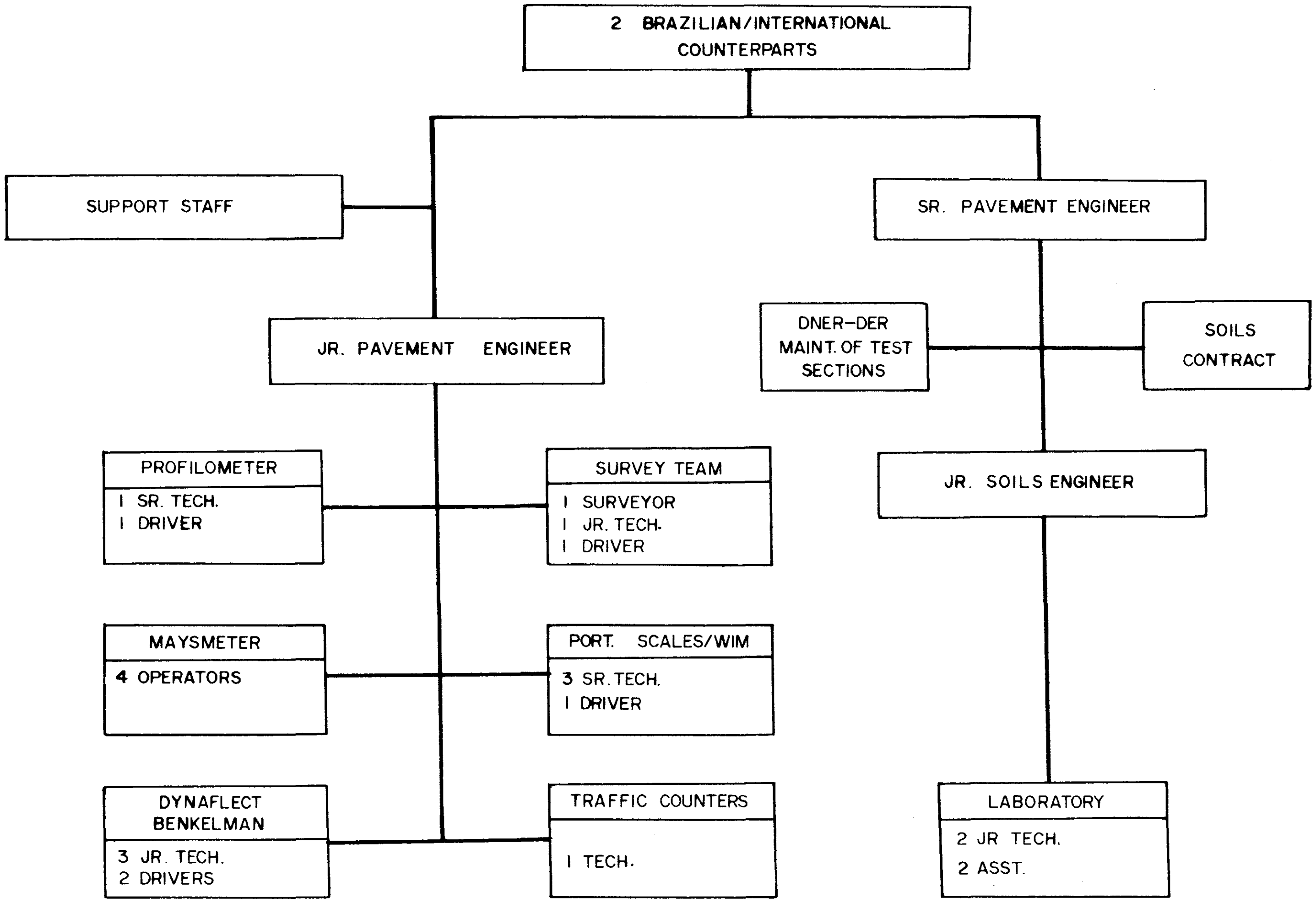

FIG. 38

ORGANIZATION OF THE PAVEMENT AND MAINTENANCE STUDY GROUP being made in response to field conditions as necessary.

The special experimental pavement which was proposed to be constructed of different paved and unpaved sections on the same stretch of road, and designed to supplement the pavement study. will probably not be constructed because of the unavailability of project funds, and the inability to find a sponsor. However, during discussions with the different road departments, an interest was expressed for the construction of special maintenance and rehabilitation experimental sections, rather than for the construction of a special experimental pavement. This outlook by the road departments is not surprising considering that a large proportion of the roads were constructed during the last ten years, and these roads are now reaching the stage where they need attention. The discussions have led to the construction of special surfacing sections on a road of the Departamento de Estradas de Rodagem of Minas Gerais (DER-MG), near Juiz de Fora, and currently under discussion is the construction of a similar experiment in conjunction with the Departamento de Estradas de Rodagem of São Paulo (DER-SP).

The special surfacing experiments are designed to determine the performance of the pavement following the application of the different surfacing types as a maintenance or rehabilitation operation. Performance will be evaluated by measuring riding quality, behavior will be monitored in terms of deflection, and distress will be related to cracking and patching. These results will be compared to control sections receiving no treatment.

The selection of the roads on which the special surfacing experiments are constructed are based on the premise that, besides the one at Juiz de Fora, further experiments will be constructed in the future. The design factorial, which considers the two factors of traffic and original surfacing type, is a simple 2 X 2 matrix as shown in Table E.1.

To optimize between the costs of construction and length of section required for obtaining meaningful results, it was decided to construct 200-m sections. Only the central 160m is used for evaluation purposes, and the 20m on either side remains as a transition.

At the Juiz de Fora experiment, four different maintenance and rehabilitation treatments were used:

- Asphaltic concrete: three different sections were constructed with layer thicknesses of 4 cm, 8 cm and 12 cm;

TABLE E.1 - THE DESIGN MATRIX FOR THE SELECTION OF ROADS ON WHICH SPECIAL EXPERIMENTAL SECTIONS ARE CONSTRUCTED

		Traffic (ADT)	
		High	Low
Original surfacing type	Surface treatment		Juiz de Fora experiment
	Asphaltic concrete		

- Cold Mix: 4-cm thick layer was used;
- Slurry seal: two types of slurry seal, a fine graded slurry with all the aggregate passing nº 4 sieve, and a coarse graded slurry with the material passing the 1/2-inch sieve, were used;
- Surface treatment: a double and a single surface treatment were employed.

The surfacings used at Juiz de Fora will serve as an example for future experiments. It is envisaged that the same technique will be used on sections to be constructed by each collaborating agency, and other surfacing types may be included depending on local practices.

The special surfacing experiments are very important to an understanding of alternative rehabilitation and maintenance policies. Construction of such sections is normally postponed because it takes such a long time before conclusions can be made.

A complete evaluation of some of these surfacings could require from five to 10 years, which is beyond the time span of the project. Nevertheless, construction of these experiments should continue until the end of the project, when they can become part of other highway research projects in Brazil.

a Testing Completed

Each field crew has specified functions to be performed at regular time intervals. Since the pavement performance study is time-based, the numerous results which have already been obtained present a disjointed picture which does not yet permit an overall analysis. Tables E.2 and E.3 summarize the different tests already performed on the two types of road sections. The different sections have been stratified by the type of experiment.

The survey crew is responsible for locating and marking the sections, measuring the geometrical characteristics, and on unpaved roads, for measuring gravel loss. The majority of the paved road sections have been located, and ultimately there will be about 50 unpaved sections under observation. The difference in the number of unpaved sections marked and the number on which gravel-loss measurements are being made is due to some sections requiring regravelling to give a wearing course thickness of at least 15 cm.

TABLE E.2 - STATUS OF TESTING ON PAVED ROAD SECTIONS AT 1 AUGUST 1977

	Paved Road main factorial	Paved Road star points	Satellite study soil cement bases	Juiz de Fora special sections
Section location	43	19	9	15
Condition survey 1st Cycle	43	19	9	15
2nd Cycle	4			
Deflection survey				
Benkelman beam and Dyna-flect 1st Cycle	43	19	2	15
2nd Cycle	40	17		
3rd Cycle	20	6		
Seasonal measurements cycle nº	12			
Roughness measurements				
Profilometer 1st Cycle	42	19	2	15
2nd Cycle	15	4		
Maysmeter 1st Cycle	43	19	2	15
2nd Cycle	15	5		
Portable scales	23	9	1	
Material tests	17	4		
Traffic classification counts	6	1		
Maintenance Required	18	5	4	
Completed	13	4		

TABLE E.3 - STATUS OF TESTING ON UNPAVED ROAD SECTIONS AT 1 AUGUST 1977

	Unpaved Road main factorial	Unpaved Road star points
Section location	13	6
Gravel loss measurements at 3-4 monthly intervals	10	2
Roughness measurements Maysmeter at 2 weekly intervals	10	3
Portable scales	8	
Surfacing material characterization tests	13	6
Traffic classification counts	4	

The roughness measuring system comprises the Profilometer and the Maysmeters. The Profilometer serves as the roughness base for the research, so correlations must be developed between the Profilometer and the different Maysmeters. A calibration course consisting of 20 paved road sections covering the range of road roughness of paved roads in the vicinity of Brasilia was established. The crews in this sector are responsible for the calibration and control verification of all the Maysmeter, including those used on the user costs surveys routes.

To check whether the Maysmeters are in calibration, they are run over the calibration sections at regular intervals. The Profilometer also regularly measures these calibration sections to detect changes in the pavement condition. The Profilometer has completed the first cycle of roughness measurements on the paved road sections, with the exception of a few sections with soil-cement bases which were marked recently, and is currently performing the second cycle. The Maysmeters also are conducting the second cycle of measurements on the paved roads The roughness of 13 unpaved sections are being measured at about fortnightly intervals. Besides the roughness measurements for the Pavement Study Group, the two Maysmeters allocated to this section have also been heavily occupied, initially measuring the routes travelled by the vehicles of the user costs surveys, and more recently carrying out measurements for the fuel and speed studies.

Deflection measurements may be used as a surrogate for pavement strength. The two types of measuring devices being used are the Dynaflect and the Benkelman beam. To develop a correlation between the two instruments, measurements are taken concurrently. Indications are that it may be difficult to develop a reliable correlation between the two instruments, so both devices are used to measure all the paved road sections. A second cycle of measurements is almost complete on the paved sections. Besides the regular measurements on all the sections, ten sections in the Federal District are being used to develop a seasonal correction factor for deflection, which is absolutely essential for meaningful analysis of the deflection data. During a one-year period, 12 measurements have been made.

An important aspect of the pavement performance study is the influence of axle loads on paved and unpaved road performance. It is necessary to obtain information on axle loads and traffic distribution on Brazilian highways. Portable scales and a dynamic weigh-in-motion system are available for collecting axle-load data. The portable scales are used to measure axle loads over five-day periods during daylight hours. Results have been obtained at 48 sites. On the heavily trafficked roads it is difficult and dangerous to obtain measurements with the portable scales, whereas at night it is impractical. For these reasons, the weigh-in-motion system is utilized. It measures all the vehicles without stopping them, and it can be used at night or during the day. Results have been obtained at two sites, and four additional site installations are planned, all located on some of the most heavily trafficked routes in Brazil.

To establish the frequency of axle loadings, traffic counts are being taken. Simple counters needing daily or weekly readings are generally used on unpaved roads. Recording traffic counters have been installed to monitor seasonal variations in traffic flow, and ten of these permanent traffic counters have been installed at strategic locations in the State of Goiás. They are used to supplement and correct manual classification counts which are only taken over a seven-day period. These traffic counters need regular visits for verification and adjustment. In the States of Minas Gerais and São Paulo, the DNER is installing similar equipment. We plan to use their data, while the data gathered by the project can also be used to their advantage. At 11 locations, manual traffic classifications counts have been taken, and it is envisaged that the assistance of the road departments will be obtained to complete the counts. In some cases this may not be necessary since regular count points are located close to the sections. Preliminary results relating to seasonal variation in traffic flow at two sites are discussed below.

Material characterization is also an important aspect of the study. All the laboratory tests are currently being executed in our soils laboratory, while the field testing is being executed by consultants. Field density, field CBR, field moisture contents and layer thicknesses have been measured on 21 paved road sections. Samples have been taken of each layer for laboratory testing, which consists of determining a grading analysis, Atterberg limits and laboratory CBR and density. Material characterization has been performed on the surfacing material of the 19 unpaved sections which have been selected.

Condition surveys are used to establish those sections requiring maintenance. The sections are located in different regions, which means that the procedure of applying the slurry seal and correcting bad distortions need to be explained afresh, and a new team needs to be trained. Up to the present time, maintenance has been applied to

17 of the paved road sections. This work is essential for addressing the objective of determining the influence of maintenance level on future pavement performance.

4 TRAFFIC VOLUMES

Traffic information is needed in the development of pavement performance relationships and to support the development and use of the model. Support activities such as traffic counting are some times insufficient, and therefore should be part of the study effort.

Manual traffic classifications counts are being obtained at all the pavement study sections. However, in many cases seasonal variations will bias these results. It is therefore essential to establish variation in traffic flows during the year. DNER is at present installing permanent traffic counters at strategic locations in the States of Minas Gerais and São Paulo. In the State of Goiás the project decided to install ten permanent traffic counters to give complete coverage of the study area in Goiás. The installations are on all the major paved routes in the southern part of Goiás, as shown in Figure 39.

a *Equipment and Data Reduction*

The permanent counters are print-punch traffic recorders, which are activated by induction loops. The equipment is installed at highway police posts which are located on the major routes or at gas stations. Initially only two installations were made, using batteries as an electrical source. The batteries discharged in about one week on the more heavily trafficked routes, and as police posts and gas stations have an electrical supply it was decided to install battery chargers with the counters at those sites.

The analog-digital system has attached to it a teletype unit which roads the paper tapes generated by the traffic counters. This system functions very satisfactorily and permits the paper tapes to be copied directly onto magnetic tape which can be processed by any computer.

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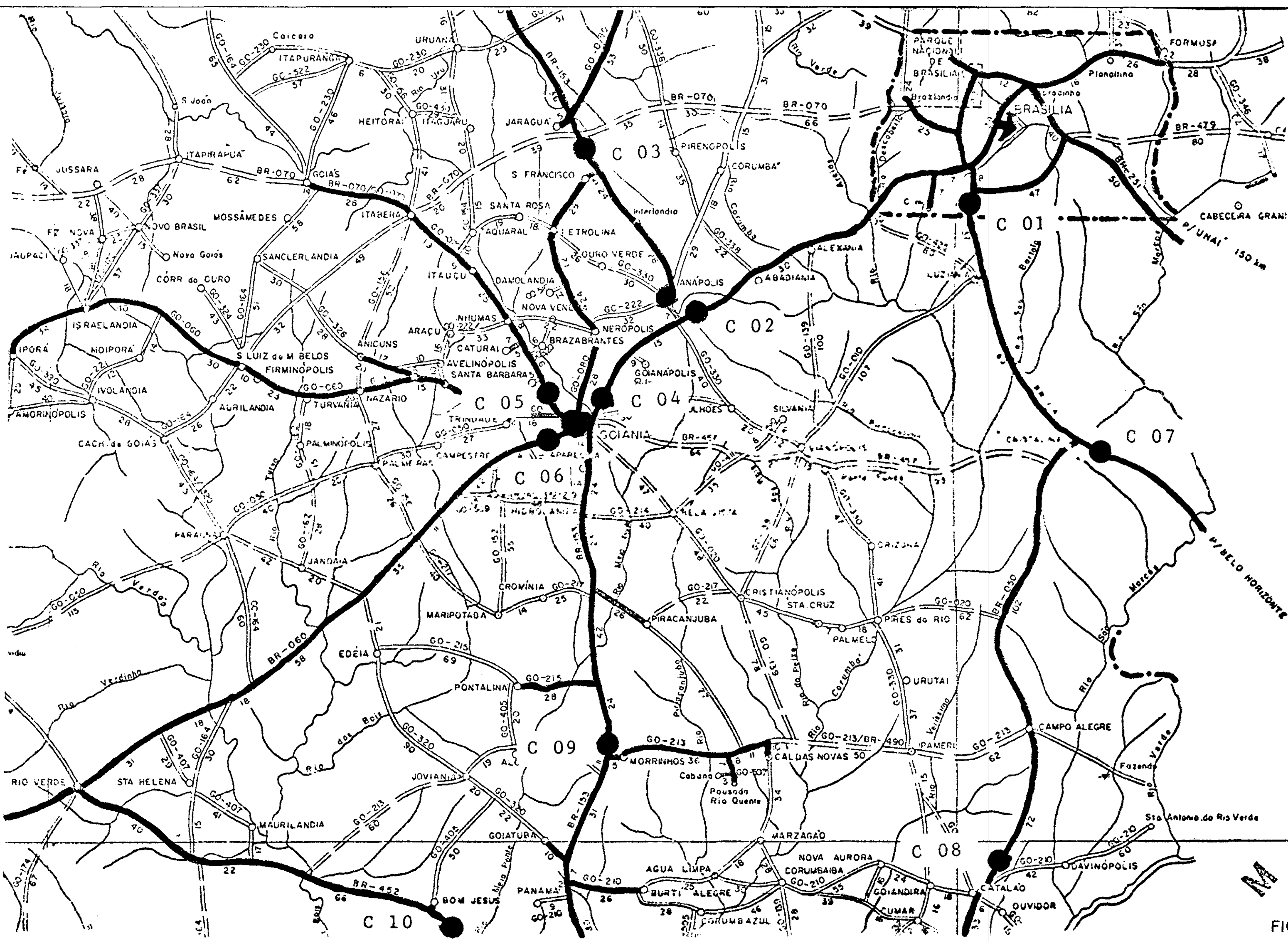

LOCATION OF PERMANENT TRAFFIC COUNTERS IN THE STATE OF GOIÁS

The traffic counter data have been processed from the initial two sites: Counter CO-1 installed on BR-040 linking Brasilia and Luziânia, and counter CO-2 located on BR-060 linking Brasilia and Anápolis. The average daily traffic (ADT) per week for the period that was measured is presented in Figures 40 and 41 for the two counters. The average daily distribution is shown in Figures 42, 43 and 44.

The traffic counters record traffic in each of the two directions, and punch the result hourly. For the period January to June 1977, the hourly traffic is presented in Figures 45 and 46.

Only limited data from the eight other traffic counters are currently available because the recent installation of these counters. In the future, data from the ten traffic sites will be used to develop seasonal weightings which will be used to expand our limited manual counts at each test section. This information also will be used in adjusting traffic volumes obtained from non-recording counters, presently being installed throughout the State of Goiás study areas, to develop traffic on user survey routes. Further, traffic counter information will be used in developing volume distribution relationships needed to use the Brazil Roadway Investment Analysis Model.

5 *AXLE LOADS*

Accurate axle-load data are very important in the determination of pavement performance relationships; therefore, axle-load distributions and average load equivalency results for the pavement test sections are being determined from vehicle weighings measured with portable scales and the weigh-in-motion system.

This information must be developed during the study because of the lack of current data. On some of the more heavily trafficked routes there are weighing stations, but at these sections only those vehicle which appear to be laden to capacity, or overladen, are weighed. Consequently, any sample taken from these results are biased because of the sampling technique used.

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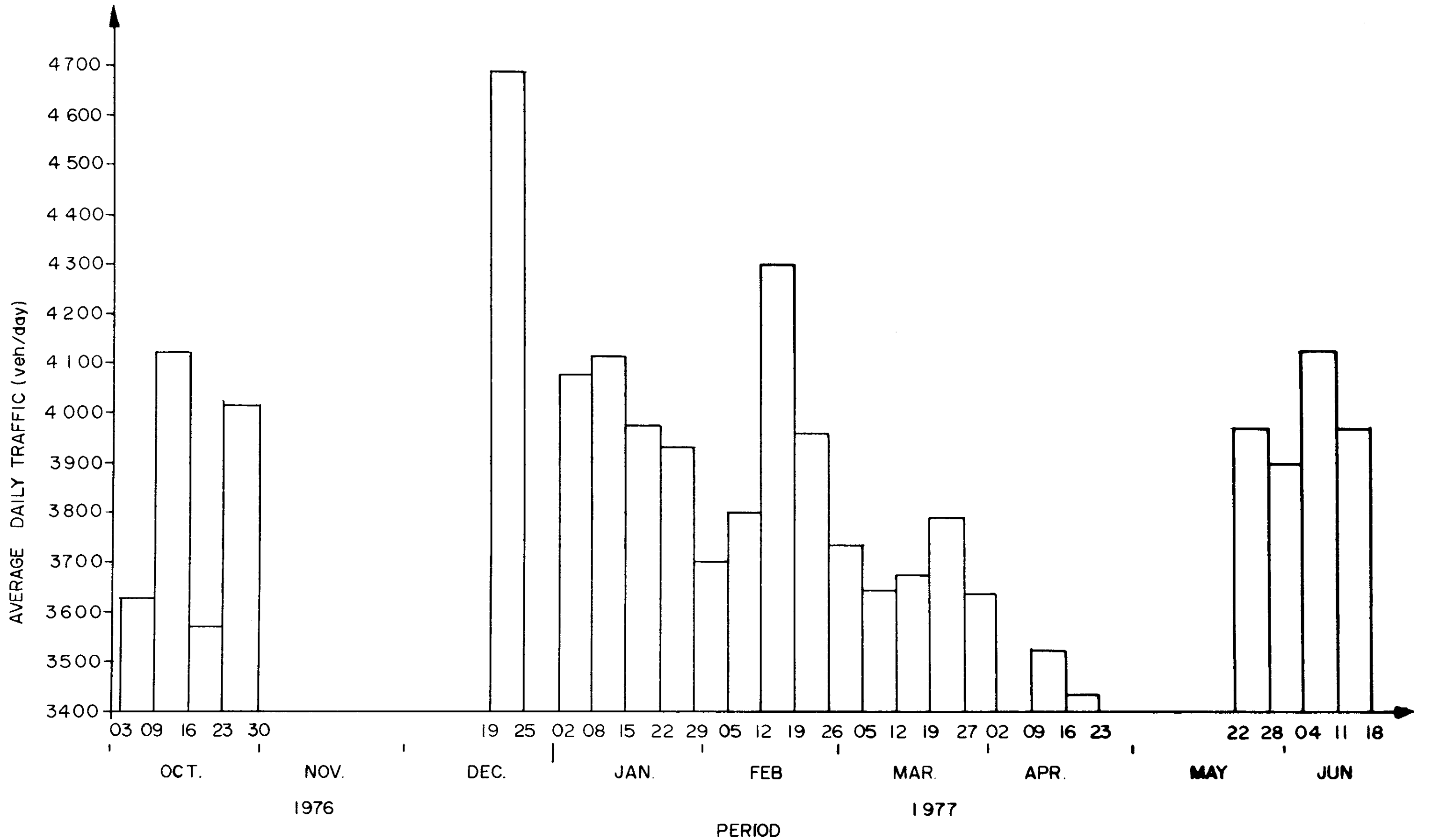

FIG. 40

AVERAGE DAILY TRAFFIC PER WEEK - BR- 040 BRASÍLIA-LUZIÂNIA (COUNTER C-01, BOTH DIRECTIONS)

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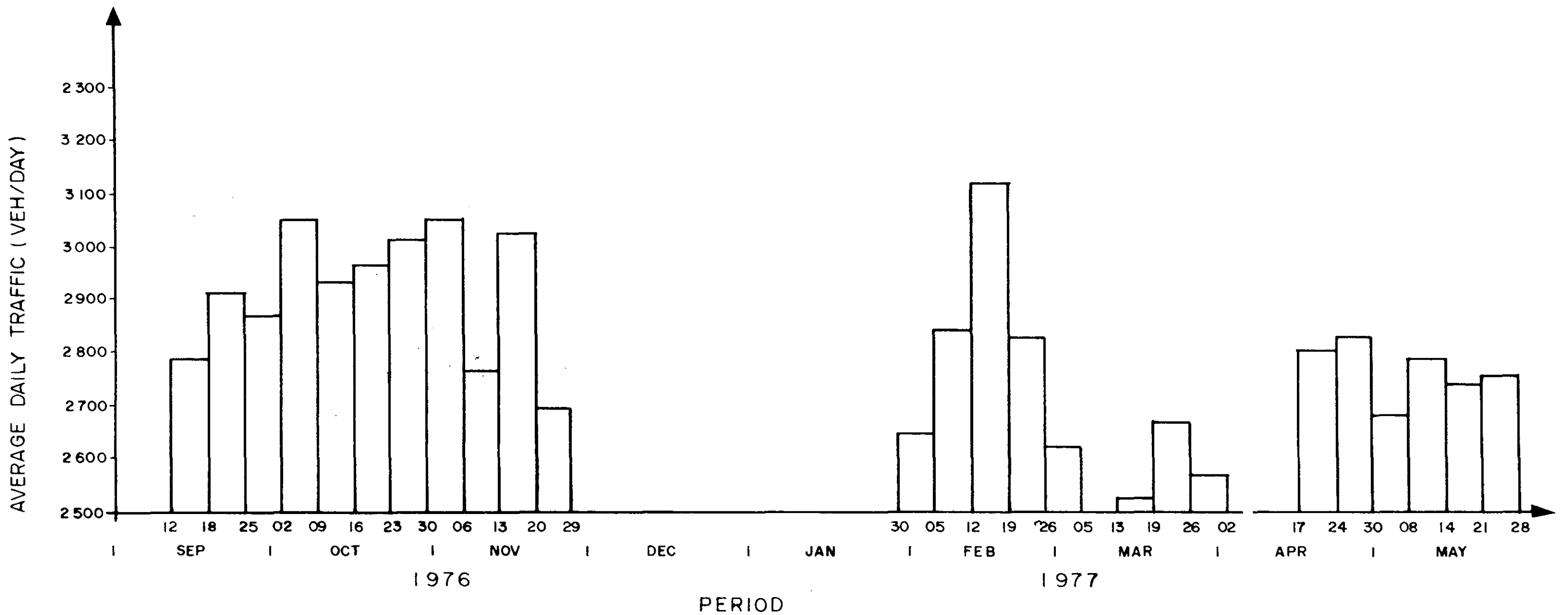

FIG. 41

AVERAGE DAILY TRAFFIC PER WEEK - BR-040 BRASÍLIA-LUZIÂNIA (COUNTER CO-1, BOTH DIRECTIONS)

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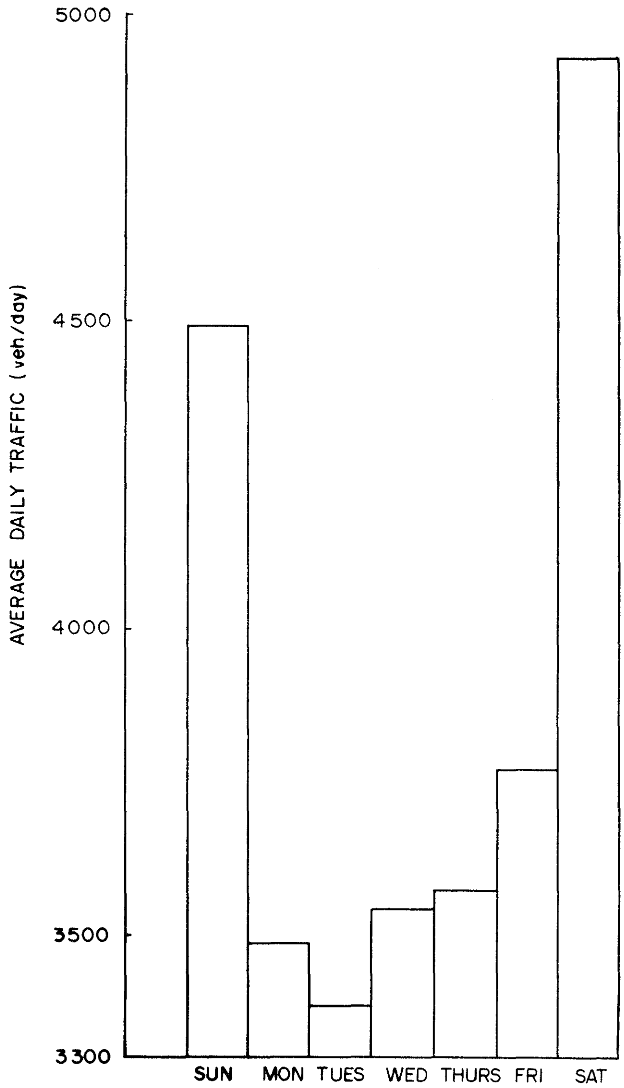

FIG. 42

AVERAGE DAILY DISTRIBUTION OF TRAFFIC (COUNTER CO-1, JAN./JUN-77)

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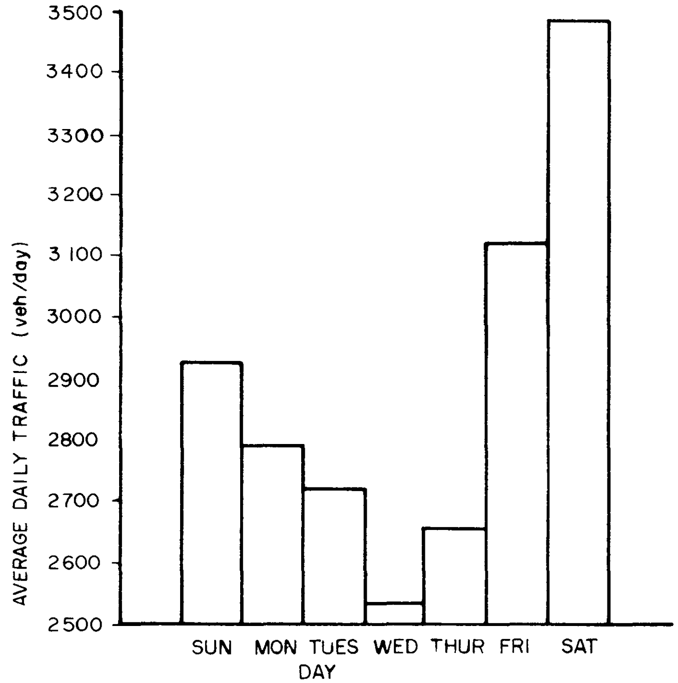

FIG.43

AVERAGE DAILY DISTRIBUTION OF TRAFFIC (COUNTER CO-2, SEP./NOV. 77)

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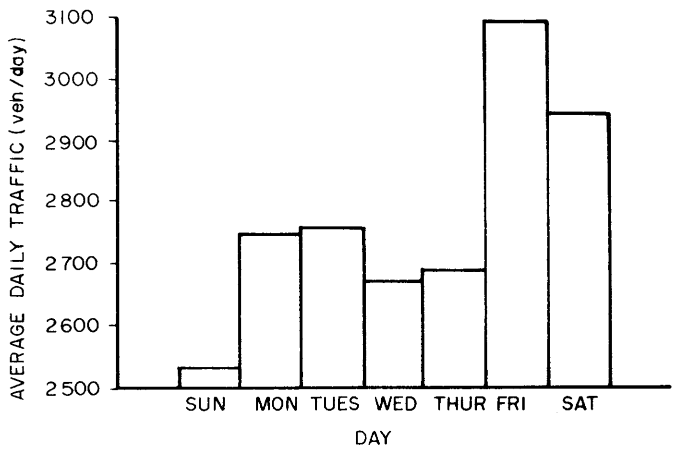

FIG. 44

AVERAGE DAILY DISTRIBUTION OF TRAFFIC (COUNTER CO-2, JAN./MAY 77)

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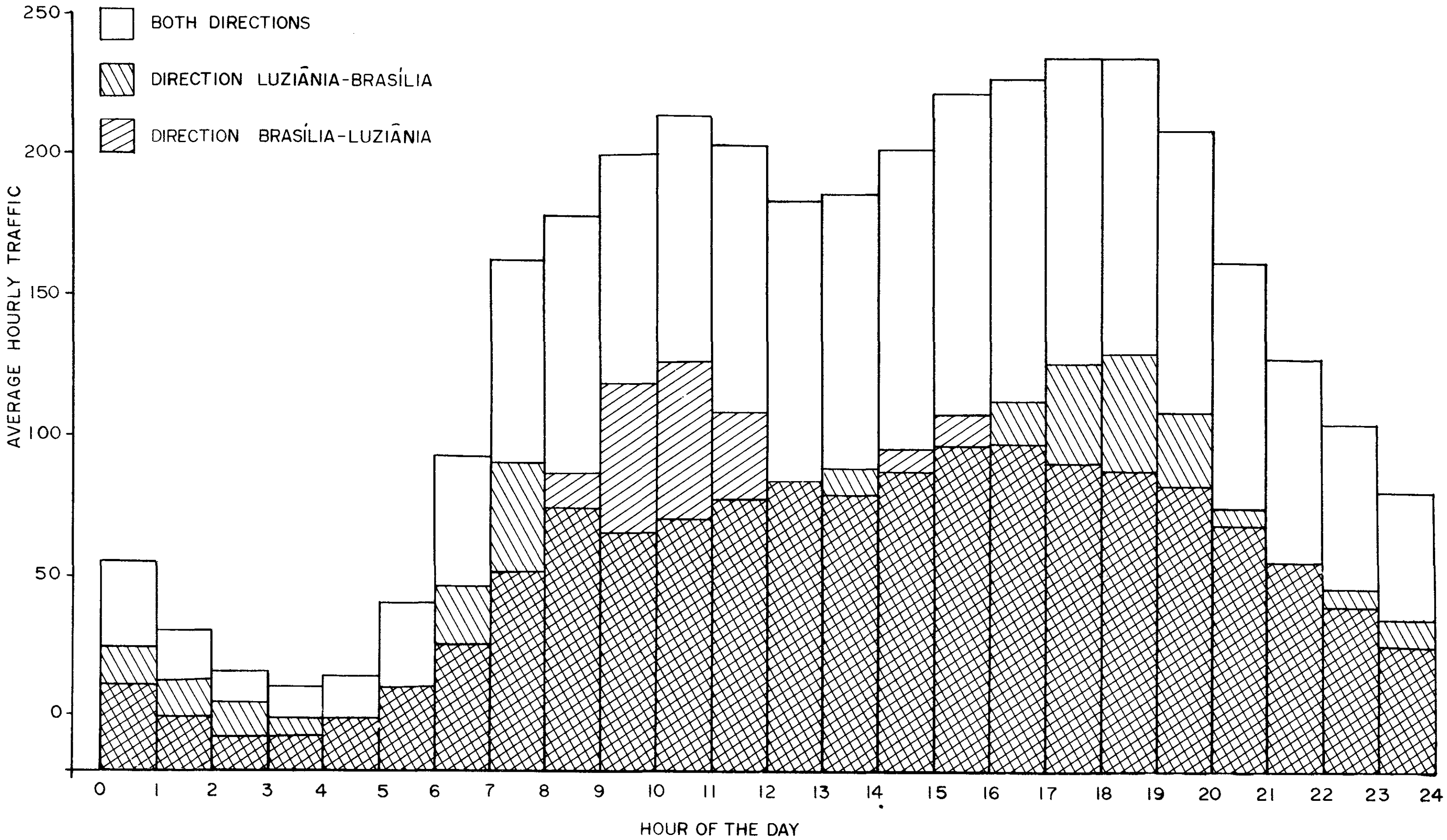

FIG. 45

HOURLY DISTRIBUTION OF TRAFFIC AT COUNTER CO-1 (JANUARY/JUNE 1977)

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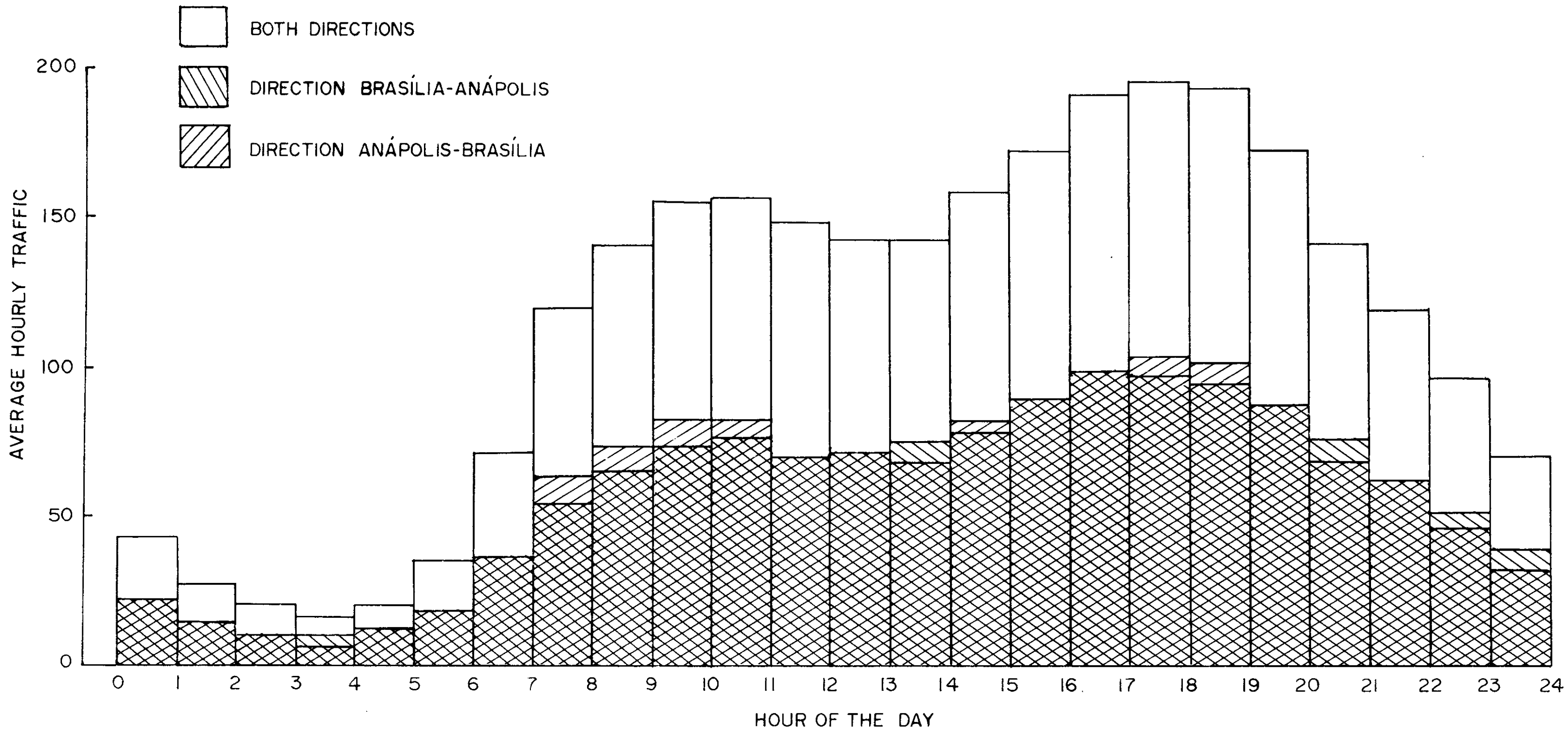

FIG. 46

HOURLY DISTRIBUTION OF TRAFFIC AT COUNTER CO-2 (JANUARY/MAY 1977)

a *Collection with Portable Scales*

Vehicle wheel weights are obtained using two portable scales. A level stretch of road (grade less than 1 percent) with good sight distance is selected in close proximity of the pavement study section. The scales are then placed on the roadway and one lane is blocked off to permit measurements as shown in Figure 47, with the two wheels of each axle being weighed simultaneously, and an entry made in a special form (Exhibit 4). The classification of vehicles is based on axle configuration, vehicle size and type; a schematic representation of the classification is presented in Figure 11. At each site, measurements are obtained during a 5-day period, generally from Monday to Friday. Because of safety considerations and to facilitate reading the scales, measurements are only conducted during daylight hours.

On roads carrying less than about 800 vehicles per day, vehicles travelling in both directions can be handled with the scales located in one lane. For roads carrying heavier traffic it is necessary to measure only one direction per day, while the other direction is measured on the following day. Vehicles are sampled during peak hours to minimize delays and thereby maintain the goodwill of long-distance haulers. Thus no more than two vehicles are kept waiting at any single time.

b *Portable Scale Results*

Data are keypunched directly from the field sheets and then processed by a verification program which checks for errors in field measurements and keypunching. A program was developed to calculate the frequency distributions of the axle loads in terms of the front axle, and single, tandem and triple rear axles. The frequency distributions have been tabulated and they are presented in Appendix A for each section that was measured.

c *Axle Load Distributions*

To facilitate the investigation of the severity of overloading on roads, the percentage of axles laden above the legal limits set by the DNER have been extracted from Appendix A, and they are presented in Table E.4. The legal limits which are in force are the fol-

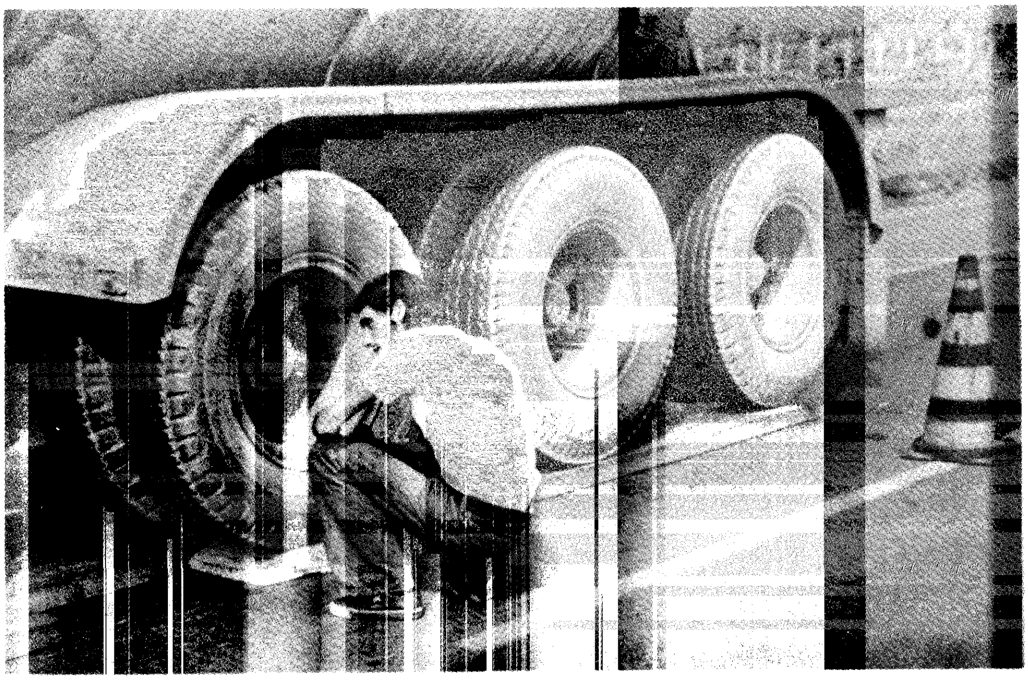

FIG. 47

AXLE WEIGHING WITH PORTABLE SCALES

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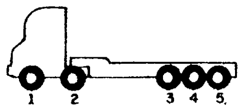
FICHA DE CAMPO · BALANÇAS PORTÁTEIS

FOLHA Nº	DATA

OPERADOR

INSTRUÇÕES DO PERFURADOR

CAMPOS NUMÉRICOS DEVEM SER PERFURADOS ALINHADOS A DIREITA.



RODOVIA	SEÇÃO	CARGA	SENTIDO	CLASSE	VEIC	ANO FABR	CARGA POR RODA (LIBRAS) ESQ.1	DIR.1	ESQ.2	DIR.2	ESQ.3	DIR.3	ESQ.4	DIR.4	ESQ.5	DIR.5	ESQ.6	DIR.6
1 2 3 4 5	6 7 8	9 10	11 12	13 14	15 16	17 18	19 20 21 22 23	24 25 26 27 28	29 30 31 32 33	34 35 36 37 38	39 40 41 42 43	44 45 46 47 48	49 50 51 52 53	54 55 56 57 58	59 60 61 62 63	64 65 66 67 68	69 70 71 72 73	74 75 76 77 78

DUPLICAR COLUNAS 1-8 INCLUSIVE

FICHA

EXHIBIT 4 - Portable Scale Field Recording Form

TABLE E.4 - PERCENTAGES OF AXLES OVERLADEN MEASURED WITH THE PORTABLE SCALES ON THE PAVEMENT STUDY SECTIONS

Section Number	Direction	Front Axle % (Nº obs)	Single Rear Axle % (Nº obs)	Tandem Rear Axle % (Nº ob)	Triple Rear Axle % (Nº obs)
001	BR020-Barragem	0.0	27.3	-	-
		(11)	(11)	-	-
	Barragem-BR020	0.0	0.0	-	-
		(10)	(10)	-	-
002	Brasília-Unaí	2.5	8.5	30.0	-
		(81)	(71)	(10)	-
	Unaí-Brasília	3.1	45.8	27.3	-
		(129)	(118)	(11)	-
002	Brasília-Unaí	0.0	4.9	0.0	-
		(68)	(61)	(7)	-
	Unaí-Brasília	0.0	58.2	80.0	-
		(60)	(55)	(5)	-
003	Formosa-Sobradinho	1.3	5.3	22.6	100.0
		(151)	(131)	(22)	(2)
	Sobradinho-Formosa	1.1	10.4	10.2	0.0
		(190)	(163)	(49)	(0)
004	BR060-Gama	2.5	74.6	70.0	0.0
		(81)	(71)	(10)	(0)
	Gama-BR060	0.0	0.0	5.6	0.0
		(72)	(58)	(18)	(1)
004	BR060-Gama	0.0	75.0	100.0	-
		(25)	(24)	(1)	-
	Gama-BR060	0.0	0.0	25.0	-
		(30)	(26)	(4)	-
006	Brasília-Luziânia	0.8	10.5	21.6	37.0
		(364)	(267)	(93)	(27)
	Luziânia-Brasília	1.3	38.6	20.4	75.6
		(450)	(303)	(83)	(29)

TABLE E.4 - (CONT'D)

Section Number	Direction	Front Axle % (Nº obs)	Single Rear Axle % (Nº obs)	Tandem Rear Axle % (Nº obs)	Triple Rear Axle % (Nº obs)
007 & 008	Sobradinho-Formosa	1.2	17.1	7.6	0.0
		(326)	(246)	(132)	(1)
	Formosa-Sobradinho	0.4	9.9	12.0	100.0
		(280)	(213)	(100)	(1)
007 & 008	Sobradinho-Formosa	0.7	18.4	15.7	0.0
		(143)	(109)	(51)	(1)
	Formosa-Sobradinho	0.8	2.2	17.2	100.0
		(128)	(89)	(52)	(1)
009	Brasília-Anápolis	0.6	6.0	13.2	40.0
		(357)	(215)	(98)	(10)
	Anápolis-Brasília	1.6	54.8	33.5	47.7
		(434)	(279)	(129)	(23)
010	Taguatinga-Brazlândia	2.2	3.2	2.6	-
		(272)	(255)	(39)	-
	Brazlândia-Taguatinga	2.2	0.6	10.3	-
		(182)	(164)	(29)	-
011	Taguat.-B.Descoberto	0.0	0.8	0.0	-
		(273)	(264)	(19)	-
	B.Descoberto-Taguat.	0.0	40.4	0.0	-
		(211)	(208)	(3)	-
201	Unaí-BR020	0.0	0.0	-	-
		(2)	(2)	-	-
	BR020-Unaí	0.0	0.0	-	-
		(5)	(5)	-	-
202	Unaí-BR020	0.0	0.0	0.0	-
		(7)	(7)	(0)	-
	BR020-Unaí	0.0	68.6	0.0	-
		(8)	(7)	(1)	-
203	EPCT-Papuda	0.0	0.0	0.0	-
		(41)	(39)	(2)	-
	Papuda-EPCT	0.0	58.2	0.0	-
		(55)	(55)	(0)	-

TABLE E.4 - (CONT'D)

Section Number	Direction	Front Axle % (Nº obs)	Single Rear Axle % (Nº obs)	Tandem Rear Axle % (Nº obs)	Triple Rear Axle % (Nº obs)
204	Border-DF/GO-BR020	0.0	9.6	85.8	-
		(28)	(21)	(7)	-
	BR020-Border-DF/GO	0.0	6.7	0.0	-
		(29)	(15)	(16)	-
021	Cristalina-Catalão	4.6	7.5	20.9	0.0
022		(65)	(40)	(24)	(2)
	Catalão-Cristalina	8.0	32.7	20.1	66.5
		(87)	(52)	(35)	(12)
024	Rio Verde-Goiânia	2.5	17.5	4.0	58.3
		(159)	(109)	(50)	(12)
	Goiânia-Rio Verde	3.0	35.9	37.1	33.3
		(170)	(117)	(54)	(9)
025	Inhumas-Goiânia	1.0	18.6	6.4	0.0
033		(385)	(295)	(140)	(2)
	Goiânia-Inhumas	1.1	10.2	10.0	40.0
		(369)	(323)	(89)	(5)
026	Uruaçu-Ceres	3.3	26.8	10.8	87.5
		(217)	(119)	(104)	(8)
	Ceres-Uruaçu	3.2	45.9	18.6	77.7
		(280)	(144)	(118)	(9)
029	BR153-Goianésia	0.0	17.1	2.3	0.0
		(114)	(70)	(44)	(3)
	Goianésia-BR153	1.9	35.5	21.4	100.0
		(104)	(76)	(28)	(1)
030	Border-MG/GO-Catalão	4.2	26.1	28.4	63.9
		(385)	(199)	(109)	(36)
	Catalão-Border-MG/GO	2.4	7.0	17.3	28.5
		(169)	(101)	(52)	(14)

TABLE E.4 - (CONT'D)

Section Number	Direction	Front Axle % (Nº obs)	Single Rear Axle % (Nº obs)	Tandem Rear Axle % (Nº obs)	Triple Rear Axle % (Nº obs)
031	Anápolis-Brasília	6.5	58.1	61.6	66.7
032		(122)	(86)	(34)	(3)
	Brasília-Anápolis	2.6	10.9	11.7	30.0
		(190)	(118)	(43)	(10)
034	BR452-C.Dourada	1.0	12.0	9.6	0.0
035		(96)	(75)	(21)	(1)
	C.Dourada-BR452	0.0	11.8	4.3	0.0
		(91)	(68)	(23)	(0)
251	Anápolis-Corumbá	2.2	16.7	48.4	75.0
252		(90)	(60)	(31)	(4)
	Corumbá-Anápolis	1.5	34.1	71.3	100.0
		(65)	(44)	(21)	(3)
101	Paracatú-Unaí	0.0	4.1	0.0	-
		(94)	(73)	(21)	-
	Unaí-Paracatú	0.0	16.5	14.3	-
		(107)	(79)	(28)	-
105	Uberlândia-Patrocínio	1.1	11.9	12.1	100.0
		(276)	(185)	(91)	(3)
	Patrocínio-Uberlândia	0.4	23.6	18.4	0.0
		(282)	(203	(76)	(1)
106	Patrocínio-Guimarânia	2.5	31.6	9.1	0.0
		(122)	(98)	(33)	(4)
	Guimarânia-Patrocínio	1.2	14.1	8.0	50.0
		(82)	(57)	(25)	(2)

TABLE E.4 - (CONT'D)

Section Number	Direction	Front Axle % (Nº obs)	Single Rear Axle % (Nº obs)	Tandem Rear Axle % (Nº obs)	Triple Rear Axle % (Nº obs)
107	Araxá-Border-MG/SP	1.3	46.0	6.7	66.6
		(76)	(63)	(15)	(3)
	Border-MG/SP-Araxá	0.0	4.8	0.0	0.0
		(94)	(82)	(18)	(11)
109	Ent.BR365/BR040-J. Pinheiro	2.8	25.3	33.1	31.7
		(181)	(99)	(69)	(19)
	J.Pinheiro-Ent.BR365/ BR040	3.1	22.9	29.4	86.8
		(277)	(109)	(109)	(15)
110	Paracatú-Border-MG/GO	5.1	25.8	41.9	66.6
		(78)	(31)	(43)	(3)
	Border-MG/GO-Paracatú	2.2	30.8	39.1	61.6
		(92)	(39)	(46)	(13)
118	Capinópolis-C.Dourada	2.0	2.3	12.5	-
		(5)	(43)	(8)	-
	C.Dourada-Capinópolis	0.0	0.0	0.0	-
		(35)	(33)	(2)	-

lowing:

Front axle	5000 kg
Single rear axle	10000 kg
Tandem rear axle	17000 kg
Triple rear axle	25500 kg

Class 1 and 3 vehicles are not included in Table E.4 and the percentages of overladen axles are given in terms of the number of medium and heavy vehicle axles which were measured. In most cases, less than 3 percent of the front axles are oveladen, althought in some cases, such as for sections 021 and 022, up to 8 percent have been recorded. These results support the theory that truck drivers prefer to keep the front axle lightly laden because it is easier to steer and not as tiring.

From 10 to 35 percent of the single rear axles are overladen, depending on the type of road traffic. Some cases have been recorded in which from 40 to 80 percent of the single rear axles were overladen. These are associated with the sand, gravel or ore haul routes. Sections 002, 004, 009, 011, 203, 031, 032, 251, 252 and 107 fall in this category. A trend similar to the single rear axles is apparent for the tandem rear axles on the sand, gravel and ore routes. The percentage of overladen axles lies between about 5 and 20. This reduction in the number of overladen axles compared to the single rear axles could be ascribed to the fact that vehicles with tandem rear axles are generally used for long-haul transport, and consequently they would pass at least one of the weigh bridges, which are located along the main haul routes. Although the sample sizes of vehicles with triple rear axles are relatively small, 30 percent or more are overladen.

(1) *Load Equivalency Computations*

The AASHTO method of traffic load equivalency calculation has been adopted by the project (Ref. 9). In the AASHTO method a variety of factors can be used depending on the pavement section which is defined by the structural number (SN). An investigation of the first ten pavement cross-sections measured showed that the majority had an SN in the vicinity of 3. Consequently, the tabulated results for SN of 3 are used in all the calculations. Also used is a terminal serviceability index of 2.0.

The equations which were used are the following with the standard single axle load of 18000 *lb* (8.2t):

- Single Axles: Equivalency factor $= \left(\frac{W}{18000}\right)^{4.32}$

- Tandem Axles: Equivalency factor $= \left(\frac{W}{33220}\right)^{4.14}$

where W = axle or axle group weight in pounds.

The AASHTO method does not take into consideration three axles in a group, the so-called triple axle. An analysis by Austin Research Engineers (Ref. 10) indicated that subgrade compressive strains can be used to predict equivalency factors. This fact was used to derive equivalency factors for triple axles, and the resulting equation is:

- Triple Axles: Equivalency factor $= \left(\frac{W}{50560}\right)^{4.22}$

for a terminal serviceability of 2.0. The verified data cards are processed by the calculation program which uses the above equations. Ref. 9 suggests that axle-load intervals be used to facilitate calculations. Since the data is in a format which permits the calculation of the equivalency factors for each axle, it was decided to calculate equivalency factor for each axle and thus enhance some accuracy.

(2) *Analysis of Equivalent Axles*

The average number of equivalent axles per vehicle and sample size per vehicle class per section in both directions are grouped per state and presented in Table E.5. Initially, standard deviations were also calculated, but verification of the weight distributions on the front and rear axles of class 4 vehicles on section 007, shown in Figures 48 and 49, indicated that particularly the rear-axle distributions are non-normal, and thus standard deviations do not have any meaning.

Returning to Table E.5, it can be seen that on some sections the average equivalent axles have been calculated for class 3 vehicles, and the results are either 0.000 or 0.0001. After the initial measurements on a few sections, it was decided to discontinue measuring this vehicle class because the results are smaller than the accuracy of measurements on the heavier trucks. This result also applies to class 1 vehicles (passenger cars), and consequently these two classes of vehicles have no influence on the structural performance of pavements. It should be borne in mind that these two vehicle classes do play an important part in the performance of surfacings, such as surface treatments

TABLE E.5 - NUMBER OF EQUIVALENT AXLES PER VEHICLE FOR SECTIONS LOCATED IN DISTRITO FEDERAL

SECTION NUMBER DATE	ROAD Nº	DIRECTION	AVERAGE NUMBER OF EQUIVALENT AXLES PER VEHICLE (NUMBER OF MEASUREMENTS PER SAMPLE)											
			VEHICLE CLASS											
			2	3	4	5	6	7	8	9	10	11	12	13
001 05/05 - 07/05/76	EPCT	BR 020 - Barragem		0.000 (8)	1.91 (11)									
		Barragem - BR 020	0.06 (1)	0.000 (3)	0.02 (9)									
002 10/05 - 17/05/76	BR 251	Unaí - Brasília	0.43 (13)	0.001 (9)	2.32 (105)	0.93 (11)								
		Brasília - Unaí	0.46 (6)	0.000 (10)	0.58 (64)	1.05 (10)		0.10 (1)						
002 27/12 - 29/12/76	BR 251	Unaí - Brasília	0.44 (4)		2.79 (51)	1.76 (5)								
		Brasília - Unaí			0.24 (61)	0.19 (7)								
003 18/05 - 21/05/76	BR 020	Formosa - Brasília	0.27 (51)	0.001 (44)	0.52 (75)	0.78 (21)	4.75 (2)		19.06 (1)		7.25 (1)			
		Brasília - Formosa	0.26 (63)	0.000 (48)	1.25 (99)	0.78 (28)		0.15 (1)						
004 24/05 - 28/05/76	DF - 20	BR 060 - Gama		0.000 (9)	3.53 (71)	2.48 (10)		0.05 (1)						
		Gama - BR 060		0.000 (5)	0.08 (56)	0.33 (14)		0.10 (1)	0.14 (1)					

TABLE E.5 - NUMBER OF EQUIVALENT AXLES PER VEHICLE FOR SECTIONS LOCATED IN DISTRITO FEDERAL (CONT'D)

SECTION NUMBER DATE	ROAD Nº	DIRECTION	AVERAGE NUMBER OF EQUIVALENT AXLES PER VEHICLE (NUMBER OF MEASUREMENTS PER SAMPLE) VEHICLE CLASS 2	3	4	5	6	7	8	9	10	11	12	13
004 04/10 - 08/10/76	DF - 20	BR 060 - Gama			3.65 (24)	1.75 (1)								
		Gama - BR 060			0.06 (26)	0.58 (4)								
006 07/06 - 11/06/76	BR 040	Brasília - Luziânia	0.47 (28)	0.001 (20)	0.50 (197)	0.81 (100)	2.08 (4)	0.86 (4)	4.10 (25)	0.21 (2)		6.04 (1)	1.36 (2)	0.11 (1)
		Luziânia - Brasília	0.64 (39)	0.001 (29)	2.35 (215)	1.25 (157)	1.50 (4)	4.98 (6)	7.45 (29)	2.84 (2)		0.11 (1)		4.46 (2)
007 and 008 14/06 - 18/06/76	BR 020	Brasília - Formosa	0.35 (60)	0.000 (106)	1.36 (178)	0.68 (85)	0.01 (1)	4.36 (3)	6.97 (1)			0.25 (1)		
		Formosa - Brasília	0.38 (58)	0.000 (85)	0.42 (132)	0.84 (77)	5.72 (10)	0.20 (2)	12.88 (1)					
007 and 008 28/09 - 01/10/76	BR 020	Brasília - Formosa	0.43 (24)		1.44 (77)	1.00 (37)	0.01 (1)	4.05 (2)	6.97 (1)			0.25 (1)		
		Formosa - Brasília	0.40 (32)		0.29 (55)	0.94 (39)		0.25 (1)	12.88 (1)					
009 28/06 - 02/07/76	BR 060	Brasília - Anápolis	0.60 (11)	0.000 (24)	0.28 (183)	0.39 (148)	1.78 (4)	1.18 (3)	3.28 (10)					
		Anápolis - Brasília	0.73 (1)	0.001 (16)	2.65 (254)	1.55 (155)		2.47 (3)	4.79 (21)		4.36 (2)			

TABLE E.5 - NUMBER OF EQUIVALENT AXLES PER VEHICLE FOR SECTIONS LOCATED IN DISTRITO FEDERAL (CONT' D)

SECTION NUMBER DATE	ROAD Nº	DIRECTION	AVERAGE NUMBER OF EQUIVALENT AXLES PER VEHICLE (NUMBER OF MEASUREMENTS PER SAMPLE)											
			VEHICLE CLASS											
			2	3	4	5	6	7	8	9	10	11	12	13
010 31/05 - 03/06/76	DF - 8	Brasília - Brazlândia	0.33 (26)	0.000 (142)	0.59 (84)	0.59 (17)		0.36 (3)						
		Brazlândia - Brasília	0.82 (10)	0.000 (92)	0.18 (60)	0.39 (19)		0.28 (2)						
011 21/06 - 25/06/76	BR 070	Brasília - Barr. do Descob.	0.30 (8)	0.000 (120)	0.08 (254)	0.10 (9)		2.92 (2)						
		Barr. do Descob. - Brasília	0.14 (7)	0.001 (65)	2.14 (202)	0.58 (3)								
201 13/07 - 16/07/76	DF-21	Unaí - BR 020		0.000 (7)	0.46 (2)									
		BR 020 - Unaí		0.001 (7)	0.57 (5)									
202 05/07 - 09/07/76	DF-21	Unaí - BR 020		0.001 (11)	0.29 (7)									
		BR 020 - Unaí		0.001 (14)	1.22 (7)	0.01 (1)								
203 11/10 - 15/10/76	DR-12	EPCT - Papuda			0.04 (39)	0.01 (2)								
		Papuda - EPCT			3.06 (55)									

TABLE E.5 - NUMBER OF EQUIVALENT AXLES PER VEHICLE FOR SECTIONS LOCATED IN DISTRITO FEDERAL (CONT'D)

SECTION NUMBER DATE	ROAD Nº	DIRECTION	AVERAGE NUMBER OF EQUIVALENT AXLES PER VEHICLE (NUMBER OF MEASUREMENTS PER SAMPLE)											
			VEHICLE CLASS											
			2	3	4	5	6	7	8	9	10	11	12	13
204 06/12 - 10/12/76	DF-17	DF/GO Border - BR 020			0.66 (21)	2.85 (7)								
		BR 020 - DF/GO Border			1.59 (14)	0.24 (14)		0.28 (1)						

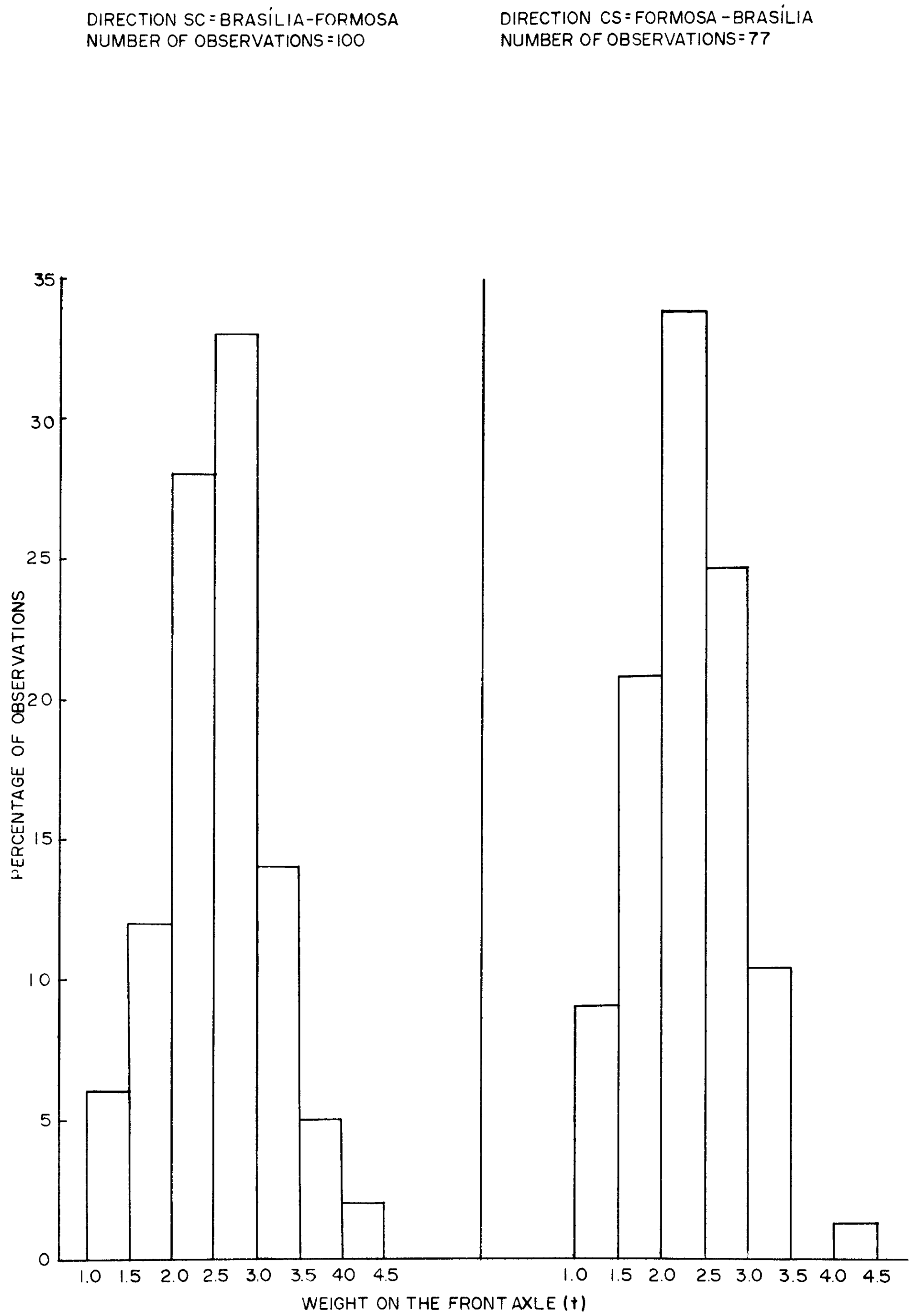


FIG. 48

HISTOGRAM OF FRONT AXLE LOADS - CLASS 4 VEHIC. - SECTION 007

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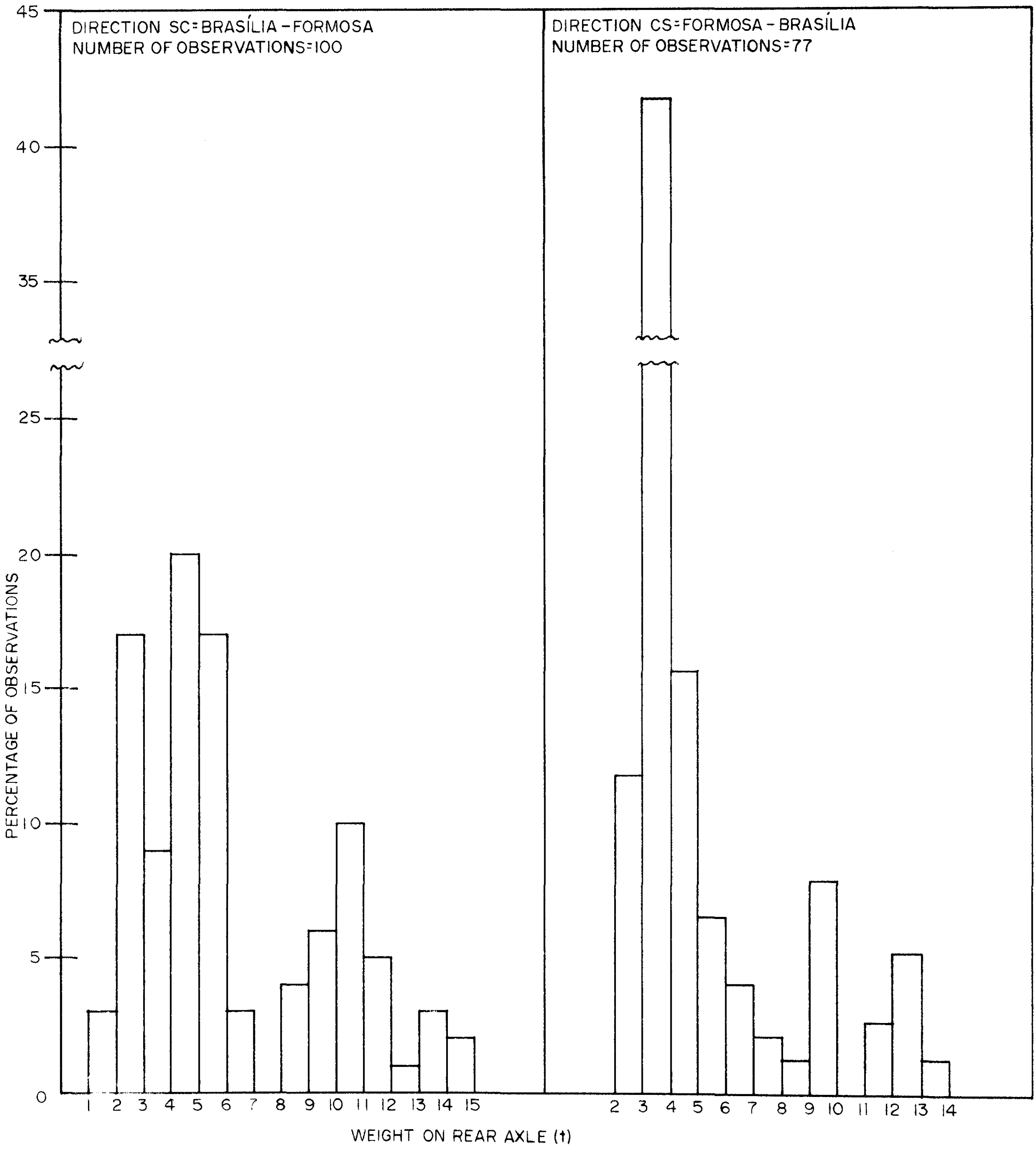

FIG. 49

HISTOGRAM OF REAR AXLE LOADS-CLASS 4 VEHIC.-SECTION 007

(Ref. 11).

To evaluate the results presented in Table E.5 , the equivalent axles per vehicle for each class, for the legal axle loads, have been calculated to use as a reference base. These results are presented in Table E.6.

The results in Table E.6 indicate that for classes 11 and 13, which are vehicles with single axles and trailers with single or tandem axles, the number of equivalent axles per vehicle are considerable in excess of the other vehicle classes. This is despite the fact that for a class 11 vehicle, the gross vehicle weight would be 35 t, whereas for a class 8 vehicle the gross vehicle weight is 40 t. Referring to Table E.5. it can be seen that very few of the class 11 or 13 vehicles exist on the road network, but those that have been measured have a severely damaging effect when laden. In those cases where the number of equivalent axles of about 0.10 has been recorded in Table E.5,it indicates that the vehicle was unladen. This is true for all the classes.

Buses, which are class 2 vehicles, are laden well below the maximum legal load on average, since on all the sections measured the minimum average number of equivalent axles was 0.22, whereas the maximum was 1.08. It was not possible to relate the number of equivalent axles per vehicle to the types of road or region. Generally, the equivalent axles of buses are equal in both directions. If no weight data is available on a particular road, the number of equivalent axles per class 2 vehicles can be estimated at between 0.5 and 1.0. It is suggested that this value be used for planning purposes and in the model, when other data are not available.

The average equivalent-axle results of class 4 vehicles are extremely variable, ranging from a minimum of about 0.1 to a maximum of 4.1, which is considerable in excess of the maximum result permissible with legal axle loads. Some stratification is possible which will permit better evaluation of the results. There are some sections which carry very heavy tip-truck traffic loaded with sand, gravel or ore in one direction, while the trucks return empty in the opposite direction. These sections are 002, 004, 009, 011, 203, 031, 032, 251, 252 and 107. The equivalent axle results on these sections are summarized in Table E.7. Compared with the maximum permissible equivalent axle loads, all sections except 011 show results exceeding the permissible for vehicles laden. In the case where no results are available,

TABLE E.6 - EQUIVALENT AXLES PER VEHICLE FOR THE MAXIMUM LEGAL AXLE LOADS

Vehicle Class	Equivalent Axles per Vehicle
2 and 4	2.48
5	1.75
6	4.83
7	4.10
8	4.02
9	3.38
10	3.30
11	7.19
12	1.67
13	6.47

TABLE E.7 - EQUIVALENT AXLE LOADS PER VEHICLE FOR CLASS 4 VEHICLES (SECTIONS LOCATED BETWEEN GRAVEL OR SAND PITS AND LOCATION OF USE)

Section Number	Number of Equivalent Axle Loads per Vehicle	
	Vehicles Laden	Vehicles Empty
002	2.32 and 2.79	0.58 and 0.24
004	3.53 and 3.65	0.08 and 0.06
009	2.65	0.28
011	2.14	0.08
203	3.06	0.04
031 and 032	4.10	0.54
107	3.50	0.39

estimates for two different cases on these haul routes can be used. The one is for roads where enforcement is strict, where the number of equivalent axles per vehicle for class 4 vehicles laden would range between 2.0 and 2.5, and the other case is for roads with no enforcement where the result would be between 3.0 and 4.0. In the unladen direction, the results would be from about 0.1 to 0.6. One route passes over four different sections, namely sections 004, 009, 031 and 032, and referring to Table E.7 it is interesting to note that all the results are similar.

On routes carrying normal over-the-highway traffic of class 4, the results generally lie between 1.0 and 2.0. These results can thus be used for estimative purposes where no data exist.

The situation for class 5 vehicles is similar to those of class 4 vehicles, except that the overloading is not as severe on the sand or gravel routes, although it does exist. In general, normal traffic exhibits between 0.7 and 1.6 standard axles per vehicle for class 5.

The other vehicle classes generally have very small sample sizes, mainly because of their relative low proportion on the road network. A special effort is being made to obtain measurements on a larger number of these vehicles. On some of the long-haul routes, larger numbers of class 8 vehicles are encountered. These are generally heavily laden to the limit or above. If data are lacking, an estimate of between 3.5 and 6.0 can be used. This figure will of course approach the value of 4.0, which is the maximum permissible, with more effective enforcement.

Thus far we have frequently referred to values which could be used in the absence of any data. It should, however, be borne in mind that for the analysis of pavement performance only actual results will be used.

(3) *Repeatability of Results*

Three of the sections in Table E.5 were repeated in order to verify the variability of measurements over time. Those sections which appeared to have unusual results were selected. Since the distributions are non-normal, standard parametric tests such as the F and t tests are not aplicable. A non-parametric test which considers the proportions of the two distributions above and below their common median was found which, although not a very strong statistical test, could be used as a good indicator (Ref. 12). This method is only meaningful for sample sizes of more than about 20. Analysis of the distributions of the repeated measurements of class 4 on section 002, class 4 on section 004, and classes 4 and 5 on sections 007 and 008 showed that there was no significant difference at the 95-percent level of confidence. In all cases a X^2 of less than 1.00 was found while the limiting X^2 is 3.84 at the 95-percent level of confidence. In trying to relate the distributions on both directions on these roads, large differences in the distributions were found, as would be expected from the average results presented in Table E.4.

This statistical technique was also tried in a attempt relate the distributions on roads carrying similar traffic, but this was not found to be successful.

d *Weigh-In-Motion System*

The system measures vehicle weights while the vehicles are travelling at normal highway speeds. It consists of two transducer units, which are built into the road in each wheelpath of a lane, and induction loops which serve as presence detectors and which also measure vehicle speeds. The supporting electronic hardware consists of a computer, which serves as calculating unit for the system and which also acts as driver for a magnetic tape unit, onto which all the data are recorded, a video screen were the data received are verified before writing onto tape, and a printer unit where the data can be printed. All this equipment is housed in a Caravan trailer, which makes the system completely mobile. Power is obtained from portable generators or from the electrical distribution network if power is close to the site.

The installations are made on tangential sections of road which have a grade of less than 1 percent, good riding quality and very little transverse deformation, to avoid problems as a result of dynamic forces. Up to the present time, two installations have been made. The installation is shown in Figure 50.

To initiate measurements, the transducers are placed into the frame and the wires to the control box are fixed to the transducers, and the computer is connected to the control box. After completion of testing, the transducers are removed and replaced by dummy transducers.

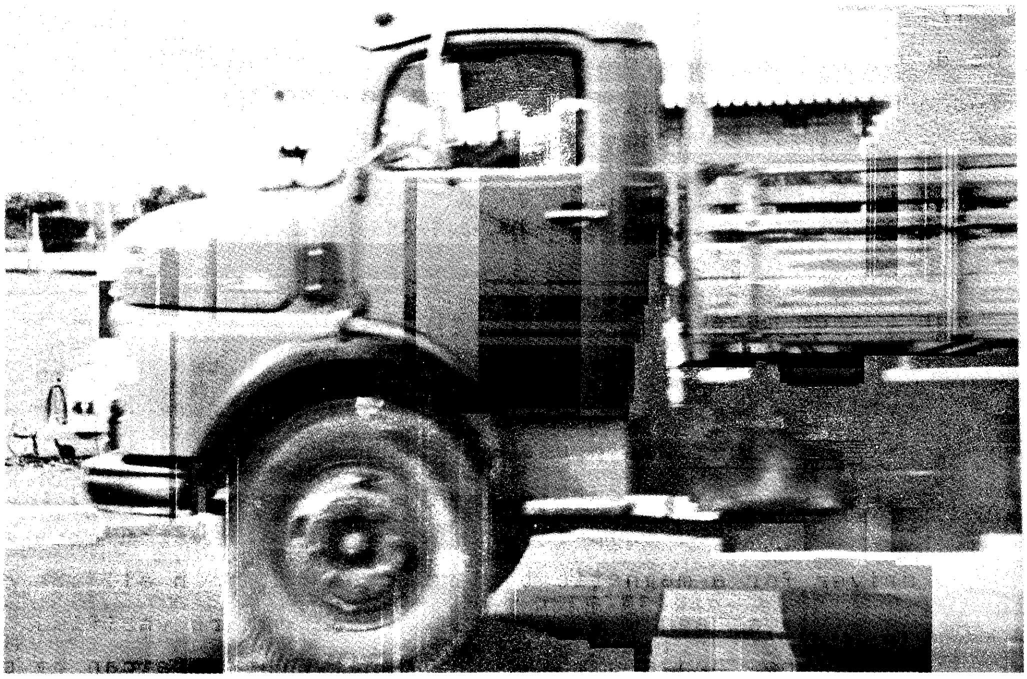

FIG. 50

VEHICLE WEIGHING WITH WEIGH-IN-MOTION SYSTEM

e Comparison of WIM and Portable Scale Results

After installation of the WIM system, a truck with known axle loads is used to calibrate the system. A necessary task is to check the reliability and calibration of the system in comparison with the portable scales. During two half-day periods, the WIM crew printed all the axle-load data of the vehicles passing and also noted the vehicle registration numbers. The portable scales were stationed about 1 km downstream, where they would not interfere with normal highway speeds at the WIM site. Axle loads of most vehicles were measured, again noting vehicle registration numbers. A comparison of the axle weights is shown in Figure 51. On the average, the portable scales weighed an equivalent of 243 kg higher than the WIM, which is on average about a 5-percent difference. This is an acceptable difference for these types of measuring devices. The slope of a regression line passing through the origin was calculated to be 0.435 for 237 points.

Another way of analyzing these results is to calculate the equivalency factors. as discussed above. These calculations for class 2 and 4 vehicles are presented in Table E,8 together with the sample sizes.

A difference of 5 percent in axle weights would result in a difference of 23.5 percent in the equivalency factors because the error in weight is raised to the power 4.32. The WIM results presented in Table E.8 lie within about 22 percent of the results measured with the portable scales, which are as would be expected from the average difference in weight between the two measuring devices.

f WIM Results for the Site on BR-040

Data were collected with the WIM at the site located at KM 1 on BR-040, near Brasilia, and adjacent to section 006. Measurements were limited to the lane carrying traffic from Belo Horizonte and Luziânia to Brasília. Previous measurements with the portable scales showed that this was the lane carrying the heavier traffic. Measurements were taken during the day from July 19 to August 2, 1977. Measurements were taken over a seven-day period from August 3 to 10, for 24 hours per day, in order to obtain comparisons between day and night axle loads.

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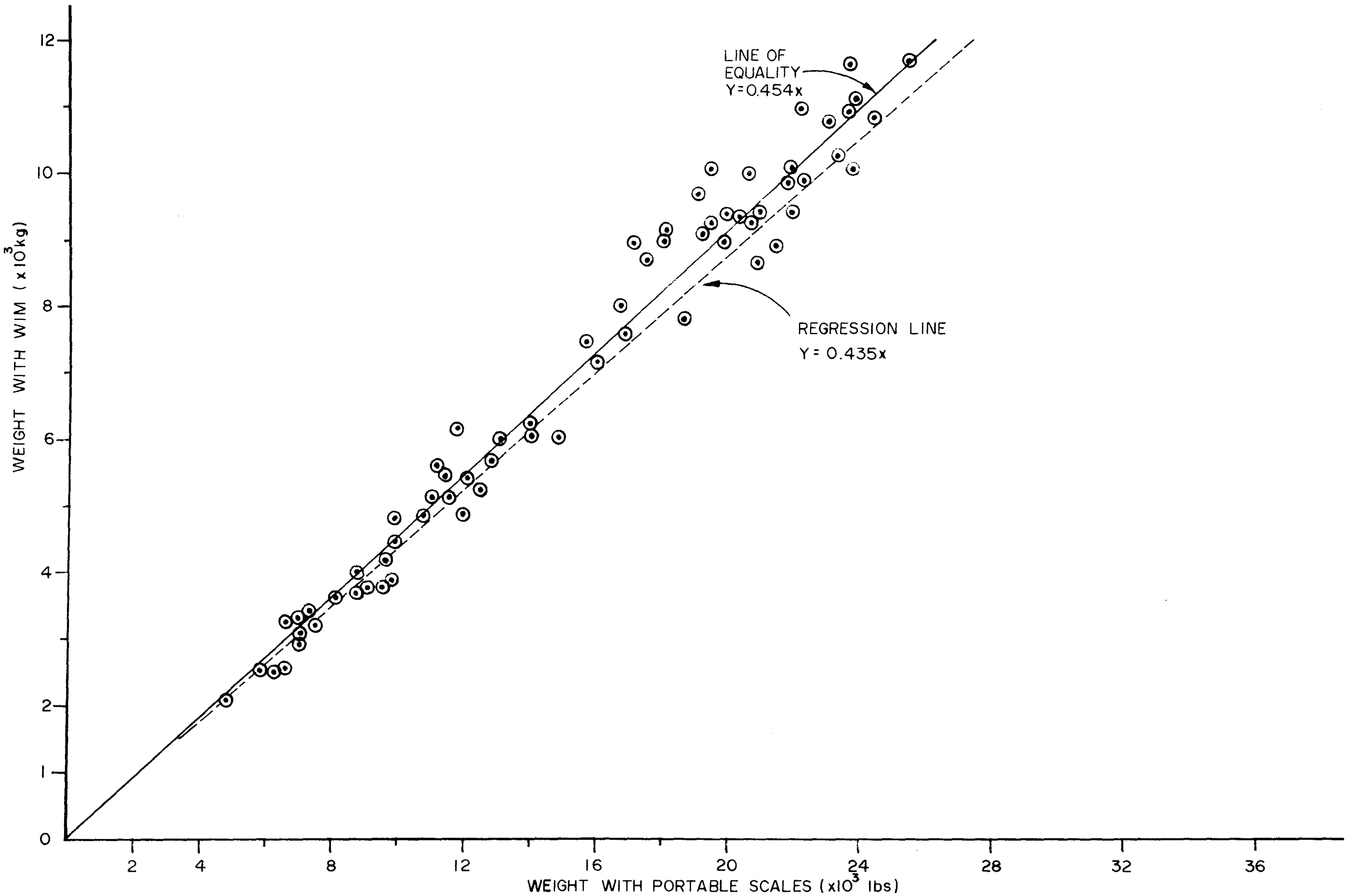

FIG. 51

COMPARISON OF AXLE LOADS MEASURED WITH THE WIM AND PORTABLE SCALES

TABLE E.8 - COMPARISON OF EQUIVALENCY FACTORS CALCULATED FROM DATA OBTAINED WITH THE PORTABLE SCALES AND THE WIM

	Equivalency Factors				Sample Size	
	CLASS 2		CLASS 4			
	Portable Scales	WIM	Portable Scales	WIM	CLASS 2	CLASS 4
2 August 1977	0.82	0.64	2.47	1.96	10	57
3 August 1977	0.92	0.66	2.76	2.15	3	20

(1) *Axle-Load Distribution*

The data collected were analyzed to give a frequency distribution of axle loads. The computer program, which uses the magnetic tape as input, uses either the class of vehicle written onto the tape by the operator, or the axle configuration and spacing to distinguish between the different vehicle classes. The frequency distributions for the two periods, day only, and day and night, are given in Appendix B. To illustrate the severity of overloading, the percentages of axles overladen are given in Table E.9.

There is little difference between the severity of overloading when night traffic is also considered. This point will be discussed further when comparing the equivalent axles per vehicle.

(2) *Equivalent Axles*

The number of equivalent axles per vehicle were calculated as in the case of the portable scales. These results are presented i Table E.10 for each day, together with the times during which measurements were made. When comparing day and night measurements, day has been defined as the hours between 08:00 and 17:00 hours each day, whereas night results were taken between 17:00 and 08:00 hours.

To facilitate the exposition about the number of equivalent axles during the day and at night, histograms (Figures 52 and 53) have been compiled, showing the number of equivalent axles during the day and at night, for the different days of the week for vehicle classes 2, 4 and 5. These classes conist of relatively large samples which make the comparisons meaningful. There is little variation in the equivalent axles per vehicle for the buses, which vary from 0.40 to 0.63 during the day and 0.35 to 0.57 at night. There is also no meaningful difference between the means calculated for day and night, which are respectively 0.48 and 0.43.

A larger variation in the number of equivalent axles is found for class 4 vehicles, for which the variation during day-time ranges from 1.12 to 1.74, and at night from 0.68 to 1.73. There is also no meaningful difference between the average equivalent axles calculated as 1.45 and 1.53 for day and night traffic, respectively,

TABLE E.9 - COMPARISON OF NUMBER OF EQUIVALENT AXLES CALCULATED FROM WIM AND PORTABLE SCALE DATA

Date	Number of equivalent axles per vehicle					
WIM	Class 2 (Sample size)	Class 4	Class 5	Class 6	Class 7	Class 8
19/7-29/7/77 (Daytime)	0.49 (251)	1.69 (814)	1.31 (322)	1.73 (13)	5.41 (14)	3.82 (22)
1/8-10/8/77 (Daytime)	0.48 (390)	1.45 (1048)	1.35 (579)	2.63 (12)	2.83 (33)	4.06 (51)
3/8-10/8/77 (Night)	0.43 (193)	1.53 (534)	1.28 (295)	2.22 (7)	3.68 (14)	3.21 (25)
Portable Scales						
7/6-11/6/76	0.64 (39)	2.35 (215)	1.25 (157)	1.50 (4)	4.98 (6)	7.45 (29)

TABLE E.10 - NUMBER OF EQUIVALENT AXLES PER VEHICLE FOR DIFFERENT DAYS OBTAINED WITH THE WIM

DATE TIME	ROAD Nº	DIRECTION	AVERAGE NUMBER OF EQUIVALENT AXLES PER VEHICLE (NUMBER OF MEASUREMENTS PER SAMPLE)											
			VEHICLE CLASS											
			2	3	4	5	6	7	8	9	10	11	12	13
19/7/77 13h40-16h30	BR040	Luziânia - Brasília	0.54 (9)		1.65 (49)	1.13 (11)		4.21 (1)						
20/7/77 10h00-16h15			0.45 (33)		1.54 (99)	1.33 (47)	3.77 (1)	4.72 (4)	3.02 (5)					
21/7/77 09h30-17h00			0.50 (44)		1.67 (115)	1.49 (44)	1.32 (3)	3.02 (1)	3.42 (3)					4.08 (1)
22/7/77 10h00-12h45			0.52 (16)		2.06 (43)	1.55 (17)	0.56 (1)	6.79 (1)	5.29 (1)			0.05 (1)		
25/7/77 12h45-17h15			0.47 (18)		1.83 (69)	1.07 (15)	1.76 (2)	8.28 (1)	9.96 (1)					4.20 (1)
26/7/77 10h05-17h10			0.51 (32)		1.50 (109)	1.17 (39)	0.79 (1)	6.69 (1)	3.75 (5)					
27/7/77 10h30-17h00			0.48 (30)		1.66 (94)	1.38 (40)			4.09 (5)					
28/7/77 09h30-16h45			0.47 (41)		2.08 (126)	1.28 (56)	2.77 (3)	4.81 (3)	2.38 (1)					
29/7/77 10h00-16h45			0.51 (28)		1.42 (110)	1.24 (53)	0.81 (2)	6.73 (2)	1.78 (1)			0.10 (1)		
1/8/77 10h30-17h00			0.48 (33)		1.68 (99)	1.24 (31)		2.23 (2)	3.93 (5)					
2/8/77 09h43-16h56			0.63 (31)		1.70 (113)	1.51 (42)	1.14 (1)	5.35 (1)	3.24 (11)			0.07 (1)		
3/8/77 11h59-17h02			0.50 (18)		1.70 (74)	1.67 (33)	1.90 (1)	5.60 (2)	1.22 (2)					
3-4/8/77 17h13-07h56			0.43 (37)		1.83 (97)	1.30 (73)	2.13 (2)	5.59 (1)	3.50 (9)					6.65 (1)
4/8/77 08h01-16h56			0.47 (45)		1.13 (138)	1.47 (88)	1.45 (1)	3.25 (8)	5.58 (4)					3.92 (1)
4-5/8/77 19h12-07h59			0.35 (27)		1.73 (80)	1.28 (42)	2.28 (2)	3.93 (5)	2.95 (3)	0.43 (2)				
5/8/77 07h54-16h50			0.48 (40)		1.26 (130)	1.39 (89)	2.61 (5)	1.71 (6)	5.31 (9)					
5-6/8/77 16h58-07h58			0.57 (19)		1.31 (90)	1.22 (25)	3.57 (1)	4.84 (2)	3.38 (3)					

TABLE E.10 NUMBER OF EQUIVALENT AXLES PER VEHICLE FOR DIFFERENT DATS OBTAINED WITH THE WIM (CONT'D)

DATE TIME	ROAD Nº	DIRECTION	AVERAGE NUMBER OF EQUIVALENT AXLES PER VEHICLE (NUMBER OF MEASUREMENTS PER SAMPLE) VEHICLE CLASS 2	3	4	5	6	7	8	9	10	11	12	13
6/8/77 08h05-17h00	BR040	Luziânia - Brasília	0.46 (39)		1.16 (89)	0.94 (52)		0.44 (3)	3.99 (8)			0.04 (1)		
6-7/8/77 17h16-08h00			0.42 (37)		0.68 (24)	1.31 (20)								
7/8/77 08h06-17h58			0.47 (59)		1.26 (66)	1.37 (47)	4.96 (2)	3.21 (3)	4.93 (4)	0.15 (1)		11.38 (1)		
7-8/8/77 22h14-06h42			0.48 (17)		1.58 (45)	1.10 (46)	1.57 (2)	6.56 (1)	3.63 (3)					
8/8/77 08h03-16h51			0.40 (38)		1.49 (101)	1.23 (66)	3.48 (1)	3.95 (3)	1.74 (3)					
8-9/8/77 17h05-07h53			0.42 (31)		1.59 (103)	1.15 (49)		1.37 (2)	2.47 (3)					
9/8/77 08h21-16h59			0.43 (45)		1.49 (136)	1.23 (67)		3.17 (4)	5.24 (2)					4.58 (1)
9-10/8/77 17h13-07h56			0.41 (25)		1.40 (95)	1.62 (40)		2.42 (3)	2.86 (4)					
10/8/77 01h05-11h30			0.52 (21)		1.74 (51)	1.45 (32)	0.62 (1)	0.64 (1)	3.93 (3)					

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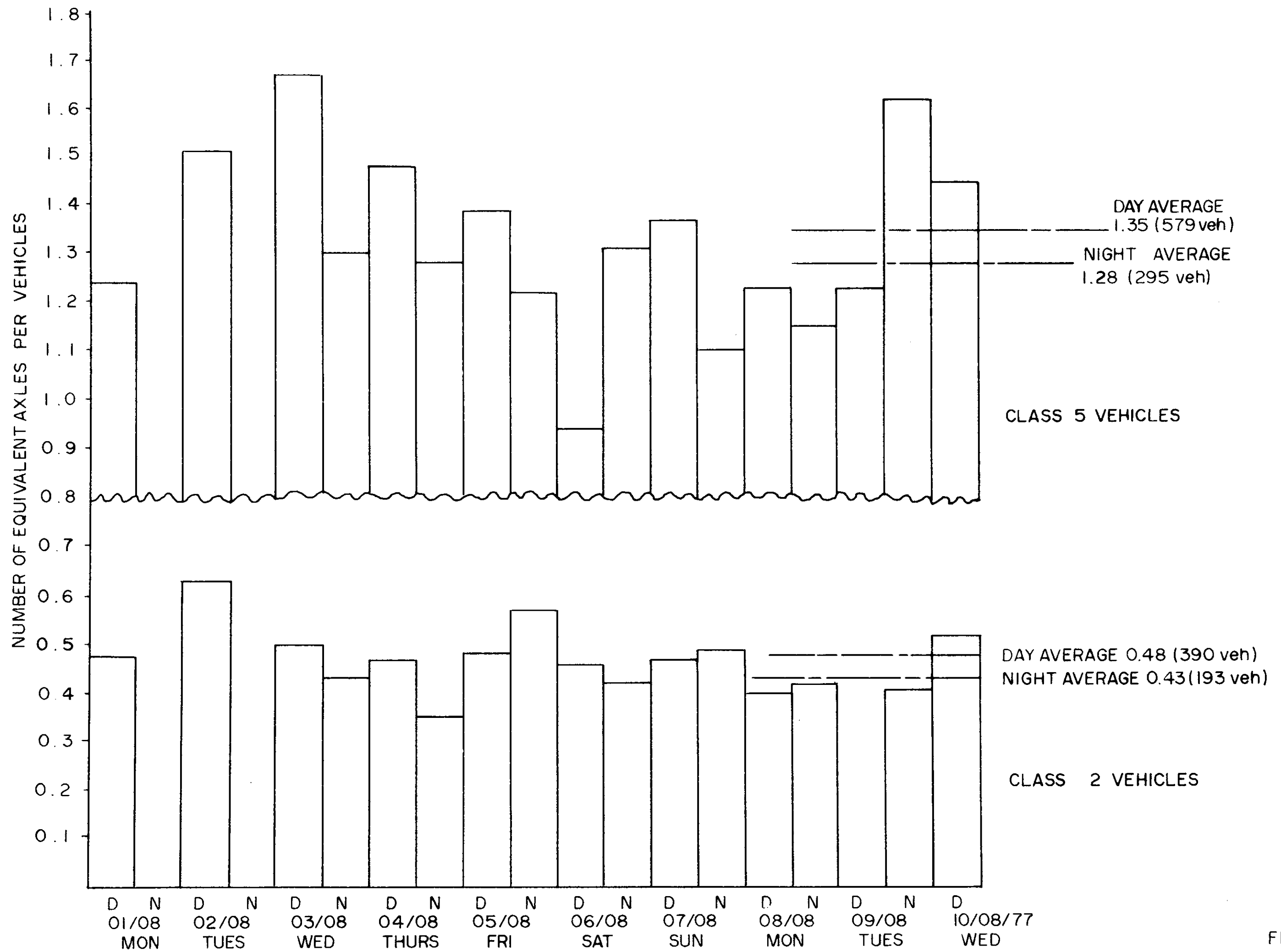

FIG. 52

NUMBER OF EQUIVALENT AXLES- CLASSES 2 AND 5 VEHICLE - DAY AND NIGHT - BR-040

MT-GEIPOT

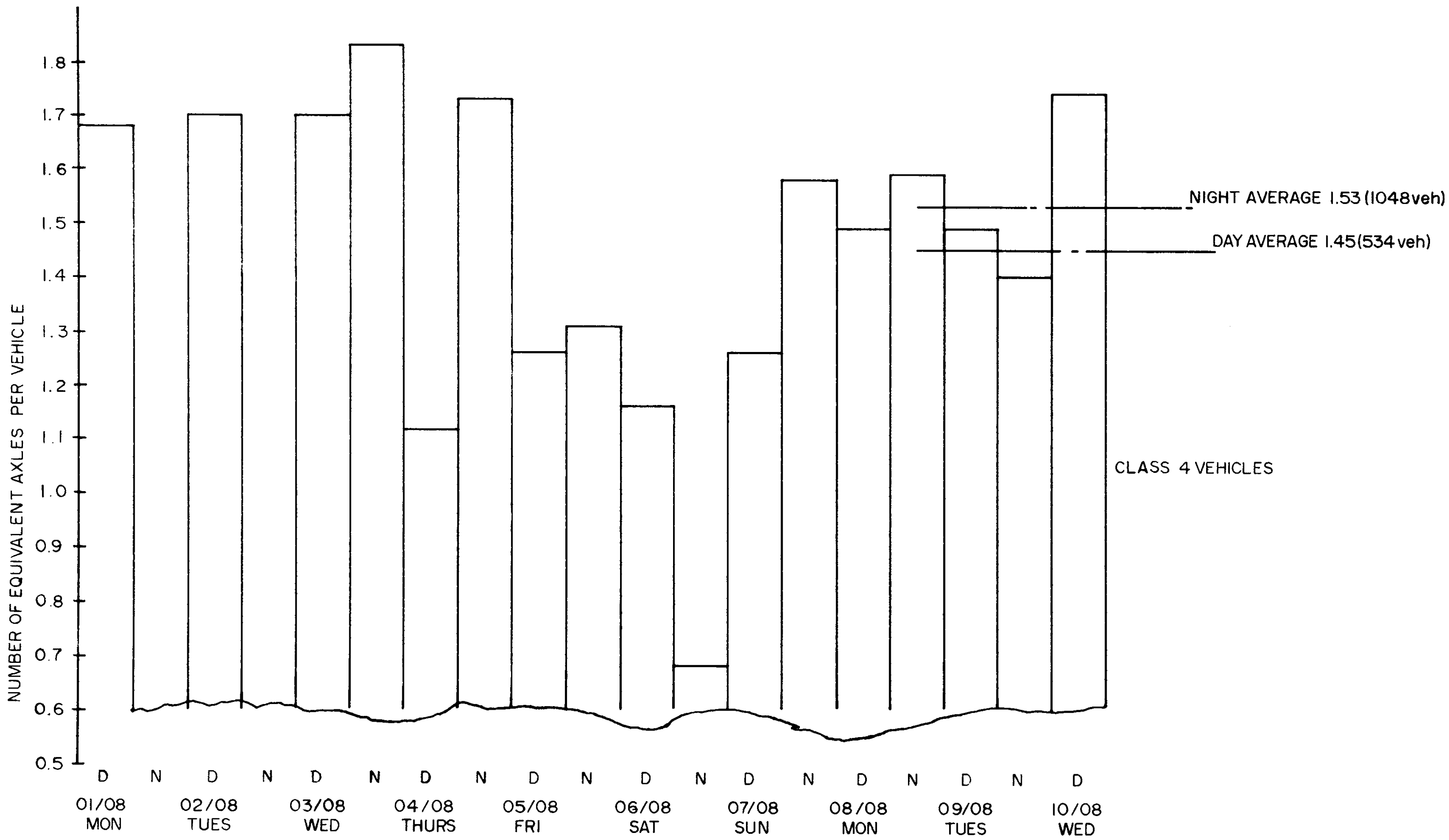

FIG.53

NUMBER OF EQUIVALENT AXLES FOR CLASS 4 VEHICLES FOR DAY AND NIGHT - BR-040

Class 5 vehicles also exhibit a relatively large variation in the number of equivalent axles per vehicle. Daytime averages range from 0.94 to 1.67, whereas night results range from 1.10 to 1.62. Again there is no meaningful difference between the total daytime and night-time averages of 1.35 and 1.28.

A further comparison was made between average equivalent axe results calculated for two daytime and one nighttime period from WIM data, as well as the results calculated from the portable-scale data for section 006 in the same direction. These results are presented in Table E.11 for vehicle classes 2, 4, 5, 6, 7 and 8, together with tha sample sizes. There are no meaningful differences for the results of class 2, 5, 6 and 7 vehicles, considering the sample sizes. The differences between the WIM and portable scale data of class 4 vehicles could be ascribed to the relatively large proportion of these vehicles, which were carrying gravel and which were weighed with the portable scales. These vehicles appear sporadically since there is no permanent gravel pit located on this route. The difference between WIM and portable scale results for class 8 vehicles are accepted to be normal variations in vehicle weights passing over the road.

9 *WIM Results for the Site on BR-060*

Data were collected with the WIM at another site, located outside the DNER residence near Anápolis on BR-060. The results obtained at this site are not directly comparable with any results obtained with the portable scales, since heavy traffic is generated by the sand pits which are located between the WIM site and the pavement study sections. Measurements, which were limited to the lane carrying traffic from Anápolis to Brasília, were taken over a seven-day period from August 17 to 24 for 24 hours per day, in order to obtain axle load distributions and comparisons between day and night equivalent axles per vehicle.

(1) *Axle-Load Distribution*

The axle-load distribution was calculated as for the first site and is presented in Appendix B. To illustrate the severity of overloading, the percentagens of axles overladen are shown in Table E.12.

TABLE E.11 - COMPARISON OF NUMBER OF EQUIVALENT AXLES CALCULATED FROM WIM AND PORTABLE SCALE DATA

Date	Number of equivalent axles per vehicle					
	Class 2 (Sample size)	Class 4	Class 5	Class 6	Class 7	Class 8
WIM						
19/7-29/7/77 (Daytime)	0.49 (251)	1.69 (814)	1.31 (322)	1.73 (13)	5.41 (14)	3.82 (22)
1/8-10/8/77 (Daytime)	0.48 (390)	1.45 (1048)	1.35 (579)	2.63 (12)	2.83 (33)	4.06 (51)
3/8-10/8/77 (Night)	0.43 (193)	1.53 (534)	1.28 (295)	2.22 (7)	3.68 (14)	3.21 (25)
Portable Scales						
7/6-11/6/76	0.64 (39)	2.35 (215)	1.25 (157)	1.50 (4)	4.98 (6)	7.45 (29)

TABLE E.12 - PROPORTION OF AXLES LADEN ABOVE THE LEGAL LIMITS MEASURED WITH THE WIM ON BR-060

Date	Percentage of Axles Overladen (Sample Size)			
	Front Axles	Single Rear Axles	Tandem Rear Axles	Triple Rear Axles
17/8-24/8/77 (Day and night)	4.1 (2385)	20.2 (1495)	48.9 (948)	44.6 (116)

(2) *Equivalent Axles*

The calculated number of equivalent axles per vehicle are presented in Table E.13 for each day, together with the times during which measurements were made. Day and night are as defined before. Histograms (Figures 54 and 55) have been compiled to facilitate the exposition on the number of equivalent axles during day and night for different days of the week for vehicle classes 2, 4 and 5. There is little variation in the equivalent axles per vehicle for buses, which vary from 0.56 to 1.18 during the day and 0.66 to 0.89 at night. There is also no meaningful difference between the means calculated for day and night, which are respectively 0.90 and 0.81.

Class 4 vehicles again exhibit a large variation in the number of equivalent axles, varying from 0.38 to 2.73 during the day and from 0.68 to 1.69 at night. There is also a fairly large different between the day and nighttime means of 1.89 and 1.28 calculated.

Class 5 vehicles also exhibit some variation, but not as much as class 4 vehicles. Daytime averages range from 1.49 to 2.05, whereas at night results range from 1.58 to 2.09. Again there is no meaningful difference between total daytime and nighttime averages of 1.70 and 1.77.

6 CONCLUSIONS

Axle-load distributions obtained with the portable scales for 34 sites show that 10 to 35 percent of the vehicles are overladen. On those routes located between the gravel or sand pit, or the mine where ore is mined and the destination of these materials, from 40 to 80 percent of the rear axles are overladen.

The data for these sites were also used to calculate the number of equivalent axles per vehicle for the different classes of vehicles. These results will be used together with traffic counts, since the road was opened to traffic to calculate the number of equivalent axles carried by a section during its life. Indications have also been given as to the number of equivalent axles to be used in case of the absence of data for planning purposes. Repeated measurements on the same section but at different time intervals, have shown that the distributions of the equivalent axles are not significantly different at the 95-percent level of confidence. For all the vehicle classes, except

TABLE E.13 - NUMBER OF EQUIVALENT AXLES PER VEHICLE FOR DIFFERENT DAYS OBTAINED WITH THE WIM

DATE TIME	ROAD Nº	DIRECTION	AVERAGE NUMBER OF EQUIVALENT AXLES PER VEHICLE (NUMBER OF MEASUREMENTS PER SAMPLE)											
			VEHICLE CLASS											
			2	3	4	5	6	7	8	9	10	11	12	13
17/8/77 14h58-16h57	BR-060	Anápolis - Brasilia	0.56 (9)		2.18 (14)	2.05 (14)			5.68 (4)					
17-18/8/77 17h03-06h51			0.71 (18)		1.09 (55)	1.79 (54)	0.90 (1)	0.07 (1)	7.14 (10)					
18/8/77 07h59-17h02			0.83 (27)		1.94 (81)	1.78 (74)	0.69 (1)	1.47 (2)	0.97 (7)	3.91 (1)				
18-19/8/77 17h27-07h59			0.77 (24)		0.80 (54)	1.58 (51)		7.20 (1)	3.89 (4)					
19/8/77 08h06-16h55			0.81 (28)		1.76 (83)	1.75 (68)	0.19 (2)	5.34 (2)	3.22 (15)					
19-20/8/77 17h05-07h52			0.85 (41)		1.69 (59)	1.83 (66)	0.19 (1)	1.33 (3)	4.80 (9)	3.81 (1)				
20/8/77 08h02-16h56			0.89 (35)		1.63 (67)	1.75 (61)	0.12 (1)	0.09 (1)	5.91 (15)					
20-21/8/77 17h04-07h56			0.66 (30)		0.68 (38)	2.09 (26)		9.67 (2)	7.93 (4)					10.84 (1)
21/8/77 08h05-16h59			0.86 (33)		0.38 (29)	1.49 (40)		2.38 (5)	13.96 (2)					
21-22/8/77 17h11-07h59			0.89 (44)		1.35 (56)	1.75 (59)		2.28 (5)	6.87 (13)					
22/8/77 08h05-16h58			0.95 (29)		2.25 (74)	1.56 (78)	1.69 (1)	1.83 (3)	2.93 (10)	3.75 (1)				
22-23/8/77 17h07-07h58			0.87 (32)		1.62 (72)	1.88 (112)		2.54 (2)	7.11 (5)	1.73 (1)				
23/8/77 08h02-17h01			0.92 (31)		1.90 (96)	1.91 (62)	0.78 (2)	4.49 (2)	2.97 (9)	3.34 (4)				
23-24/8/77 17h22-07h58			0.78 (25)		1.36 (71)	1.59 (71)		2.77 (5)	7.65 (5)					
24/8/77 08h05-14h36			1.18 (18)		2.73 (46)	1.54 (57)	0.06 (1)	4.96 (4)	3.29 (4)					

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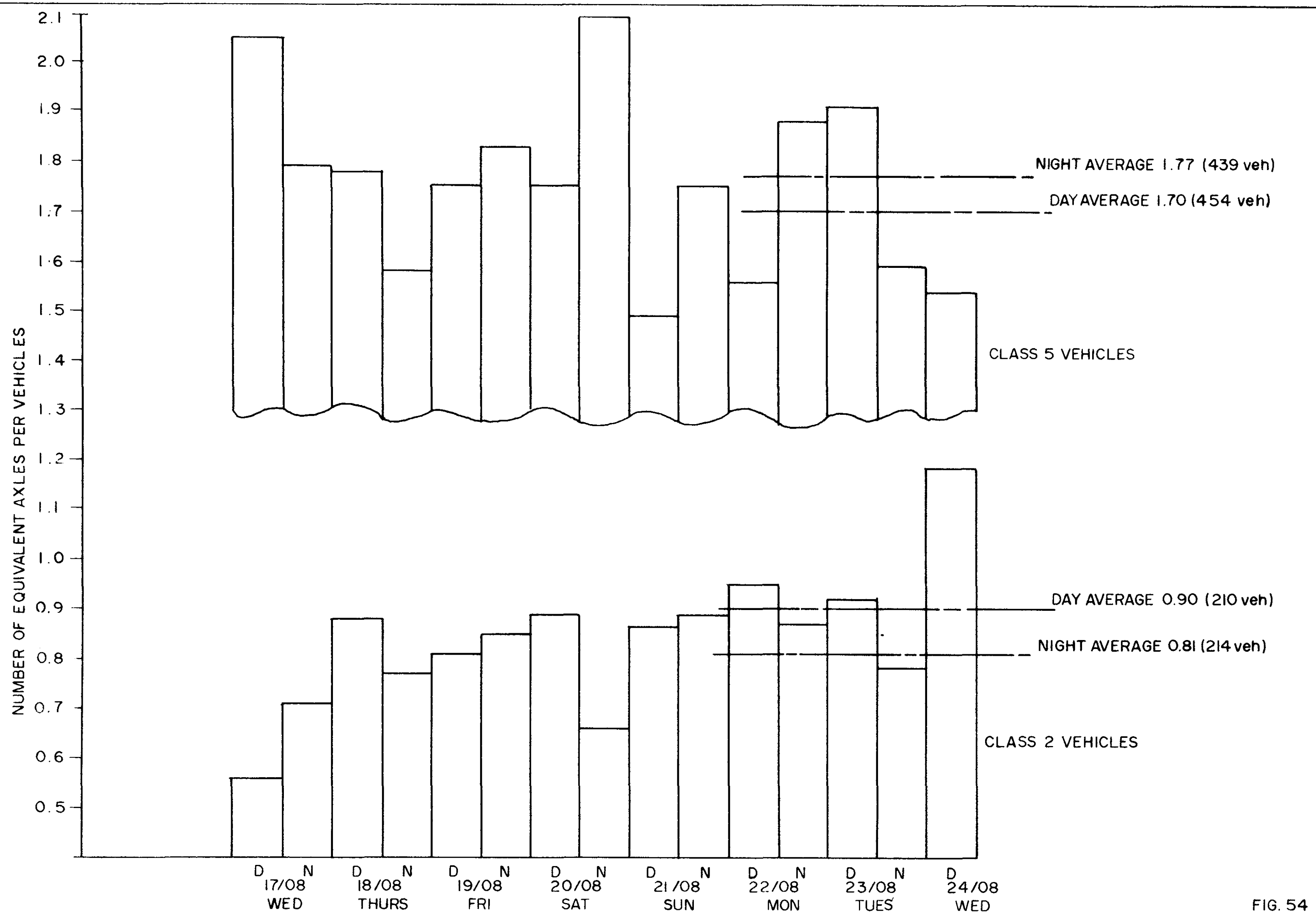

FIG. 54

NUMBER OF EQUIVALENT AXLES FOR CLASSES 5 AND 2 VEHICLES FOR DAY AND NIGHT - BR-060

MT-GEIPOT

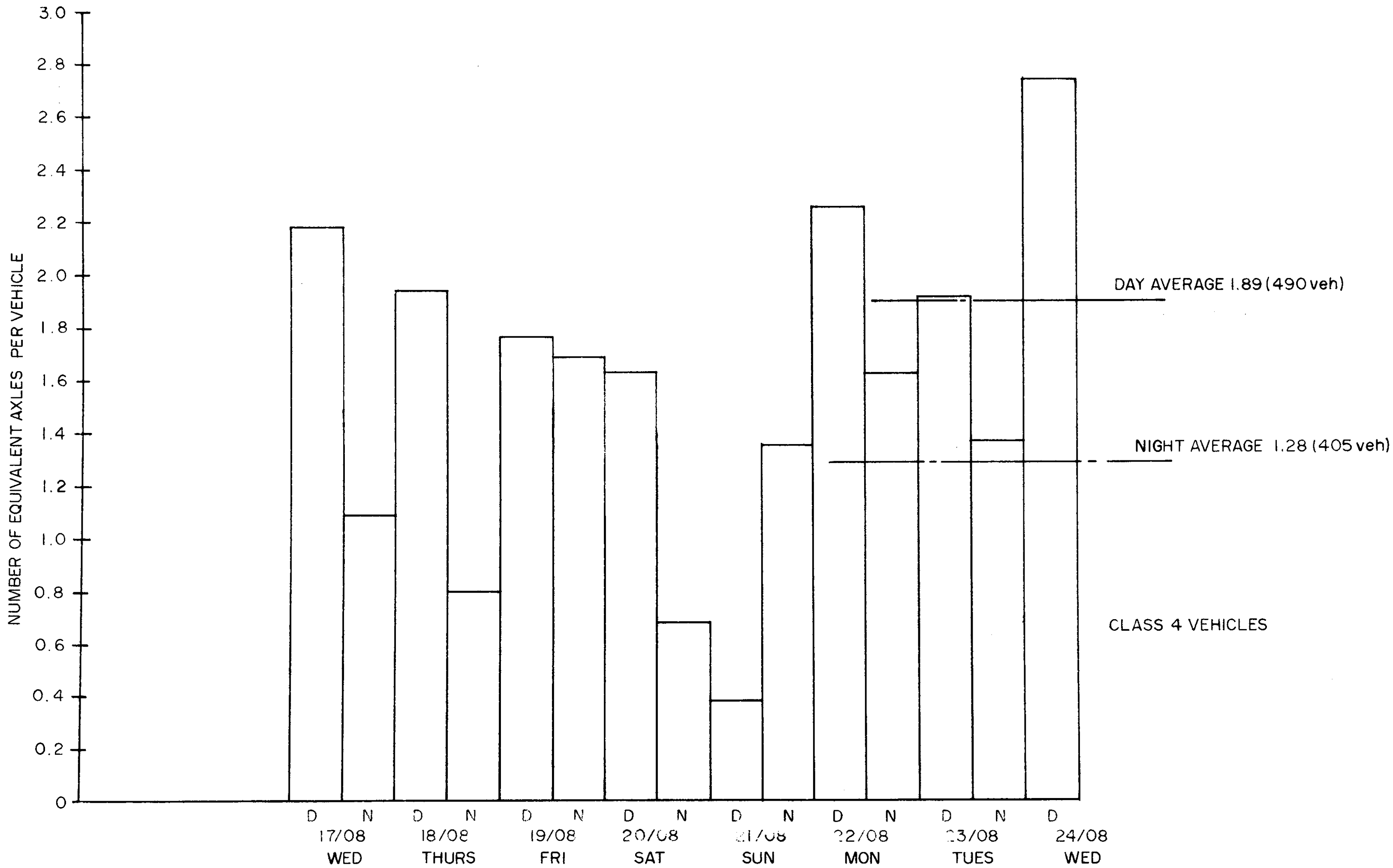

FIG. 55

NUMBER OF EQUIVALENT AXLES FOR CLASS 4 VEHICLES FOR DAY AND NIGHT - BR-060 class 2, there is a meaningful difference between the number of equivalent axles in both directions.

Some very interesting results have been obtained with the WIM system. Axle loads measured are similar to those measured with the portable scales. Meaningful differences in the number of equivalent axles per vehicle for class 4 and 5 vehicles were recorded for different days of the week during the day as well as at night. However, when considering average day and average night results over a week period, there is no meaningfull difference. Therefore, the procedure adopted to measure at one site over a five-day period during daylight hours with the portable scales appears to be valid, and not influenced by daily variations, or day-to-night variations. These conclusions will be verified at future WIM installations, since the equipment is expected to take regular measurements at six sites.

7 SUMMARY

The pavement performance and maintenance studies is program geared to complete a model by November 1978. The experiments are, however, designed and developed to continue under the auspices of highway authorities in Brazil after the term of the project staff has expired.

To complete a model by November 1978 it is essential that the different relationships being developed by our group be available for input into the model by July 1978. This means that data to be used in comparing maintenance alternatives will have a maximum 15 months time base, and many of the sections with maintenance would only be nine months old.

8 WORKPLAN AND SCHEDULE

Figure 56 shows the activities planned for the remainder of the study. All of the principal measurement activities on both the paved and unpaved test sections are shown to the very end of the study period. The assumption made is that this work will be carried forward by State highway authorities following the termination of the activities of this research project.

GEIPOT
Empresa Brasileira de Planejamento de Transportes

WORK PLAN AND SCHEDULE

ACTIVITY	PERÍODO														
	1977				1978										
	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N
Measure roughness with Maysmeter and Profilometer on paved sections	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Measure roughness with Maysmeter on unpaved sections	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Arrange contract with consultants for field testing		■													
Carry out in-situ material tests on paved sections	■	■	■	■	■	■	■	■							
Carry out in-situ material tests on unpaved sections	■	■	■	■	■	■	■	■	■	■	■	■			
Take traffic counts and vehicle weight surveys on test sections	■	■	■	■	■	■	■	■	■	■	■				
Measure deflections on paved sections with Benkelman beam and Dynaflect	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Carry out deflection measurements to obtain seasonal weighting factors	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Carry out condition surveys on paved sections	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Measure looseness of gravel, rut depth, etc. on unpaved sections	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Analyze available data	■	■	■	■	■	■	■	■	■	■	■	■			
Develop relationships for the model (BRIAM)					■	■	■	■	■	■	■	■			
Write first draft of Final Report												■			
Complete contractual obligation and Final Report													■	■	■

FIG. 56