CHAPTER 6
CALIBRATION AND VALIDATION OF THE MODEL

6.1 PURPOSE OF CALIBRATION AND VALIDATION OF THE MODEL

In order to verify if a model is satisfactory, it is essential to compare its simulation results with actual known responses. Validation is the process of examining if a simulation model produces satisfactory predictions (of traffic behavior, in the case of the MST). For any segment of a highway, the basic elements for the validation of the MST will be simply the average speed observed on the course, variance in traffic flow, composition of traffic and directional division. However, due to the nature of the assumptions of the Model, it is improbable that the results will, in first instance, agree with field observations. Therefore, the Model requires calibration, which can be defined as the process of adjusting the parameters, the assumptions and the logic of the Model, in such a way that the simulation results agree satisfactorily with field observations.

6.2 CALIBRATION OF FREE-SPEED MODEL

Since the behavior of the vehicle in the MST is, to a great extent, controlled by the free-speed matrices, it is essential that these free speeds, derived from the SPEEDS program or from the MTC, be compared with field observations. The free-speed experiment was carried out both on straight and curved sections, all of which were homogeneous segments with uniform grades. Aside from this - as already stated - certain assumptions were made with respect to the representation of vertical curves in terms of equivalent grades.

Observations of average speed were made on relatively short highway segments (4 - 5 km) on undulated terrain. Observers were positioned along each of these segments so that, through the utilization of intermediate time records, they could ensure that traffic conditions were truly free. After that, the mean of the average speeds of each vehicle class was compared with the estimates generated by the Model.

The differences between observed speed and estimated speed thus identified required additional efforts in data gathering and analysis. Two procedures were then adopted so that the Model would produce more satisfactory results:

(a) the data of specific equations were analyzed again with the inclusion of more recent data and, in some cases, other equations were adopted;

(b) the logic of the program was altered so as to include some speed-change equations representing specific situations.

As can be noted in Table 6.1, at the conclusion of this calibration process the analysis of variance did not reveal significant differences between the speeds computed by the MTC and those effectively observed on the test segments.

6.3 *CALIBRATION OF SIMULATION MODEL*

In the calibration of the MST under non-free flow conditions, the effects of interaction among vehicles (the headway distribution among them at any point along the highway section) were considered. Aside from this, the MST specifies number, size and distribution of queues, as well as overtaking operations, all of which are factors based on various suppositions and on the logic of the Model. These traffic flow characteristics, provided by the MST as output, were statistically compared with field observations and adjusted accordingly, as done in Australia, in September 1980, by Kaesehagen and others, and described by Moser (1980).

What is important to the operation of the Model is to number each one of the vehicles as they are introduced into the highway segment. As already indicated, use is made of a compound exponential distribution of the Schuhl type, together with prediction equations with parameters similar to those developed by Grecco and Sword (1968) for use in probability equations. However, Grecco and Sword (1968) made no mention of the occurrence of overtaking operations at the observation points, nor of the fact that these vehicles were included in the headway distribution. Since overtaking operations may occur at most points along the highway, it is necessary to record

TABLE 6.1 - MEAN SPEEDS GENERATED BY THE MTC VERSUS FIELD OBSERVATIONS

	SPEED (km/h
FIELD	64.2
MTC	64.2

	GRADE (%)	SPEED (km/h)
FIELD	0	68.6
MTC	0	69.7
FIELD	6	62.0
MTC	6	61.5

	TYPE OF SURFACING	SPEED (km/h)
FIELD	PAVED	72.8
MTC		71.0
FIELD	UNPAVED	59.9
MTC		60.8

	VEHICLE CLASS	SPEED (km/h)
FIELD	CAR	73.8
MTC		74.2
FIELD	BUS	64.3
MTC		61.2
FIELD	EMPTY UTILITY	68.9
MTC		68.6
FIELD	LOADED UTILITY	62.4
MTC		63.9
FIELD	EMPTY TRUCK	60.2
MTC		62.3
FIELD	LOADED TRUCK	55.4
MTC		55.0

	GRADE SIGN	SPEED (km/h)
FIELD	+	57.2
MTC	+	57.5
FIELD	-	71.2
MTC	-	71.0

Source: MOSER, Barry. Recalibration of the TAFA Speed Prediction (TB6), May 2, 1980, ICR/BM/073/80.

the vehicle in the overtaking mode, whenever this occurs at the observation points. In the same way, these vehicles should be considered as Model outputs, so that parameters can be developed for a headway distribution that takes this specific situation into consideration.

The order, classification and headway between vehicles at kilometer zero (start of segment), and at the sampling station at km 0.5, are presented in the Appendix. The headways are represented by the number of time increments, the latter being designated by (-). This type of presentation clearly shows the number, size, composition and distribution of queues for direct comparison with field observations. It also shows the headway distribution for various classes of vehicles in the overtaking mode at the start of the section and at the sampling station. At the present time, the MST routine for the generation of vehicles does not permit vehicles to enter the segment with a headway below the minimum. The vehicles in the overtaking mode at the start of the section are included in the headway distribution. However, at the sampling station, the vehicles listed in the overtaking mode are excluded from the distribution, since they could have no headway at all or even be slightly ahead the overtaken vehicle.

As the vehicles are introduced into the highway segment, a listing including the descriptive variables (class, additional length, etc.) and the operational variables (performance, speed, etc.) of the vehicles in both lanes is also given as output. The program also provides the option of generating a listing of the vehicle files for each time increment. This file contains the number of the lane, number of the vehicle, number of the previous vehicle, number of the posterior vehicle, class of the vehicle, operation mode, performance, speed, headway, distance covered, accumulated time, travel time and accumulated fuel consumption. Though this is a rather voluminous output, it does allow the user to describe the behavior of each vehicle along the entire segment.

Considering the fact that a satisfactory headway distribution can be developed for the vehicles at the moment they enter the segment, the headway distribution and the average simulated speeds for a given highway segment should agree with the field observations obtained at the sampling stations.

The differences between the average simulated speeds and those observed are a direct result of the Model's overtaking rules. To verify the correspondence between the simulated and the actual, it was also necessary to record the number of overtakings observed in the field, in each segment, comparing these to those simulated. The number of simple and multiple overtakings made between the start of the segment and the sampling station is presented and explained in the Appendix. The item "multiple overtaking" indicates the number of vehicles overtaken at a single time, in a queue.

Should the Model underestimate or overestimate the number of overtakings or the safety margin, or both, it will become necessary to adjust the overtaking speed differential or the maximum number of vehicles that can be overtaken in a queue, or both.

Once the procedure described above was established, the traffic flow times and speeds observed in seven segments with different characteristics and traffic of between 200 and 1,000 vehicles per hour (sum of both directions) were timed with a chronometer. Table 6.2 presents the most important characteristics of each test section between the three observation stations.

The calibration consisted in adjusting the parameters that constitute the Model's input data, in such a way that the MST would reproduce traffic flows that were comparable to those actually observed on the test sections. After successive processing operations, the parameters which resulted in the best approximations were the speed differences between the cars which overtake, and those that are overtaken, as well as the time the former spend in the opposite lane.

Input parameters	1st version	2nd version
Speed difference between automobiles	10 km/h	13 km/h
Speed difference between automobiles and other vehicles	10 km/h	15 km/h
Time spent in opposite lane	60 sec	30 sec

At the conclusion of the statistical analyses, approximations were obtained with deviations of less than 5%, a level considered fully acceptable for a simulation model.

TABLE 6.2 - GRADES OF TEST SECTIONS USED IN TRAFFIC-FLOW OBSERVATIONS - EXPERIMENTS TB-8 AND TB-9

TEST SECTION		PREDOMINANT GRADE BETWEEN STATIONS					% COURSE			ADT
		1 → 2		1 → 2		1 → 3	IN CURVES	VISIBILITY OF 500m		
		Gr.	Ext.	Gr.	Ext.			1 → 3	1 → 3	
TB - 8	568	5%	500m	5%	500m	1000m		~50%	~90%	12000
	571	5%	500m	5%	500m	1000m	~90%[1]	0%	0%	15000
	572	0%	540m	0%	500m	1040m		100%	100%	6600
	573	1.1	557m	1.1	464m	1021m	~40%[2]	~60%	~30%	7800
TB - 9	574	~5%	1100m	-4~	1500m	2.6km		~70%	~70%	4400
	575	-2.5~	1500m	~1.5	2600m	4.1km	~25%[3]	~80%	~80%	4600
	576	-5.8~	1400m	~6%	1300m	2.7km	~50%[4]	<10%	<10%	4000

[1] Approximately 90% of course with curves of $R < 250$m

[2] Approximately 40% of course with curve of $R = 1500$m

[3] Approximately 25% of course with curve of $R \simeq 1200$m

[4] Approximately 50% of course with curves of $R < 400$m

	Average Speeds	Headways	Overtakings
Actual data	66.9 km/h	2.382 seconds	430
Simulated data	65.8 km/h	2.345 seconds	413

6.4 VALIDATION OF SIMULATION MODEL

The process of validation of the MST consisted of the three following steps:

1) The travel times of a sample of vehicles between stations 4 and 5 (primary lane) and between stations 3 and 2 (opposite lane) on test section no. 568 (Figure 6.1) were recorded. (These data, as well as the mean, standard deviation and variance by vehicle class are found in Tables 6.3 and 6.4, respectively).

2) The MST was also used to simulate the behavior of the vehicles between the same stations 4 and 5 and between stations 3 and 2. (The results obtained are presented in Tables 6.5 and 6.6).

3) The hypothesis of equality of variances between the travel times observed and those simulated - utilizing the Bartlett test (Ostle, 1972) - and the hypothesis of equality of the means between the travel times observed and simulated, by vehicle class, were tested. These tests and their results are described below.

6.4.1 *Bartlett Test*

There are a number of possible procedures for testing the equality of variances of two samples. The Bartlett test of two samples was used in this analysis. (It is the standard parametric test in such cases).

In order to develop the Bartlett test of two samples it is necessary to define the following variables:

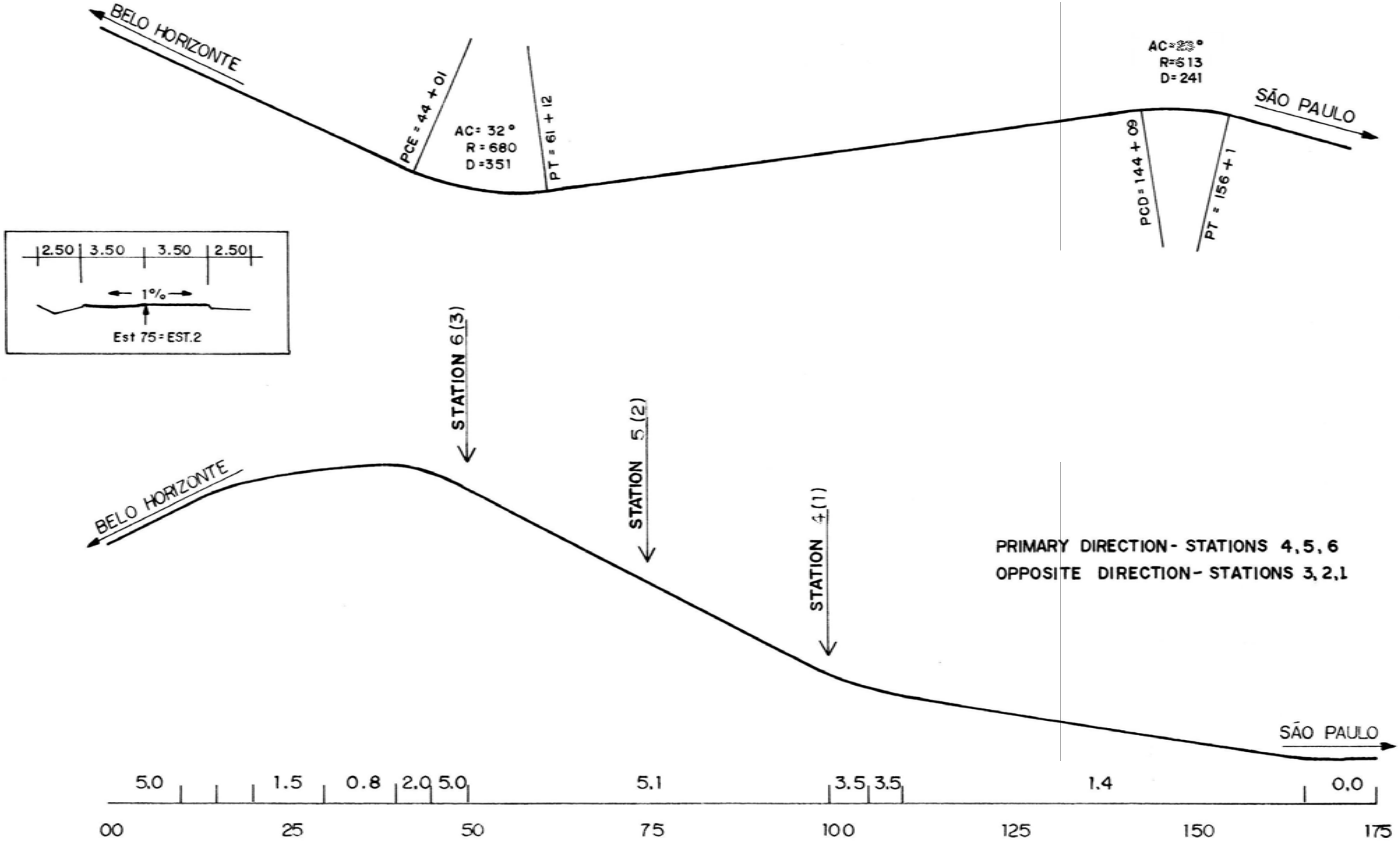

FIGURE 6.1 - PROFILE OF TEST SECTION Nº 568.

HIGHWAY: BR - 381
LOCALITY: AT 23 km FROM MG - SP BORDERLINE
HORIZONTAL SCALE 1:10000
VERTICAL SCALE 1:1000

TABLE 6.3 - TRAVEL TIMES (IN SECONDS) OF THE VEHICLES OBSERVED BETWEEN STATIONS 4 AND 5 OF TEST SECTION No.568 (PRIMARY LANE)

CLASSES					
1 (CARS)	2 (UTILITIES)	3 (LIGHT TRUCKS)	4 (MEDIUM TRUCKS)	5 (BUSES)	6 (HEAVY TRUCKS)
24.07	27.26	43.07	64.00	40.96	
32.02	36.66	25.24	74.17	39.37	
31.40	42.58	48.22	69.56	33.70	
25.24	47.81	30.28	68.02	33.51	
23.47	24.89	40.97	33.50	26.45	
29.02	27.45	27.83	40.80	29.65	
22.43	31.37	26.70	42.58	37.20	
25.64	31.77	38.59	59.23	25.29	
20.62	31.90	29.10	68.15	26.25	
25.31	31.38	29.24	-	42.47	
$\bar{x}$ = 25.92	$\bar{x}$ = 33.31	$\bar{x}$ = 33.92	$\bar{x}$ = 57.78	$\bar{x}$ = 33.49	
S_1 = 3.73	S_2 = 7.16	S_3 = 8.05	S_4 = 14.87	S_5 = 6.40	
S_1^2 = 13.94	S_2^2 = 51.23	S_3^2 = 64.74	S_4^2 =221.18	S_5^2 = 40.98	

SOURCE: Speed Experiment in a Traffic Flow (TB-8) of the PICR.

TABLE 6.4 - TRAVEL TIMES (IN SECONDS) OF THE VEHICLES OBSERVED BETWEEN STATIONS 3 AND 2 OF TEST SECTION No. 568 (OPPOSITE LANE)

CLASSES					
1 (CARS)	2 (UTILITIES)	3 (LIGHT TRUCKS)	4 (MEDIUM TRUCKS)	5 (BUSES)	6 (HEAVY TRUCKS)
26.45	27.64	28.74	25.55	24.41	25.69
35.96	28.87	37.47	25.92	23.38	27.17
26.18	31.34	23.13	28.63	19.23	25.91
33.24	22.65	29.89	33.09	25.55	36.37
33.53	22.66	28.87	28.88	23.81	30.58
24.43	26.58	27.23	34.87	23.54	30.19
25.26	27.36	27.91	32.21	26.22	23.36
25.08	30.39	33.02	32.83	37.21	24.99
35.78	27.69	34.94	31.07	38.42	24.99
26.79	28.29	28.46	27.72	31.33	26.51
$\bar{x} = 29.27$	$\bar{x} = 27.35$	$\bar{x} = 29.96$	$\bar{x} = 30.07$	$\bar{x} = 27.31$	$\bar{x} = 27.71$
$S_1 = 4.73$	$S_2 = 2.85$	$S_3 = 4.13$	$S_4 = 3.20$	$S_5 = 6.30$	$S_6 = 3.77$
$S_1^2 = 22.42$	$S_2^2 = 8.14$	$S_3^2 = 17.09$	$S_4^2 = 10.22$	$S_5^2 = 39.72$	$S_6^2 = 14.27$

SOURCE: Speed Experiment in a Traffic Flow (TB-8) of the PICR.