TABLE 6.5 - TRAVEL TIMES SIMULATED BY THE MST (IN SECONDS) OF THE VEHICLES BETWEEN STATIONS 4 AND 5 OF TEST SECTION no. 568 (PRIMARY LANE)

VEHICLE CLASS	RANGE		MEAN	STANDARD DEVIATION	VARIANCE	COEFFICIENT OF VARIATION	No. OBSERVATIONS
	MINIMUM	MAXIMUM					
1	20.54	33.52	24.78	3.39	11.49	13.7	13
2	21.57	34.31	25.91	3.73	13.91	14.4	13
3	-	-	-	-	-	-	-
4	25.63	44.74	35.44	5.58	31.14	15.7	14
5	-	-	-	-	-	-	-
6	33.76	36.04	35.15	1.00	1.00	2.8	3

TABLE 6.6 - TRAVEL TIMES SIMULATED BY THE MST (IN SECONDS) OF THE VEHICLES BETWEEN STATIONS 3 AND 2 OF TEST SECTION No. 568 (OPPOSITE LANE)

VEHICLE CLASS	RANGE		MEAN	STANDARD DEVIATION	VARIANCE	COEFFICIENT OF VARIATION	No. OBSERVATIONS
	MINIMUM	MAXIMUM					
1	23.55	41.05	28.03	4.19	17.55	14.9	13
2	26.80	36.04	30.71	3.11	9.67	10.1	12
3	-	-	-	-	-	-	-
4	26.06	44.25	36.31	5.14	26.41	14.2	23
5	28.84	37.40	33.56	3.06	9.36	9.1	5
6	25.03	41.18	33.34	5.86	34.33	17.6	5

X_{1kj} = the travel times of the vehicles of class k in the first sample, that is, of the sample of observed values.

X_{2kj} = the travel times of the vehicles of class k in the second sample, that is, of the sample of simulated values.

j = $1,2....,n_{ik}$; $i=1,2$

The vehicle classes are as follows:

k = 1 - cars
k = 2 - utilities
k = 3 - light trucks
k = 4 - medium trucks
k = 5 - buses
k = 6 - heavy trucks

Y_{1kj} and Y_{2kj} are respectively defined as being:

$$Y_{1kj} = X_{1kj} - \overline{X}_{1k}$$

and

$$Y_{2kj} = X_{2kj} - \overline{X}_{2k}$$

The Bartlett method, presented in Table 6.7, uses the following notations as definitions of the variances of each sample:

$$S^2_{1k} = \sum_{j=1}^{n_{1k}} Y^2_{1kj}/(n_{1k}-1)$$

and

$$S^2_{2k} = \sum_{j=1}^{n_{2k}} Y^2_{2kj}/(n_{2k}-1)$$

The results of the Bartlett test are presented in Table 6.8. Comparing the corrected statistic χ^2, which was calculated in Table 6.8 with the χ^2 from the table for the eight vehicle classes (3 in the primary lane and 5 in the opposite lane), the conclusion is drawn that the variances of the speeds observed and those obtained

TABLE 6.7 - BARTLETT TEST OF HOMOGENEITY OF VARIANCES OF TWO SAMPLES

SAMPLE i	$\Sigma\ Y^2_{ik}$	DEGREES OF FREEDOM (d.f.)	1/d.f.	S^2_{ik}	$\log S^2_{ik}$	(d.f.) $\log S^2_{ik}$
1	$\sum_{j=1}^{n_{ik}} Y^2_{1kj}$	$n_{1k} - 1$	$1/(n_{1k} - 1)$	S^2_{1k}	$\log S^2_{1k}$	$(n_{1k} - 1) \log S^2_{1k}$
2	$\sum_{j=1}^{n_{2k}} Y^2_{2kj}$	$n_{2k} - 1$	$1/(n_{2k} - 1)$	S^2_{2k}	$\log S^2_{2k}$	$(n_{2k} - 1) \log S^2_{2k}$
SUM	W_{YY}	$\sum_{i=1}^{2} (n_{ik} - 1)$	$\sum_{i=1}^{2} 1/(n_{ik}-1)$			$\sum_{i=1}^{2} (n_{ik} - 1)\log S^2_{ik}$

Notes: (1) The estimate of combined variance is given by:

$$S^2_{ik} = W_{YY} / \sum_{k=1}^{2} (n_{ik} - 1)$$

(2) The test uses the statistic χ^2_1 described below:

$$\chi^2_1 = (\ell n\ 10) \left[B - \sum_{i=1}^{2} (n_{ik} - 1) \log S^2_{ik}\right]$$

Where:

$$B = (\log S^2_{ik}) \sum_{i=1}^{2} (n_{ik} - 1)$$

(3) The following correction factor can be used:

$$C = 1 + [1/3\ (2-1)] \left\{ \sum_{i=1}^{2} [1/(n_{ik} - 1)] - 1 \right\} / \sum_{i=1}^{2} (n_{ik} - 1)$$

(4) Finally, χ^2_1 corrected $= (1/C)\ \chi^2_1$

If $\chi^2_1 \geq \chi^2_{1\ (1-k)2}$, i.e. , χ^2 from the table, the hypothesis

$H_o : \sigma^2_1 = \sigma^2_2$ will be rejected.

through simulation are not statistically different, for the majority of the classes.

6.4.2 *Test of Equality of Two Means*

In the test of equality of two means (Hamburg, 1974), there are two hypotheses:

$H_o \quad : \mu_{1k} - \mu_{2k} = 0$

$H_1 \quad : \mu_{1k} - \mu_{2k} \neq 0$

where:

μ_{1k} = mean of the travel times of the vehicle population of class k;

μ_{2k} = mean of the simulated travel times of the vehicles of class k.

To test the null hypothesis, the statistic t_k is used:

$$t_k = \frac{(\bar{x}_{1k}-\bar{x}_{2k})-0}{S_{(\bar{x}_{1k}-\bar{x}_{2k})}} = \frac{\bar{x}_{1k}-\bar{x}_{2k}}{S_{(\bar{x}_{1k}-\bar{x}_{2k})}}$$

where:

$S_{(\bar{x}_{1k}-\bar{x}_{2k})}$ is the standard deviation of the difference between the two means.

Contrary to what occurs in the case of large samples, in this case it is necessary to admit the equality of the variances of the two populations. The hypothesis of this equality was submitted to the Bartlett test and could not be rejected.

An aggregate estimate of the variance is obtained by combining the variances of the two samples in a weighted mean, using as weights the numbers of degrees of freedom $n_{1k}-1$ and $n_{2k}-1$. This aggregate estimate of variance, designated by S_k^2, is given by:

TABLE 6.8 - APPLICATION OF THE BARTLETT TEST OF EQUALITY OF TWO VARIANCES - TEST SECTION No. 568

(continued)

VEHICLE CLASS	COMPARED SAMPLES O=OBSERVED S=SIMULATED	ΣY^2_{ik}	DEGREE OF FREEDOM (d.f.)	1/(d.f.)	S^2_{ik}	log S^2_{ik}	d.f. (log S^2_{ik})
			PRIMARY LANE				
1	O	125.48	9	0.111	13.942	1.144	10.299
	S	137.88	12	0.083	11.49	1.060	12.720
SUM		263.36	21	0.194			23.019
2	O	461.07	9	0.111	51.23	1.710	15.385
	S	166.92	12	0.083	13.91	1.143	10.287
SUM		627.99	21	0.194			25.672
3	O	582.66	9	0.111	64.74	1.811	16.300
	S	-	-	-	-	-	-
SUM		582.66	9	0.111			16.300
4	O	1769.44	8	0.125	221.18	2.345	18.758
	S	404.82	13	0.076	31.14	1.493	19.409
SUM		2174.26	21	0.201			38.167
5	O	368.78	9	0.111	40.976	1.613	14.513
	S	-	-	-	-	-	-
SUM		368.78	9	0.111	40.976	1.613	14.513
6	O	-	-	-	-	-	-
	S	2.00	2	0.50	1.00	0.00	0.00
SUM		2.00	2	0.50			
			OPPOSITE LANE				
1	O	201.75	9	0.111	22.417	1.351	12.155
	S	210.60	12	0.083	17.55	1.244	14.928
SUM		412.35	21	0.194			27.083
2	O	73.23	9	0.111	8.137	0.910	8.194
	S	106.37	11	0.090	9.67	0.985	10.835
SUM		179.60	20	0.201			19.029
3	O	153.79	9	0.111	17.088	1.233	11.094
	S	-	-	-	-	-	-
SUM		153.79	9	0.111	17.088	1.233	11.094
4	O	92.02	9	0.111	10.224	1.010	9.087
	S	581.02	22	0.045	26.41	1.421	31.262
SUM		673.04	31	0.156			40.349
5	O	357.49	9	0.111	39.721	1.599	14.389
	S	37.44	4	0.25	9.36	0.971	3.884
SUM		394.93	13	0.361			18.273
6	O	128.45	9	0.111	14.272	1.154	10.390
	S	137.32	4	0.25	34.33	1.535	6.14
SUM		265.77	13	0.361			16.530

TABLE 6.8 - APPLICATION OF THE BARTLETT TEST OF EQUALITY OF TWO VARIANCES - TEST SECTION No. 568

(Conclusion)

VEHICLE CLASS	ESTIMATE OF COMBINED VARIANCE (S_k^2)	$B=(\log S_k^2)\sum_{i=1}^{2}(n_{ik}-1)$	$\chi^2_{(i-1)}=\log_e 10\left[B-\sum_{i=1}^{2}(n_{ik}-1)\log S_{ik}^2\right]$	$C=1+\{1/3(2-1)\left[\sum_{i=1}^{2}1/(n_{ik}-1)-1/\sum_{i=1}^{2}(n_{ik}-1)\right]\}$	χ^2 CORRECTED
			PRIMARY LANE		
1	12.54	23.06	0.094	0.987	0.095
2	29.90	30.99	12.246	0.987	12.407
3	-	-	-	-	-
4	103.54	42.32	9.563	0.987	9.689
5	-	-	-	-	-
			OPPOSITE LANE		
1	19.636	27.153	0.161	0.987	0.163
2	8.98	19.066	0.085	0.987	0.086
3	-	-	-	-	-
4	21.711	41.437	2.505	0.991	2,528
5	30.379	19.273	2,303	0,984	2.340
6	20.444	17.373	1.941	0,984	1.973

$$S_k^2 = \frac{(n_{1k}-1)\ S_{1k}^2 + (n_{2k}-1)\ S_{2k}^2}{n_{1k} + n_{2k} - 2}$$

The estimate of the standard deviation of the difference between the two means is therefore:

$$S_{\bar{x}_{1k}-\bar{x}_{2k}} = \sqrt{\frac{S_k^2}{n_{1k}} + \frac{S_k^2}{n_{2k}}} = S_k\sqrt{\frac{1}{n_{1k}} + \frac{1}{n_{2k}}}$$

The results of the application of this test are found in Table 6.9.

The test of equality of the means indicates that there are no significant differences between the mean travel times observed and those simulated.

On the basis of the tests carried out (equality of means and variances), the conclusion can be drawn that the MST adequately simulates the behavior of the vehicles and constitutes a valid model for all classes of vehicles.

TABLE 6.9 - TEST OF EQUALITY OF TWO MEANS - TEST SECTION No. 568

	CALCULATED DATA				TABLES	
CLASS (k)	No. OF OBSERVATIONS IN THE TWO SAMPLES		t_k CALCULATED BETWEEN TWO SAMPLES	DEGREES OF FREEDOM	t_k FROM THE TABLE	LEVEL OF SIGNIFICANCE
	n_{1k}	n_{2k}				
PRIMARY LANE						
1	10	13	+ 0.216	23	1.714	0.10
2	10	13	+ 0.588	23	1.714	0.10
3	10	-	-	-	-	-
4	9	14	+ 0.492	23	1.714	0.10
5	10	-	-	-	-	-
6	-	3	-	-	-	-
OPPOSITE LANE						
1	10	13	+ 0.150	23	1.714	0.10
2	10	12	- 0.874	22	1.717	0.10
3	10	-	-	-	-	-
4	10	23	- 0.753	33	1.693	0.10
5	10	5	- 0.376	15	1.753	0.10
6	10	5	- 0.503	15	1.753	0.10