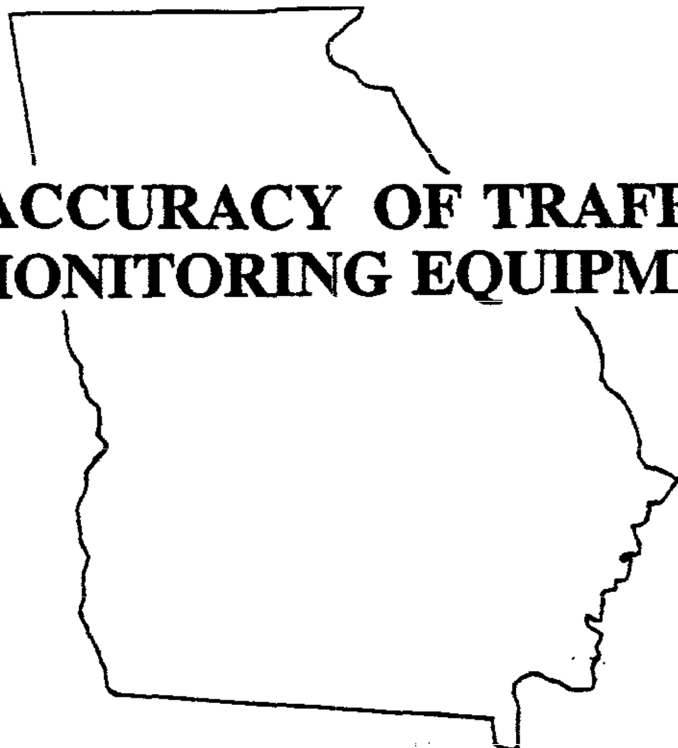
CONTRACT RESEARCH
GDOT RESEARCH PROJECT NO. 9210
FINAL REPORT

GEORGIA DEPARTMENT OF TRANSPORTATION

ACCURACY OF TRAFFIC MONITORING EQUIPMENT



GEORGIA
INSTITUTE OF TECHNOLOGY

Contract Research
GDOT Research Project 9210
Final Report

ACCURACY OF TRAFFIC MONITORING EQUIPMENT

By:

Bruce A. Harvey
Glenn H. Champion
Steven M. Ritchie
Craig D. Ruby

June 1995

In Cooperation With

Prepared for:

Georgia Department of Transportation
Office of Materials and Research
15 Kennedy Drive
Forrest Park, Georgia 30050

Project Funded by:

Federal Highway Administration
Office of Highway Information Mgmt.
400 Seventh Street, S. W.
Washington, D. C. 20590

Submitted by:

Communications and Networking Division
Information Technology and Telecommunications Laboratory
Georgia Tech Research Institute
Georgia Institute of Technology
Atlanta, Georgia 30332-0821

Technical Report
GTRI Project A-9291

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
GDOT 9210		

4. Title and Subtitle	5. Report Date
ACCURACY OF TRAFFIC MONITORING EQUIPMENT	June 1995
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Bruce Harvey, G.H. Champion, S.M. Ritchie, C.D. Ruby	
9. Performing Organization Name and Address	10. Work Unit No.
Georgia Tech Research Institute Georgia Institute of Technology Atlanta, GA 30332-0821	11. Contract or Grant No.
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Federal Highway Administration Office of Highway Information Management 400 Seventh Street, SW Washington, D.C. 20590	Final Report
	14. Sponsoring Agency Code

15. Supplementary Notes

Performed in cooperation with the U.S. Department of Transportation Federal Highway Administration

16. Abstract

A total of 13 sensors and classifier configurations from 10 commercially available equipment vendors were tested to determine their accuracy in classifying vehicles into 13 FHWA vehicle classes, in measuring axle spacings, and in measuring overall vehicle length. A majority of the participating vendors used a P-L-P (piezo-loop-piezo) sensor configuration in the roadway, while the remaining vendors used either a P-P or L-P-L sensor configuration.

Tests provided comparison of the vehicle-by-vehicle data from the classifers with ground truth data obtained from a video tape of the traffic stream in the test lane. Vehicle classes and measurements were obtained from the video tape through the use of a computer-aided data reduction system developed specifically for this project.

Classification accuracies ranged from 78.8% to 96.2%, if class 2 (passenger vehicles) and class 3 (small pickup trucks) are combined. The classification of class 9 vehicles (a majority of the trucks) was very good on most classifers. Classification accuracy, axle spacing measurement errors, and overall length measurement errors appeared to be independent on the sensor configurations.

17. Key Words	18. Distribution Statement
traffic monitoring equipment, vehicle classification, classifiers	No restrictions

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT F 1700.7 (8-69)

PREFACE

Under Contract Number 10-9210-50520, Task Order No. 27, the Georgia Department of Transportation (GaDOT), Office of Materials and Research has tasked the Georgia Tech Research institute (GTRI) to conduct a Federal Highway Administration (FHWA) funded study of the accuracy of automatic vehicle classification equipment. The program was monitored by Mr. Rick Deaver of the GaDOT Office of Materials and Research and Mr. Perry Kent of the FHWA Office of Highway Information Management. Mr. Darrell Elwell and Mr. Scott Knight of the GaDOT Planning Data Services Bureau provided an experienced GaDOT road crew under the supervision of Mr. Bob Creasman to perform the equipment installations described in this report.

This report is authored by the Georgia Tech Research Institute (GTRI) of the Georgia Institute of Technology. The effort was directed by Dr. Bruce Harvey under the general supervision of Mr. Eric Barnhart, Chief of Communications and Networking Division.

EXECUTIVE SUMMARY

In this project, a number of vehicle classifiers were tested to determine their accuracy in classifying vehicles into the 13 FHWA vehicle classes, in measuring axle spacings, and in measuring overall vehicle length. The scope of the project was limited to commercially available equipment that was available in September 1992. The objectives of the project were to:

- Determine the adequacy of vehicle counting devices.
- Determine the adequacy of various types of equipment to correctly sort vehicles into the 13 FHWA vehicle classes (as identified in the FHWA Traffic Monitoring Guide).
- Determine the adequacy of automatic measurement of overall vehicle length.
- Determine how the vehicle and axle sensor technology affects the accuracy of the vehicle classification.
- Determine the effects of vehicle repetitions, heavy axle loadings, and weather on pneumatic tube axle sensors and other types of vehicle and axle sensors.

A total of 13 sensor and classifier configurations from 10 equipment vendors were installed from December 1992 to April 1993 on the west bound side of I-20 near Covington, Georgia (30 mi. east of Atlanta). They were all installed in a single lane for side-by-side comparison.

All of the classifiers tested (excluding the one used for the pneumatic tube tests) used a combination of magnetic loop detectors and piezoelectric axle sensors. Although a wider variety of sensor technologies were desired for the project, none of the vendors using other sensors responded to the FHWA request for participation with commercially available equipment. A majority of the participating vendors used a P-L-P (piezo-loop-piezo) sensor configuration in the roadway, while the remaining vendors used either a P-P or L-P-L sensor configuration.

Three tests were conducted in order to fully characterize the performance of the classification equipment. Two 48-hour tests were conducted on May 5-7, 1993 and September 9-11, 1993. These tests provided comparison of the vehicle-by-vehicle data from the classifiers with ground truth data obtained from a video tape of the traffic stream in the test lane. The classifiers were assessed to determine their classification accuracy, and their ability to accurately measure axle spacings and overall length. The performance of the classifiers was assessed parametrically versus the percentage of vehicle with more than 2 axles, the air temperature, and the pavement temperature.

The third test conducted was a 7-day test performed on September 9-16, 1993 in conjunction with the second 48-hour test. During this test, the classifiers were programmed to bin the data in 15 minute increments. The purpose of the test was to assess the long term performance characteristics of the equipment. The data was compared to determine how accurately the classifiers counted the number of axles, and the number of vehicles in each vehicle class. The 7-day test was also used to assess the performance of the equipment as a function of time in service by comparing the accuracy in the first day of testing with the accuracy in the last day of testing.

An augmented pneumatic tube test was conducted in parallel with the second 48-hour test. This test used a Peek TrafiCOMP III (Peek 241) and four road tubes to monitor the traffic in two lanes. The objective of this test was to assess the ability of road tubes to monitor traffic in multiple lanes. A setup error resulted in the classifier recording all traffic in both lanes into one file. Therefore, the problem of separating the traffic into the two lanes and removing duplications was made much more difficult. Therefore, analysis of this test was postponed until a re-test can be conducted.

Ground truth data for the 48-hour and 7-day tests was obtained from a side-mounted video camera viewing the traffic stream. The vehicle classes and measurements were obtained from the video tape through the use of a computer-aided data reduction system developed specifically for this project. The computer data reduction system was named the Computer Vehicle Classification and Reduction System (CVCRS), and was capable of assisting an operator in the recording of time stamped vehicle classes along with measurements of axle spacings and overall vehicle length.

The classification accuracies resulting from this test ranged from 63.5% to 79.1%. The most common errors occurred between Class 2 (passenger vehicles) and Class 3 (other 2-axle, 4-tire vehicles). A small pickup truck (class 3) is very difficult to distinguish from a large car (class 2) based on length and axle spacing. If class 2 and 3 are combined, then the classification accuracies ranged from 78.8% to 96.2%.

Temperature of the air and pavement was found to have little effect on the performance of the classifiers. However, the range of temperatures was somewhat limited for this test. The percentage of trucks (vehicles with more than 2 axles) tended to have some effect on the classifier accuracies. The classification of class 9 vehicles (a majority of the trucks) was very good on most classifiers, and hence the classification accuracy tended to improve as the percentage of trucks increased. The longer vehicle lengths and axles spacings did, however, result in greater measurement errors as the percentage of trucks increased.

The sensor configuration used by the classifiers did not appear to have a significant effect on the accuracy. Classification accuracy, axle spacing measurement errors, and overall length measurement errors appeared to be independent on the sensor configurations. The primary factor observed in this test to affect the classification accuracy was the performance of the axle sensors. The ability of the equipment to accurately classify vehicles was linearly dependent on the ability of the sensor and classifier to accurately count the number of axles. Therefore, performance of the piezoelectric axle sensor and the interface electronics in the classification equipment are the primary factors effecting the accuracy of the equipment.

A further opportunity has arisen to collect more data concerning the performance of these classification equipments. *Road construction is under* way at the test site and will result in the sensors in the roadway being overlaid as part of a widening of the road. This presents an opportunity to test the performance of the devices after a pavement overlay. This issue is important to the maintainability of a traffic monitoring site. The results of the overlay tests will be reported in and addendum to this report.

TABLE OF CONTENTS

PREFACE . . . iii

EXECUTIVE SUMMARY . . . v

TABLE OF CONTENTS . . . ix

LIST OF FIGURES . . . xiii

LIST OF TABLES . . . xvii

1. INTRODUCTION AND SCOPE . . . 1
   1.1 Background . . . 1
   1.2 Participating AVC System Vendors . . . 2

2. EQUIPMENT INSTALLATION . . . 5
   2.1 EVALUATION SITE . . . 5
      2.1.1 Evaluation Site Specifications . . . 5
      2.1.2 Site Location and description . . . 5
      2.1.3 Test Facilities and Instrumentation . . . 6
   2.2 GENERAL INSTALLATION PROCEDURES . . . 8
      2.2.1 Axle Sensor Installation . . . 8
      2.2.2 Loop Installation . . . 10
      2.2.3 System Testing . . . 11
   2.3 AVC SYSTEM INSTALLATIONS . . . 12
      2.3.1 Mikros Systems . . . 13
      2.3.2 Peek Traffic Inc. . . . 16
      2.3.3 PAT Equipment Corporation . . . 19
      2.3.4 MITRON Systems Corporation . . . 22
      2.3.5 Electronic Control Measure . . . 26
      2.3.6 TimeMark . . . 29
      2.3.7 International Road Dynamics . . . 32
      2.3.8 Golden River Limited . . . 36
      2.3.9 Diamond Traffic Products . . . 39
   2.4 INSTALLATION SUMMARY AND CONCLUSIONS . . . 43

3. TEST SESSIONS . . . 45
   3.1 OVERVIEW OF TEST PROCEDURES . . . 45
   3.2 DETAILS OF INDIVIDUAL TESTS . . . 47
      3.2.1 First 48-Hour Detailed Test . . . 47
         3.2.1.1 Test Date and Conditions . . . 47
         3.2.1.2 Participating Vendors . . . 47
         3.2.1.3 Problems and Exceptions to Test Procedures . . . 48

TABLE OF CONTENTS (cont.)

3.2.2 Second 48-Hour Detailed Test 49
3.2.2.1 Test Date and Conditions 49
3.2.2.2 Participating Vendors 49
3.2.2.3 Problems and Exceptions to Test Procedures ... 49
3.2.3 Seven-Day Test 51
3.2.3.1 Test Date and Conditions 51
3.2.3.2 Participating Vendors 51
3.2.3.3 Problems and Exceptions to Test Procedures ... 51

4. DATA REDUCTION AND ANALYSIS 53
4.1 THE COMPUTER VEHICLE CLASSIFICATION AND REDUCTION SYSTEM (CVCRS) 53
4.1.1 Hardware 53
4.1.2 Software 53
4.2 HANDLING LANE CHANGES 56
4.3 THE STANDARD DATA FORMAT 57
4.4 THE "BINNED" PROGRAM 58
4.5 THE "ANALYZE" PROGRAM 59
4.6 TYPICAL ANALYSIS OUTPUTS 61

5. CLASSIFIER RESULTS 65
5.1 OVERVIEW OF GENERAL RESULTS 65
5.2 TEST RESULTS FROM INDIVIDUAL CLASSIFIERS 65
5.2.1 Mikros Systems 66
5.2.1.1 First 48-Hour Test 66
5.2.1.2 Second 48-Hour Test 70
5.2.1.3 Seven-Day Test 74
5.2.2 Peek Traffic Inc. 75
5.2.2.1 First 48-Hour Test 75
5.2.2.2 Second 48-Hour Test 79
5.2.2.3 Seven-Day Test 83
5.2.3 Peek Traffic Inc. Gk-6000 84
5.2.3.1 First 48-Hour Test 84
5.2.3.2 Second 48-Hour Test 91
5.2.3.3 Seven-Day Test 98
5.2.4 PAT Equipment Corporation, Inc. AVC-100 (P-L-P) 100
5.2.4.1 Seven-Day Test 101
5.2.5 PAT Equipment Corporation, Inc. AVC-100 (L-P-L) 102
5.2.5.1 First 48-Hour Test 102
5.2.5.2 Second 48-Hour Test 106
5.2.5.3 Seven-Day Test 110
5.2.6 Mitron Systems Corp. MSC-3000 DCP 111

5.2.7 Electronic Control Measure HESTIA 113
5.2.7.1 First 48-Hour Test 113
5.2.7.2 Second 48-Hour Test 117
5.2.7.3 Seven-Day Test 121
5.2.8 TimeMark, Inc. Delta II 122
5.2.8.1 First 48-Hour Test 122
5.2.8.2 Second 48-Hour Test 126
5.2.8.3 Seven-Day Test 130
5.2.9 International Road Dynamics, Inc. TC/C 530-4D/4P/4L (PR-L-PR) 131
5.2.9.1 First 48-Hour Test 131
5.2.9.2 Second 48-Hour Test 135
5.2.9.3 Seven-Day Test 139
5.2.10 International Road Dynamics, Inc. TC/C 530-4D/4P/4L (P-L-P) 140
5.2.10.1 First 48-Hour Test 140
5.2.10.2 Second 48-Hour Test 144
5.2.10.3 Seven-Day Test 148
5.2.11 Golden River Traffic Ltd. Marksman 660 149
5.2.11.1 First 48-Hour Test 149
5.2.11.2 Second 48-Hour Test 149
5.2.11.3 Seven-Day Test 153
5.2.12 Diamond Traffic Products TT-2001 (Autologger Maxi) 154
5.2.12.1 First 48-Hour Test 154
5.2.12.2 Second 48-Hour Test 158
5.2.12.3 Seven-Day Test 162
5.2.13 Diamond Traffic Products (Philips Vibracoax) 163
5.2.13.1 First 48-Hour Test 163
5.2.13.2 Second 48-Hour Test 167
5.2.13.3 Seven-Day Test 171
5.3 CLASSIFICATION ACCURACY VERSUS SENSOR ERRORS 172

6. ANSWERS TO SPECIFIC QUESTIONS 173

7. AUGMENTED PNEUMATIC TUBE TEST 183

8. SUMMARY AND CONCLUSIONS 185

APPENDIX A 187

APPENDIX B 191

TABLE OF CONTENTS (cont.)

APPENDIX C 213

APPENDIX D 225

LIST OF FIGURES

Figure 1. Test Instrumentation Conceptual Drawing 7
Figure 2. Overall Layout of Evaluation Site 12
Figure 3. Mikros Installation Configuration Drawing 14
Figure 4. Mikros Axle Sensor Profile 15
Figure 5. Peek Installation Configuration Drawing 17
Figure 6. Peek Axle Sensor Profiles 18
Figure 7. PAT Installation Configuration Drawing 20
Figure 8. PAT Axle Sensor Profiles 21
Figure 9. Mitron Installation Configuration Drawing 24
Figure 10. Mitron Axle Sensor Profiles 25
Figure 11. ECM Installation Configuration Drawing 27
Figure 12. ECM Axle Sensor Profiles 28
Figure 13. TimeMark Installation Configuration Drawing 30
Figure 14. TimeMark Axle Sensor Profiles 31
Figure 15. IRD Installation Configuration Drawing 34
Figure 16. IRD Axle Sensor Profiles 35
Figure 17. GRI Installation Configuration Drawing 37
Figure 18. GRI Axle Sensor Profiles 38
Figure 19. Diamond Installation Configuration Drawing 41
Figure 20. Diamond Axle Sensor Profiles 42
Figure 21. Correct Configuration of the Lane-Change Camera, Time/Date Generator and VCR 50
Figure 22. The CVCRS System 54
Figure 23. The Standard Data Format 58
Figure 24. Example Output of the BINNED Program 62
Figure 25. Example Output of the Analyze Program 63
Figure 26. Classification Matrix for the Mikros Systems TEL-2CM 1st 48-Hour Test 67
Figure 27. Measurement Accuracy Versus Speed (MPH) Mikros TEL-2CM - 1st 48-Hour Test 68
Figure 28. Classification Matrix for the Mikros Systems TEL-2CM 2nd 48-Hour Test 71
Figure 29. Measurement Accuracy Versus Speed (MPH) Mikros TEL-2CM - 2nd 48-Hour Test 72
Figure 30. Classification Matrix for Peek TrafiCOMP III 1st 48-Hour Test 76
Figure 31. Measurement Accuracy Versus Speed (MPH) Peek TrafiCOMP III - 1st 48-Hour Test 77
Figure 32. Classification Matrix for Peek TrafiCOMP III 2nd 48-Hour Test 80
Figure 33. Measurement Accuracy Versus Speed (MPH) Peek TrafiCOMP III - 2nd 48-Hour Test 81

LIST OF FIGURES (cont.)

Figure 34. Classification Matrix for Peek GK-6000 (Lane 1) 1st 48-Hour Test 85
Figure 35. Measurement Accuracy Versus Speed (MPH) Peek GK-6000 (Lane 1) - 1st 48-Hour Test 86
Figure 36. Classification Matrix for Peek GK-6000 (Lane 2) 1st 48-Hour Test 87
Figure 37. Measurement Accuracy Versus Speed (MPH) Peek GK-6000 (Lane 2) - 1st 48-Hour Test 88
Figure 38. Classification Matrix for Peek GK-6000 (Lane 1) 2nd 48-Hour Test 92
Figure 39. Measurement Accuracy Versus Speed (MPH) Peek GK-6000 (Lane 1) - 2nd 48-Hour Test 93
Figure 40. Classification Matrix for Peek GK-6000 (Lane 2) 2nd 48-Hour Test 94
Figure 41. Measurement Accuracy Versus Speed (MPH) Peek GK-6000 (Lane 2) - 2nd 48-Hour Test 95
Figure 42. Classification Matrix for PAT AVC-100 (L-P-L) 1st 48-Hour Test 103
Figure 43. Measurement Accuracy Versus Speed (MPH) PAT AVC-100 (L-P-L) - 1st 48-Hour Test 104
Figure 44. Classification Matrix for PAT AVC-100 (L-P-L) 2nd 48-Hour Test 107
Figure 45. Measurement Accuracy Versus Speed (MPH) PAT AVC-100 (L-P-L) - 2nd 48-Hour Test 108
Figure 46. Classification Matrix for ECM HESTIA 1st 48-Hour Test 114
Figure 47. Measurement Accuracy Versus Speed (MPH) ECM HESTIA - 1st 48-Hour Test 115
Figure 48. Classification Matrix for ECM HESTIA 2nd 48-Hour Test 118
Figure 49. Measurement Accuracy Versus Speed (MPH) ECM HESTIA - 2nd 48-Hour Test 119
Figure 50. Classification Matrix for TimeMark Delta II 1st 48-Hour Test 123
Figure 51. Measurement Accuracy Versus Speed (MPH) TimeMark Delta II - 1st 48-Hour Test 124
Figure 52. Classification Matrix for TimeMark Delta II 2nd 48-Hour Test 127
Figure 53. Measurement Accuracy Versus Speed (MPH) TimeMark Delta II - 2nd 48-Hour Test 128
Figure 54. Classification Matrix for IRD TC/C 530-4D/4P/4L (PR-L-PR) 1st 48-Hour Test 132

LIST OF FIGURES (cont.)

Figure 55. Measurement Accuracy Versus Speed (MPH) 133
IRD TC/C 530-4D/4P/4L (PR-L-PR) - 1st 48-Hour Test

Figure 56. Classification Matrix for IRD TC/C 530-4D/4P/4L 136
(PR-L-PR) 2nd 48-Hour Test

Figure 57. Measurement Accuracy Versus Speed (MPH) 137
IRD TC/C 530-4D/4P/4L (PR-L-PR) - 2nd 48-Hour Test

Figure 58. Classification Matrix for IRD TC/C 530-4D/4P/4L 141
(P-L-P) 1st 48-Hour Test

Figure 59. Measurement Accuracy Versus Speed (MPH) 142
IRD TC/C 530-4D/4P/4L (P-L-P) - 1st 48-Hour Test

Figure 60. Classification Matrix for IRD TC/C 530-4D/4P/4L 145
(P-L-P) 2nd 48-Hour Test

Figure 61. Measurement Accuracy Versus Speed (MPH) 146
IRD TC/C 530-4D/4P/4L (P-L-P) - 2nd 48-Hour Test

Figure 62. Classification Matrix for Golden River Marksman 660 150
2nd 48-Hour Test

Figure 63. Measurement Accuracy Versus Speed (MPH) 151
Golden River Marksman 660 - 2nd 48-Hour Test

Figure 64. Classification Matrix for Diamond TT-2001 155
(Autologger) 1st 48-Hour Test

Figure 65. Measurement Accuracy Versus Speed (MPH) 156
Diamond TT-2001 (Autologger) - 1st 48-Hour Test

Figure 66. Classification Matrix for Diamond TT-2001 159
(Autologger) 2nd 48-Hour Test

Figure 67. Measurement Accuracy Versus Speed (MPH) 160
Diamond TT-2001 (Autologger) - 2nd 48-Hour Test

Figure 68. Classification Matrix for Diamond TT-2001 164
(Philips) 1st 48-Hour Test

Figure 69. Measurement Accuracy Versus Speed (MPH) 165
Diamond TT-2001 (Philips) - 1st 48-Hour Test

Figure 70. Classification Matrix for Diamond TT-2001 168
(Philips) 2nd 48-Hour Test

Figure 71. Measurement Accuracy Versus Speed (MPH) 169
Diamond TT-2001 (Philips) - 2nd 48-Hour Test

Figure 72. Classification Accuracy Versus Sensor Errors 172

LIST OF TABLES

Table I. Vendor Classifiers and Configurations Installed 3

Table II. Accuracy Summary for Mikros Systems TEL-2CM 69
1st 48-Hour Test

Table III. Accuracy Summary for Mikros Systems TEL-2CM 73
2nd 48-Hour Test

Table IV. Long-Term Count/Classification Accuracy 74
Mikros Systems TEL-2CM

Table V. Accuracy Summary for Peek TrafiCOMP III 78
1st 48-Hour Test

Table VI. Accuracy Summary for Peek TrafiCOMP III 82
2nd 48-Hour Test

Table VII. Long-Term Count/Classification Accuracy 83
Peek TrafiCOMP III

Table VIII. Accuracy Summary for Peek GK-6000 (Lane 1) 89
1st 48-Hour Test

Table IX. Accuracy Summary for Peek GK-6000 (Lane 2) 90
1st 48-Hour Test

Table X. Accuracy Summary for Peek GK-6000 (Lane 1) 96
2nd 48-Hour Test

Table XI. Accuracy Summary for Peek GK-6000 (Lane 2) 97
2nd 48-Hour Test

Table XII. Long-Term Count/Classification Accuracy 98
Peek GK-6000 (Lane 1)

Table XIII. Long-Term Count/Classification Accuracy 99
Peek GK-6000 (Lane 1)

Table XIV. Long-Term Count/Classification Accuracy 101
PAT AVC-100 (P-L-P)

Table XV. Accuracy Summary for PAT AVC-100 (L-P-L) 105
1st 48-Hour Test

Table XVI. Accuracy Summary for PAT AVC-100 (L-P-L) 109
2nd 48-Hour Test

Table XVII. Long-Term Count/Classification Accuracy 110
PAT AVC-100 (L-P-L)

Table XVIII. Binned Count/Classification Accuracy 112
Mitron MSC-3000 DCP - 1st 48-Hour Test

Table XIX. Accuracy Summary for Peek ECM HESTIA 116
1st 48-Hour Test

Table XX. Accuracy Summary for ECM HESTIA 120
2nd 48-Hour Test

Table XXI. Long-Term Count/Classification Accuracy 121
Electronic Control Measure HESTIA

LIST OF TABLES (cont.)

Table XXII.	Accuracy Summary for TimeMark Delta II 1st 48-Hour Test	125
Table XXIII.	Accuracy Summary for TimeMark Delta II 2nd 48-Hour Test	129
Table XXIV.	Long-Term Count/Classification Accuracy TimeMark Delta II	130
Table XXV.	Accuracy Summary for IRD TC/C 530-4D/4P/4L (PR-L-PR) 1st 48-Hour Test	134
Table XXVI.	Accuracy Summary for IRD TC/C 530-4D/4P/4L (PR-L-PR) 2nd 48-Hour Test	138
Table XXVII.	Long-Term Count/Classification Accuracy IRD TC/C 530-4D/4P/4L (PR-L-PR)	139
Table XXVIII.	Accuracy Summary for IRD TC/C 530-4D/4P/4L (P-L-P) 1st 48-Hour Test	143
Table XXIX.	Accuracy Summary for IRD TC/C 530-4D/4P/4L (P-L-P) 2nd 48-Hour Test	147
Table XXX.	Long-Term Count/Classification Accuracy IRD TC/C 530-4D/4P/4L (P-L-P)	148
Table XXXI.	Accuracy Summary for Golden River Marksman 660 2nd 48-Hour Test	152
Table XXXII.	Long-Term Count/Classification Accuracy Golden River Marksman 660	153
Table XXXIII.	Accuracy Summary for Diamond TT-2001 (Autologger) 1st 48-Hour Test	157
Table XXXIV.	Accuracy Summary for Diamond TT-2001 (Autologger) 2nd 48-Hour Test	161
Table XXXV.	Long-Term Count/Classification Accuracy Diamond TT-2001 (Autologger)	162
Table XXXVI.	Accuracy Summary for Diamond TT-2001 (Philips) 1st 48-Hour Test	166
Table XXXVII.	Accuracy Summary for Diamond TT-2001 (Philips) 2nd 48-Hour Test	170
Table XXXVIII.	Long-Term Count/Classification Accuracy Diamond TT-2001 (Philips)	171
Table XXXIX.	Classification Accuracy	174
Table XL.	Accuracy of Axle Spacing Measurements	176
Table XLI.	Overall Length Measurement Errors	179
Table XLII.	Overall Length Measurement Percentiles	180

1. INTRODUCTION AND SCOPE

1.1 Background

There have been significant changes in the sophistication and technological approaches to the gathering of vehicle classification and volume count data since the last major study of vehicle classification accuracy. This has included the use of new types of sensors, such as piezoelectric, the development of programmable classifiers that allow the user to specify the dimensional thresholds for various vehicle types, and the introduction of vehicle classifiers that retain individual vehicle information rather than binning the data. This study addresses the need for controlled testing of the latest Automatic Vehicle Classification (AVC) equipment. The equipment is limited to commercially available devices that provide volume counts and vehicle classifications.

The objectives of the program are to:

- Determine the adequacy of vehicle counting devices.
- Determine the adequacy of various types of equipment to correctly sort vehicles into the 13 FHWA vehicle classes (as identified in the FHWA Traffic Monitoring Guide).
- Determine the adequacy of automatic measurement of overall vehicle length.
- Determine how the vehicle and axle sensor technology affects the accuracy of the vehicle classification.
- Determine the effects of vehicle repetitions, heavy axle loadings, and weather on pneumatic tube axle sensors and other types of vehicle and axle sensors.

Multiple testing sessions are planned over an 18 month period with various AVC accuracy characteristics being analyzed with respect to parameters such as vehicle speed, traffic volume, pavement temperature and others.

1.2 Participating AVC System Vendors

The FHWA provided the Georgia Department of Transportation (GaDOT) with a list of vendors that had indicated a willingness to participate in the assessment project. GaDOT and GTRI contacted each vendor to schedule equipment acquisition and testing. The vendors were asked to specify equipment and sensor selections, configurations, and installation procedures for maximum classification accuracy. Each vendor agreed to provide the equipment to the project on a no-charge loan basis. Permanently installed sensors were purchased by GaDOT directly from the AVC vendor assuring that each vendor was able to select and provide the best sensor for his equipment.

A list of participating vendors (including addresses and points of contact) is included as Appendix A. Table 1 lists the equipment configurations supplied for test by each vendor. In the "Configuration" column, the "P" is a piezoelectric axle sensor, and the "L" is an inductive loop vehicle presence sensor.

Table I. Vendor Classifiers and Configurations Installed

EQUIPMENT VENDOR	MODEL NUMBERS	CONFIGURATION, AXLE SENSOR TYPE
Mikros Systems	TEL-2CM	L-P-L, Philips Vibracoax
Peek Traffic, Inc.	TrafiCOMP III GK-6000	P-L-P, Philips Vibracoax P-P, Philips Vibracoax P-P, Philips Vibracoax
PAT Equipment Corporation, Inc.	AVC-100 AVC-100	P-L-P, Atochem Roadtrax Series 'P' L-P-L, Philips Vibracoax
MITRON Systems Corp.	MSC-3000 DCP	P-P, Autologger MINI
Electronic Control Measure	HESTIA	P-L-P, ECM PB2N33/25
TimeMark, Inc.	Delta II	P-P, Philips Vibracoax
International Road Dynamics, Inc.	TC/C 530-4D/4P/4L	PR-L-PR, Dynax AS-400 (Resistive) P-L-P, Philips Vibracoax
Golden River Traffic	Marksman 660	P-L-P, Traffic 2000
Diamond Traffic Products	TT-2001	P-L-P, Autologger Maxi P-L-P, Philips Vibracoax