TRANSPORTATION DATA REQUIREMENTS: EVALUATION OF PORTABLE TRAFFIC RECORDERS

by

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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SUMMARY

The objective of this study was to evaluate the accuracy of the Department's portable traffic recorder models under diverse types of traffic conditions. The study was conducted by (1) reviewing the characteristics of five models of traffic recorders, (2) selecting six field study sites, and (3) devising procedures for testing the recorders.

Combined data from the six study sites revealed that the ranking of the traffic recorders in descending order of accuracy was: (1) Stevens, (2) Streeter Amet (SA) MR 101-A, (3) SA-Traficounter, (4) K-Hill, and (5) SA-Traficounter Junior. The low relative errors obtained with the Stevens (1.9%) and SA-MR 101-A (2.6%) demonstrated that they are capable of meeting high accuracy standards.

It is recommended that the practice of using two traffic recorders on divided highways should be replaced where conditions permit by the use of a plastic tee-joint to connect two road hoses to one recorder in the median area. A study of the types and rates of malfunctions of the recorders is also recommended.

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INTRODUCTION

An evaluation of the Department's traffic count programs was requested because of interest in finding means of obtaining better data than heretofore available and at lower costs.(1) In response to the request a study is being conducted for the purpose of (1) determining the Department's needs for traffic count data, (2) relating these to an evaluation of the traffic counting program and procedures, (3) identifying problems and deficiencies with data requirements, and (4) seeking improvements to the program. To accomplish these objectives, supportive data are needed for the following subject areas.

- 1. portable traffic recorders
- 2. manual traffic counts
- 3. statistical sampling procedures

This report focuses upon the accuracy of the portable traffic recorders.

The Department uses portable recorders to count traffic on three highway systems.⁽²⁾ In the case of secondary roads, it costs the Department an estimated \$202,377 yearly to collect, process, and publish data from traffic recorder counts at about 37,000 locations. On urban routes, an estimated \$63,450 is spent yearly gathering recorder traffic counts from 2,328 locations. On interstate, arterial and primary routes, the Department has recently introduced the use of traffic recorders in special situations; however, most traffic counts are collected by observers who manually record vehicle classification and travel direction data. On these last named routes, an estimated \$521,933 is spent yearly gathering traffic counts from 1,364 locations. Basically, the types of portable traffic recorders used by the Department have traffic detection systems based upon use of a narrow roadway hose linked to a device responsive to air pressure (Figure 1). When the wheels of passing vehicles compress the roadway hose, a resulting change of air pressure should be detected and counted by the battery-powered recorder. The traffic detection systems are subject to errors in the form of either undercounts or overcounts resulting from malfunctions ecting the clock mechanism, numerical recorder, tape printer —on some models — or battery charge and electrical circuit. Counting errors could also occur under typical traffic conditions because of vehicle speed, size, axle combinations, braking, turning, changing traffic lanes, or passing maneuvers.

Because the accuracy of portable traffic recorders had not been studied recently in Virginia, it was anticipated that this study would be helpful in developing procedures for improving traffic count programs. Ideally, the desired improvements should lower program costs while providing acceptable accuracy.



Figure 1. Operational use of roadway hose with traffic recorder, the STREETER AMET TRAFICOUNTER model.

PURPOSE AND SCOPE

The objective was to evaluate the accuracy of the Department's portable traffic recorder models under diverse traffic conditions. The scope of the study was limited to conducting traffic counts and noting any problems with the operation of the recorders at six highway study sites.

TYPES OF TRAFFIC RECORDERS

To review the characteristics of the five models of traffic recorders used by the Department, recorders were borrowed from the Traffic and Safety Division and the Salem District traffic engineer. Three units each of the K-Hill, SA-Traficounter Junior, SA-Traficounter and SA-MR 101-A were obtained for testing at field study sites. After an initial phase of testing, three of the Stevens model recorders were also borrowed for use.

Accumulative Recorders

The K-Hill and SA-Traficounter Junior are accumulative type recorders. These have operational advantages because they are the smallest, lightest, and least expensive of the Department's recorders. One disadvantage is that technicians making the traffic counts are restricted by having to write down the time and traffic count readings both at the start and end of counting periods. The Department uses accumulative type recorders to collect 24-hour traffic counts on secondary roads.

Nonaccumulative Recorders

The SA-Traficounter, SA-MR 101-A, and Stevens are nonaccumulative type recorders. These offer operational advantages because they can provide a continuous series of traffic counts by a given time period (e.g., 15 minutes) and print these on a roll of tape. The disadvantages are that they are larger, heavier, and more costly than accumulative recorders.

The SA-Traficounter has been used to collect daily traffic volumes by 15-minute periods at 1-day count stations on urban routes and at the Department's 16 automatic traffic recorder stations where counts are made continuously throughout the year. It has been reported that the Department will no

longer purchase SA-Traficounters and its needs for nonaccumulative traffic recorder units has recently been met by the purchase of SA-MR 101-A or Stevens models.

Both the SA-MR 101-A and Stevens recorders have solid state electrical components. The Stevens has the additional capability of punching coded entries on data tapes which correspond to the printed traffic counts. The Department has considered developing a system for having the punched data tape entries directly translated by automated data processing equipment to reduce the costs required for manually processing the data. The SA-MR 101-A recorders are being used to collect traffic counts on urban routes and the Stevens recorders are being used at the Department's automatic traffic recorder stations.

STUDY SITES

Six study sites were selected to permit initial testing of the recorders under favorable traffic counting conditions and proceeding to testing under progressively more unfavorable conditions. Table 1 summarizes the types of recorder models tested along with the locations and traffic characteristics of the study sites.

<u>Site l</u>

Site 1 on Route 29 southwest of Charlottesville was chosen because it had exceptionally favorable conditions for the use of traffic recorders in obtaining counts. These included a moderate 67 km/hr (40 mph) speed limit, a moderate traffic volume of about 3,000 vehicles/day, of which a moderate 2.3% was comprised of trucks having more than 2 axles, and controlled access under which vehicles travel one-way in a single traffic lane. Figure 2 shows how both nonaccumulative and accumulative recorders were positioned on an expressway ramp to Route 29 business and Fontaine Avenue during eight traffic counting periods. The site conditions excluded situations in which the recorders could undercount traffic because of vehicles passing simultaneously and overcount traffic because of vehicles turning, changing traffic lanes, or excessively speeding onto traffic recorder hoses. Although the above are not representative of the conditions found at most locations where Department personnel are using recorders on secondary, primary, and urban routes, they were helpful in this study.

Study Site سر 6 ი \sim Ŧ **س**-MR 101-A Stevens MR 101-A Stevens MR 101-A Stevens Traf. K-Hill Traf. Jr. MR 101-A K-Hill Traf. Jr. Recorder Models Traf. Traf. K-11111 Traf. Jr. 10.9 250 Rte. No. 743 29 29 7 0.1 mile E. of Dulles Acess Rd, Fairfax Co. 1.3 mile N. of Rte. 631, Albemarle Co. 0.4 mile W. of Rte. 29, Albemarle Co. 0.1 mile E. of Rte. 747, Botetourt Co. 0.2 mile S. of 631, Albemarle N.B. ramp to Rte. 29 business, Albemarle Co. Location Rte. Co. km/hr (mph) Speed Limit 92 (55) 92 (55) 75 (45) 67 (40) 92 (55) 75 (45) 18,000 12,500 14,500 4,000 6,000 3,000 Est. VPD. ہ Trucks ا ver over 2 axles 13.10.5 0.6 1.6 з. З 2.3 Suburban Suburban Suburban Suburban Suburban Rural **T**ype Area Lanes No. 2 \sim Ν \sim \sim Hwy. Median Yes No × × × × × × Traffic Direction One- Two-Way Way × × × × × × Vehicles Change Lanes Yes No × × × × × × Study Peak 0 0 ان 5 0 ယ Periods Non-· Peak ω 2 8 ഗ æ ω

Recorders Tested and Traffic Characteristics at Study Sites

TABLE 1



Figure 2. Placement of traffic recorders.

Site 2

Site 2 was on Route 743 north of Charlottesville and was chosen in order to allow testing of accumulative type recorders under moderately favorable counting conditions on a secondary route. The conditions included a moderate 75 km/hr (45 mph) speed limit, a traffic volume of about 6,000 vehicles per day, which was considered moderate for a suburban highway segment, a low 0.5% rate of trucks with over 2 axles, and two-way traffic where vehicles could cross the recorder hoses simultaneously in a no-passing zone, which prohibited vehicles from changing between the two traffic lanes. These conditions are generally found on secondary routes located near cities.

Site 3

Site 3, on Route 604 north of Roanoke, was selected to provide unfavorable conditions for testing accumulative type recorders on a secondary route. The conditions included a 92 km/hr (55 mph) speed limit — the maximum allowed in Virginia; a traffic volume of about 4,000 vehicles per day, which was considered high for a rural highway segment; an exceptionally high 13.1% rate of trucks with over 2 axles; and two-way traffic in a no-passing zone for two traffic lanes. These conditions are found on secondary route segments located near primary or interstate routes.

Site 4

Site 4, on Route 250 west of Charlottesville, was chosen to test nonaccumulative type recorders under moderately favorable counting conditions on a primary route. The conditions included a moderate 75 km/hr (45 mph) speed limit; a traffic volume of about 14,500 vehicles per day, which was considered high for a suburban highway segment; a low 1.6% rate of trucks with over 2 axles; and two-way traffic in a passing zone for two traffic lanes. These conditions are typical for primary routes located in the Department's urban transportation study areas.

Site 5

Site 5 was on Route 29 north of Charlottesville and was selected because it provided unfavorable conditions for testing nonaccumulative type recorders on an arterial route. The conditions included a high 92 km/hr (55 mph) speed limit, a high traffic volume of about 12,500 vehicles per day in one direction, a moderate 3.3% rate of trucks with over 2 axles, and one-way traffic where vehicles could cross recorder hoses

simultaneously or change between traffic lanes on a four-lane highway divided by a median area. These conditions are representative of those found on arterial routes in the suburban sections of the Department's urban transportation study areas.

Site 6

Site 6, on Route 7 west of Falls Church, was chosen for testing nonaccumulative type recorders on an arterial route having exceptionally unfavorable counting conditions equivalent to those found on rural segments of interstate highways. The conditions included an estimated 18,000 vehicles per day in one direction, the highest traffic volume reported for any 92 km/hr (55 mph) segment of the Virginia arterial highway system; ⁽³⁾ a low 0.6% rate of trucks with over 2 axles; and one-way traffic where vehicles could pass by simultaneously or change traffic lanes on a four-lane divided highway. Most of the traffic counts there were also affected by a rainstorm and commuter rush hour congestion that occasionally restricted vehicle travel speeds. Although these conditions are not typical for arterial highways, they appeared similar to those found on rural segments of interstate highways.

DATA COLLECTION

Test Procedures

The operational condition of traffic recorder battery charges and clock-timing mechanisms were checked before traffic counts were obtained. One problem found was that the three SA-Traficounters had minor increases (up to 3 seconds) and decreases (up to 18 seconds) to the times between "hourly" recorder prints upon data tapes. Overall, the mechanical clocks ran 10-38 minutes late after 7 days of operation. Consequently, it became necessary to devise a special procedure for controlling errors with clock synchronization during subsequent testing.

A schedule was devised for collecting test data for comparing traffic recorder and manual counts of vehicle axles at the six highway study sites during the period August 1977 -January 1978. The parameter for manual counts was the number of vehicle axles, because numerical readings on traffic recorders should be increased by one each time the wheels to a pair of vehicle axles pass over a traffic hose. Two special procedures were applied when setting up groups of traffic recorders at various sites. The first was used to avoid problems with clock synchronization and to have the same vehicles counted by all traffic recorders. Before starting a 12-60 minute manual count, in accordance with traffic volume levels, all traffic hoses were disconnected and nonaccumulative recorders were set to read zero for volume count. Initial readings were noted for the accumulative counters. Next, all recorders were switched on and the traffic hoses were connected when starting each manual count. After each manual count, the hoses were disconnected. Nonaccumulative recorders were operated until the last partial time period of traffic volumes could be printed on the recorder tapes. Then, differences between initial and final traffic volume readings were tabulated for each recorder.

After an initial test phase, a second special procedure was developed by the research technician for use with the Stevens and SA-MR 101-A recorders. A road hose was connected to a 0.91-cm (3/8-in) diameter plastic tee-joint which was linked by short hoses to either two SA-MR 101-A or two Stevens recorders. Preliminary and subsequent testing revealed that this procedure reduced the number of road hoses required without affecting the traffic counts. This procedure has direct application in the regular traffic count program where it is necessary to obtain counts on highways having raised or wide median areas. While separate road hoses are placed on each side of a median area, where conditions permit, both could be connected to an inexpensive plastic tee-joint and to one recorder set in the median area as shown in Figure 3.



Figure 3. Plastic T joint linking two roadway hoses and a Stevens model recorder in a highway median area.

This procedure could provide substantial advantages by reducing both the number of recorder units required and the time necessary to compile and process the data as compared to the established practice of having to use two recorders, one on each road hose.

The only adjustments to traffic recorder controls were made before the start of the tests so as to adhere to the practice used in the Department's traffic count programs.

Additional Counting Error

One difference between the test procedures and the procedures used by Department personnel should be explained. The special testing procedure used to avoid problems with clock synchronization was intended to allow comparison of the best possible level of accuracy for all types of recorders. However, the accuracy of three recorder models can be adversely affected by clock-timing problems.

For the three SA-Traficounters, as long as mechanical clocks remain properly adjusted, the effect of errors in clocktiming should be considered negligible. The potential for problems with these should diminish because the Department is gradually replacing these units with other types of nonaccumulative recorders.

Although an investigation of the question is beyond the scope of this study, it is likely that one unmeasured problem with clock-timing is associated with the Department's use of the K-Hill and SA-Traficounter Junior, which do not have attached clock devices. In practice, an individual sets these accumulative counters in operation and is supposed to read the volume shown on the traffic recorder after returning to a study site 24 hours later. When individuals fail to adhere to a 24-hour schedule, differences in counting time periods, which are unlikely to be reported, would certainly vary the level of accuracy for affected traffic counts.

ANALYSIS

The analysis section of the report was developed by (1) gathering general information concerning problems with the operation of traffic recorders and statistical computations, (2) identifying problems in the operation of specific recorders, and (3) comparing traffic recorder data within and across study sites.

General Information

Recorder Operation Problems

Problems with traffic recorder operations resulted in eight cases involving four sites in which some recorder counts were not obtained. Apparently, the omission of these recorder counts did not obstruct the development of the analysis.

The identification of the eight problems indicated that, as expected, malfunctions do occur. However, because of the limited scope of this project, no quantitative estimates of the rates of malfunction are possible. These deficiencies clearly demonstrated that more should be learned about recorder malfunctions. Information from a study of the types and rates of malfunctions should be used to establish an effective system for preventing, detecting, and correcting problems with recorder operations in order to improve the management of traffic count program activities.

Statistical Computations

The data from each study site were used to compute equations describing least square lines that best fit a direct linear correlation between manual and recorder traffic counts. To measure how well the equations fit the relationship between manual and recorder counts, two basic linear regression statistics were computed.⁽⁴⁾ First, the correlation coefficient provides an index of how closely traffic counts tend toward a direct linear correlation. For example, when a coefficient is close to 1.0, data points closely follow the pattern for a linear regression line. Second, measures of the dispersal of recorder counts about regression lines were provided by the standard error of the estimate, which is similar to the standard deviation. Low standard errors are advantageous because they identify cases where the variability of the recorder data is minimal.

The Control Data Corporation package program SIMREG was used to compute regression equations, correlation coefficients, standard errors of the estimate and 95% confidence bands. Additionally, the relative error between recorder and manual counts was computed for each type of traffic recorder.(5) The relative error is the percentage of absolute average difference between recorder and manual counts divided by the manual counts; consequently, low relative errors are advantageous.

The traffic count data for study sites 1-6 were used to compute the corresponding regression equations, correlation coefficients and standard errors of the estimate by recorder model and study site and those are summarized in Appendix 1. The appendix data will be shown in figures which include graphs of the 95% confidence bands for each set of manual and recorder counts and will be discussed later. When referring to the graphs, recorder models are shown to have obtained highly accurate traffic counts in cases where regression lines are close to a 45 degree match line between recorder and manual counts and the 95% confidence bands are relatively narrow.

Within Site Comparisons

Site 1 - Accumulative and Nonaccumulative Recorders, Exceptionally Favorable Conditions

During testing at site 1, problems were encountered with traffic operation of the recorders in five cases. Before testing, an SA-Traficounter malfunctioned by locking up and had to be replaced. Initial testing showed that an SA-Traficounter Junior was miscounting traffic because a spring device was missing. Also an SA-MR 101-A failed to print traffic count tabulations. Unexpectedly, once the SA MR 101-A battery was changed, correct traffic counts were printed on the tapes; however, the corresponding time periods were printed out of phase. Before data could be obtained during another series of four time periods, 7 days after the recorders were put into continuous operation, an SA-Traficounter battery failed. Finally, a preliminary check of the data resulted in a special check of one K-Hill model which had a numerical recorder that was consistently overcounting traffic by 5%.

The site 1 traffic count data from Appendix 1 are shown in Figure 4. The graph for the SA-MR 101-A recorder data in the upper left shows that highly accurate traffic counts were obtained; the 95% confidence band was exceptionally narrow and encompassed the 45° match line. By comparison, the graph of the SA-Traficounter data in the upper right showed a

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Figure 4. Comparisons of manual versus recorder traffic counts (pairs of axles) for site 1, showing match lines and 95% confidence bands.

trend towards overcounting vehicle axle pairs since most of the area in the 95% confidence band was below the 45° match line. Similarly, the SA-Traficounter, Jr., data in the lower right showed a trend towards undercounting; most of the area in the 95% confidence band was above the 45° match line.

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The appendix data, graphs, and computed relative errors, were compared for each of four recorder models. The ranking for the accuracy of the recorder models in descending order and the corresponding relative errors were (1) SA-MR 101-A (0.8%), (2) K-Hill (1.0%), (3) SA Traficounter Junior (2.4%), and (4) SA Traficounter (3.1%). Overall, the four models tested obtained unusually accurate traffic counts, and both the nonaccumulative and accumulative recorders obtained accurate counts under these exceptionally favorable conditions.

Site 2 - Accumulative Recorders - Moderately Favorable Conditions

The two problems with the recorders at site 2 involved an SA-Traficounter Junior radically overcounting traffic and a K-Hill battery having to be replaced.

The traffic count data for site 2 from Appendix 1 are shown in Figure 5. Comparisons showed that the ranking order



Figure 5. Manual versus recorder traffic counts (pairs of axles) at site 2.

by recorder accuracy and relative errors were (1) the K-Hill (6.0%) and (2) the SA-Traficounter Junior (7.4%). In this comparison the accuracy of both of these accumulative type recorders on a secondary route were adversely affected by relatively conspicuous errors.

Site 3 - Accumulative Recorders, Unfavorable Conditions

Two problems with the recorders occurred during testing at site 3. A roadway hose was found to have leaks and the mechanical components of a K-Hill recorder were clogged by dirt and corrosion.

Figure 6 shows the site 3 traffic count data from Appendix 1. The comparisons showed that the ranking by accuracy and corresponding relative errors were (1) the K-Hill (3.4%) and (2) the SA-Traficounter Junior (6.7%). Thus, the K-Hill was the most accurate accumulative type recorder under unfavorable counting conditions on a secondary road.



Figure 6. Manual versus recorder traffic counts for site 3.

Site 4 - Nonaccumulative Recorders, Moderately Favorable Conditions

There were no problems with the operation of the recorders at site 4.

The traffic count data for the site are shown in Figure 7. Comparisons of these data revealed that the ranking order for the most accurate to the least accurate recorders, and their corresponding relative errors, were (1) Stevens (1.0%), (2) SA-MR 101-A (1.5%), and (3) SA-Traficounter (2.0%). Overall, all models obtained exceptionally accurate traffic counts under the moderately favorable conditions on a primary route.

Site 5 - Nonaccumulative Recorders, Unfavorable Conditions

The only problem with the recorders at site 5 was a failure of the battery for the SA-Traficounter.

The site 5 traffic count data are shown in Figure 8. Here, the comparisons showed the descending order of accuracy for the recorders and the corresponding relative errors to be (1) Stevens (2.2%), (2) SA-Traficounter (3.9%), and (3) SA-MR 101-A (4.7%). The Stevens was clearly the most accurate nonaccumulative type recorder under unfavorable counting conditions on an arterial route.

Site 6 - Nonaccumulative Recorders, Exceptionally Unfavorable Conditions

There were no problems with the recorders at site 6. The data for this site 6 are shown in Figure 9. The comparisons showed the ranking by accuracy and relative errors to be (1) the Stevens (2.5%) and (2) the SA-MR 101-A (3.3%). Both of these nonaccumulative recorder models obtained fairly accurate traffic counts under the exceptionally unfavorable counting conditions at site 6.

Comparisons Across Sites

Study Sites 1-6

The Appendix 1 data, graphs, and computed relative errors listed in Table 2 for all study sites were compared for each of the five recorder models. The accuracy ranking for the models and the corresponding average relative errors were (1) Stevens (1.9%), (2) SA-MR 101-A (2.6%), (3) SA-Traficounter (3.0%), (4) K-Hill (3.5%), and (5) SA-Traficounter Junior (5.5%).





Figure 8. Manual versus recorder traffic counts for site 5.



Figure 9. Manual versus recorder traffic counts for site 6.

TABLE 2

Relative Error of Recorders by Study Site and Counting Conditions

					Relative Error	°°	
No.	Counting Conditions	Recorder Type	Stevens	SA-MR 101-A	SA- Traficounter	K-Hill	SA- Traficounter Junior
Т	Exceptionally Favorablè	Accum. and Nonaccum.	1	0.8	3.1	1.0	· * 2.4
7	Moderately Favorable	Accum.	1 1 1	1	1	6.0	7.4
ო	Unfavorable	Accum.	1 5 1	1	l T L	3.4	6.7
÷	Moderately Favorable	Nonaccum.	1.0	1.5	2.0	1 1	1
ß	Unfavorable	Nonaccum.	2.2	4.7	3 . 9	1	
Q	Exceptionally Unfavorable	Nonaccum.	2.5	3.3	L L	1	I I I I
Combined* (1-6)			1.9	2.6	3.0	3 ° 5	5.5

* Combined - average with all test sites weighted equally.

Study Sites 4, 5, and 6

The low relative errors obtained with the Stevens and SA-MR 101-A recorders provided the opportunity for additional statistical comparisons. Data from test sites 4-6, which were thus obtained under moderate and unfavorable traffic counting conditions, were used to compare combined test results for these models. The results were not combined for the other models, which had lesser accuracy characteristics.

Regression equations, correlation coefficients and the standard errors of the estimate for the combined traffic counts are summarized in Appendix 2. Figures 10 and 11 are graphs of the combined counts for the Stevens and SA-MR 101-A recorders. The figures demonstrate that the recorders are capable of meeting high standards of accuracy because the regression lines are close to the 450 match lines between recorder and manual counts, and the 95% confidence bands are relatively narrow. Generally, the recorder counts were slightly lower than the manual counts, a finding thought to be attributable mostly to vehicles passing simultaneously and the closely spaced axles on tractor trailers, which comprised 1% of the passing traffic. Therefore, it would be possible to improve the accuracy by using correction factors to raise the counts by the recorders, The tendency for the Stevens and SA-MR 101-A recorders to undercount axle pairs by about 2% and 3%, respectively, should be accounted for whenever Department personnel need to calculate mathematical factors for converting axle pair counts into vehicle counts and, subsequently, into annual average daily traffic values.

SUMMARY OF FINDINGS

An analysis of the test data and observations made during the study revealed the following:

- 1. Because testing for the study was limited to three units each of the Department's five models of traffic recorders, the identification of eight problems in the operation of the recorders did not provide quantitative information representative of the types and rates of recorder malfunctions.
- 2. Under exceptionally favorable counting conditions, each model tested obtained unusually accurate traffic counts; however, the most accurate models and corresponding relative errors were the SA-MR 101-A (0.8%), a nonaccumulative recorder; and the K-Hill (1.0%), an accumulative type.



Figure 10. Manual versus Stevens model traffic counts (pairs of axles) - sites 4, 5, and 6.



Figure 11. Manual versus SA-MR 101-A traffic count (pairs of axles) — sites 4, 5, and 6.

- 3. Under moderately favorable and unfavorable counting conditions on secondary routes, the accuracy of both types of accumulative recorders was adversely affected by relatively conspicuous errors ranging from 3.4% to 7.4%.
- 4. Under moderately favorable counting conditions on a primary route, each nonaccumulative type recorder obtained exceptionally accurate counts and the corresponding relative errors were Stevens (1.0%), SA-Mr 101-A (1.5%), and SA-Traficounter (2.0%).
- 5. Under unfavorable counting conditions on an arterial route, the Stevens was clearly the most accurate nonaccumulative type recorder. The ranking and relative errors were Stevens (2.2%), SA-Traficounter (3.9%), and SA-MR 101-A (4.7%).
- 6. Under unfavorable counting conditions equivalent to those found on rural segments of interstate highways, fairly accurate counts were obtained. The ranking and relative errors were Stevens (2.5%) and SA-MR 101-A (3.3%).
- 7. Combining the data from all study sites revealed the order of accuracy to be: (1) Stevens, (2) SA-MR 101-A, (3) SA-Traficounter, (4) K-Hill, and (5) SA-Traficounter Junior. The low relative errors obtained with the Stevens (1.9%) and SA-MR 101-A (2.6%) demonstrated that they are capable of meeting high standards of accuracy.
- 8. It was found that when obtaining traffic counts on divided highways, and where practical, the separate road hoses placed on each side of a median area could be connected by a plastic tee-joint to one traffic recorder to obtain counts on both sides of the highway. This practice could lead to the elimination of one recorder unit and reduce the labor and computer effort for data processing.

RECOMMENDATIONS

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- 1. A study of the types and rates of malfunctions in the operation of traffic recorders should be made to establish an effective system for preventing, detecting, and correcting operational problems with the portable recorders.
- 2. The practice of using two traffic recorders on divided highways should be eliminated, where conditions permit, by using a plastic tee-joint to connect two road hoses to one recorder in the median area.

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APPENDIX 1

LINEAR REGRESSION CALCULATIONS INDIVIDUAL SITES

Recorder Model	Site No.	Regression Equation	Correlation Coefficient	Standard Error
Stevens	4	Y = 0.95 X +16.85	0.994	1.54
	5	Y = 1.01 X -10.38	0.991	2.22
	6	Y = 1.02 X -15.75	0.976	3.87
SA-MR 101-A	1	Y = 1.01 X - 0.79	0.999	1.07
	4	Y = 0.93 X +22.09	0.982	2.58
	5	Y = 0.99 X -12.53	0.973	3.82
	6	Y = 1.00 X -13.25	0.961	4.87
SA-Traficounter	1	Y = 1.07 X - 7.30	0.979	5.73
	4	Y = 0.88 X +44.34	0.822	8.93
	5	Y = 1.06 X -31.49	0.953	5.64
K-Hill	1	Y = 1.01 X - 1.27	0.995	2.66
	2	Y = 0.83 X +32.86	0.575	13.66
	3	Y = 0.96 X + 2.61	0.930	4.95
SA-Traficounter, Jr.	1 2 3	Y = 0.99 X - 0.85 Y = 0.84 X +31.67 Y = 0.81 X +39.38	0.974 0.474 0.649	5.94 17.40 12.11

APPENDIX 2

Recorder	Site	Regression	Correlation	Standard
Model	No.	Equation	Coefficient	Error
Stevens	4,5,6	Y = 1.01 X - 8.69	0.997	3.43
SA-MR 101-A	4,5,6	Y = 1.05 X -29.84	C.995	4.66

LINEAR REGRESSION CALCULATIONS COMBINED SITES