A Study of Driver Noncompliance with Traffic Signals

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There is a perception among traffic engineers that driver noncompliance with traffic control devices is a significant problem. Summarized in this paper are the results of a study of driver noncompliance at 12 signalized intersections in the Washington, D.C., metropolitan area to determine whether driver noncompliance is a problem and to define its relationship to intersection operational characteristics and roadway features. The results indicated that driver noncompliance is a problem that requires attention. It was found that higher violation rates occurred at intersections with low annual average daily traffic volume levels. These high violation rates were predominant on one-lane approaches during the off-peak hours. A correlation analysis indicated moderately high associations between high traffic signal violation rates and low traffic volumes. This research study recommends that drivers, local police, and local traffic engineers be informed that driver noncompliance with traffic signals is a problem with potential safety consequences and should be addressed through education, increased enforcement, and the application of sound engineering principles.

Traffic engineers have expressed a growing concern over the lack of driver compliance with traffic control devices in recent years. Driver noncompliance with traffic control devices, especially regulatory control devices, has been increasing significantly over the years. Drivers' apparent disregard for and perhaps lack of confidence in traffic control devices has been recognized by the American Association of State Highway and Transportation Officials' (AASHTO) Highway Subcommittee on Traffic Engineering. The AASHTO Standing Committee on Highways conducted a nationwide survey in October 1985 to determine if a driver noncompliance problem exists and, if so, what can be done to correct it. Surveys were sent to each state and the District of Columbia traffic engineer. They were asked to comment on motorist noncompliance with traffic control devices. To the question "Is traffic control device noncompliance a significant problem?" 34 of the 46 respondents said "yes" while 12 states answered "no" (*1*).

Other research studies in recent years have indicated that specific traffic control devices are being violated more than others. For example, studies have found that the violation rate with stop signs has been increasing linearly since 1935 (*2*). In another study it was found that the violation rate (i.e., not stopping when required) increased from 0.1 percent to 0.6 percent when the signal configuration changed from regular operation to flashing red (*3*). In another instance, the violation rate increased by a factor of five when sign configurations (a symbol only, instead of a symbol and message) were changed (*4*).

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The traffic control device violations may result from the combined effects of human behavior characteristics and related traffic operational characteristics. Such human factors might include the driver age, vision, and perceived travel time. Highway geometrics and such traffic operation characteristics as volume, type of regulatory control, and speed may also affect driver noncompliance.

In order to develop solutions, however, the problem of driver noncompliance must be defined in terms of where, when, how, how much, how serious, and why. The objective of this study was to determine the magnitude of driver noncompliance with traffic signals at intersections as it related to roadway features and traffic operational characteristics.

Driver noncompliance with traffic signals was studied at 12 intersections in Virginia, Maryland, and the District of Columbia during June and July of 1986. Drivers were observed under various operational conditions at signalized intersections during the peak and off-peak day and nighttime hours. Violation frequencies, operational characteristics, and roadway features were recorded and analyzed. The results of this study, which was sponsored by the Federal Highway Administration's Graduate Research Fellowship Grant program, are documented fully elsewhere (*5*).

METHODOLOGY

The experimental plan for determining the magnitude of driver noncompliance with traffic signals was made up of five parts:

1. Measures of effectiveness (MOEs),
2. Sample size,
3. Site selection criteria,
4. Data collection procedures, and
5. An analysis plan.

Measures of Effectiveness

The principal MOEs were the four driver violation types defined as follows. Each type was expressed in terms of hourly frequency and rate—violations per 100 vehicles.

- Running the red signal (RUNRED)—the number of through and left-turning vehicles entering the intersection past the near curb line after the onset of the red signal indication.
- Right-turn-on-red (NOSTOP)—the number of right turning vehicles not coming to a complete stop during the red signal indication.

- No right turn on red (NRTOR)—the number of vehicles making a right turn on red when there is a "No Turn on Red" sign.
- Total violations (TOTVIOL)—the total number of vehicles that violate the red signal indication (i.e., the sum of the three previous MOEs).

Violation rates were calculated per 100 vehicles for each MOE—RUNRED, NOSTOP, NRTOR, and TOTVIOL—based on its corresponding traffic volume—through left turn (THLTVOL), right turn (RTVOL), right turn (RTVOL), and total volume (TOTVOL), respectively.

Sample Size

Twelve signalized intersections were selected from a population of 30 intersections. The sample intersection population was limited because of the available information provided by each transportation agency, a short data collection time period of 2 months, and the manual data collection effort by only one observer.

The minimum sample of observations (380) for each intersection was found using a standard statistical estimating procedure that determined the minimum number of observations needed to meet a desired level of confidence and permitted error (*6*).

Site Selection Criteria

The intersection location and characteristics used as criteria in the selection of sites included the number of approaches (four only), number of approach lanes (one or two lanes), average annual daily traffic (AADT) (high, medium, and low), right turn on red (permitted or prohibited), approach speed limits (25 to 30 mi/hr), and jurisdiction in which the intersection was located.

The results of applying the site selection criteria are given in Table 1. The primary site selection criterion, AADT volume level, was used to stratify the intersection approaches into low, medium, and high AADT. Low was fewer than 7,500 entering vehicles per day, medium was 7,500 to 15,000, and high was greater than 15,000. These AADT volume levels were selected based on the volume ranges in the intersection population. Ranges of AADT volume levels were used to determine if violation rates or frequencies varied according to volume levels. Although AADT cannot indicate volume variations throughout the day, it was recognized that most of the travel occurred during the 7:00 a.m. to 11:00 p.m. study time period.

A balanced number of approach lanes was sought, with the selected sites consisting of 21 one-lane approaches and 27 two-lane approaches, for a total of 48 approaches.

The other regulatory control of interest was the "No Turn On Red" sign posted at a signalized intersection. Posted speed limits were controlled to reduce the variation of vehicle approach speeds that might influence driver noncompliance. All intersections had approach speed limits posted at 25 mi/hr, except for one intersection with a 30 mi/hr limit.

With respect to jurisdiction, Arlington and Fairfax counties in Virginia; Montgomery County, Maryland; and Washington, D.C., were represented by three, three, two, and four intersections, respectively.

Data Collection Procedures

Intersection inventory data were obtained by calling and visiting the transportation agencies in each jurisdiction and by visiting the sites. Operational data were collected for 2-hr periods during each of the morning peak, midday off peak, afternoon peak, and evening off-peak time frames, a total of 8 hr per intersection approach. Data collection for the 12 intersections was performed between June 23 and July 25, 1986. Dry pavement conditions existed throughout each observation time period except for one 2-hr off-peak period at one intersection.

Traffic volumes were counted on a rotation of 5-min (or nearest multiple signal cycle length) time intervals per approach for 2 hr. This provided a 15-min sample count per hour per approach. While counting traffic, all approaches were monitored for traffic violations. Thus, recorded violations represented total counts, while hourly volumes were obtained by expanding the 15 min of sample counts for each approach. Data collection quality was maintained by having only one observer collect all data.

Analysis Plan

To quantify driver noncompliance with traffic signals, the number of violations and violation rates for each MOE were

TABLE 1 CHARACTERISTICS OF SAMPLED INTERSECTIONS

Intersection No.	No. of Approach Lanes/AADT	Jurisdiction	Signal Location	Land Use
1	1/low AADT; 2/low AADT	Washington, D.C.	Post corner	Office
2	2/medium AADT and high AADT	Washington, D.C.	Post corner	Commercial
3	1/low AADT; 2/low AADT	Washington, D.C.	Post corner	Commercial
4	2/medium AADT and high AADT	Washington, D.C.	Post corner	Commercial
5	2/medium AADT	Arlington Co., Va.	Overhead	Commercial
6	1/low AADT and medium AADT	Arlington Co., Va.	Overhead	Residential
7	1/low AADT; 2/low AADT	Arlington Co., Va.	Cantilever arm	CBD[a]
8	1/low AADT and medium AADT	Fairfax Co., Va.	Overhead	Office
9	1/low AADT; 2/high AADT	Fairfax Co., Va.	Cantilever arm	Commercial
10	1/low AADT; 2/high AADT	Fairfax Co., Va.	Overhead	Commercial
11	2/medium AADT	Montgomery Co., Md.	Cantilever arm	CBD
12	1/low AADT; 2/low AADT	Montgomery Co., Md.	Post corner	Residential

[a]CBD = central business district.

examined to assess the overall noncompliance problem. Intersection characteristics such as the number of approach lanes, grades, stop bar distance to the near curb, signal location (i.e., post corner, overhead), land use, cycle lengths, curb parking, and traffic volume levels were examined in conjunction with violation occurrence. The resulting relationships indicated which independent variables (i.e., time, volumes, number of lanes, etc.) were related to the dependent variables (MOEs). These relationships were examined for each signalized intersection and for all 12 intersections combined. Pearson's correlation coefficients were also calculated to determine if the MOEs were associated with traffic volumes. These analyses established where, when, and how, as well as the magnitude of driver noncompliance with traffic signals.

FINDINGS

The MOEs will be discussed first with respect to violation frequency and rate and then by examining the intersection characteristics at intersections with similar violation rates. Characteristics of the sample of intersections used in the analysis included AADT volume levels, number of approach lanes, intersection jurisdiction, traffic signal location, and primary land use and are summarized by intersection in Table 1. The distribution of these characteristics by number of approaches and number of intersections is shown in Table 2.

TABLE 2 DISTRIBUTION OF INTERSECTION CHARACTERISTICS

	No. of Approaches	No. of Intersections
AADT volume levels		
Low	24	
Medium	16	
High	8	
No. of lanes		
One	21	
Two	27	
Jurisdiction		
Montgomery Co.		2
Arlington Co.		3
Fairfax Co.		3
District of Columbia		4
Signal location		
Post corner		5
Overhead spanwire		4
Cantilever arm		3
Primary land use		
CBD		2
Commercial		6
Residential		2
Office		2

Frequency Violation and Rate

Presented in Table 3 for each MOE are the total violations for all observation hours, the range of violations per hour, the percentage of time that at least one violation per hour was observed, and the average number of hourly violations per intersection approach. The number of violations per hour per approach was the greatest for NOSTOP, while NRTOR was the lowest. This result implies that drivers obeyed the "No Turn On Red" sign more often than drivers who properly executed RTOR by coming to a complete stop before turning right.

TABLE 3 OVERALL VIOLATIONS

	Measures of Effectiveness			
	NOSTOP	NRTOR	RUNRED	TOTVIOL
Violation sum	767	64	469	1,300
Range of violations per hour	0 to 23	0 to 8	0 to 11	0 to 23
Percent of at least one violation per total observed hours	74	48.7	54.3	85.9
No. of violations per intersection approach per hour	2.56	0.84	1.25	3.46

The violation rates by MOE for each intersection are given in Table 4. As expected, NOSTOP violation rates were significantly higher at all sites than the other MOEs. The propensity for many drivers to not come to a full stop before turning right on red has been recognized since the implementation of RTOR. The most hazardous violation, RUNRED, was observed for about one of every 200 through vehicles entering the intersection. Overall 1.25 violations occurred for every 100 vehicles entering the intersection.

TABLE 4 TRAFFIC VIOLATION RATES BY MEASURES OF EFFECTIVENESS AND INTERSECTION

Intersection	Overall Rate NOSTOP	NRTOR	RUNRED	TOTVIOL
1	12.20	2.28	0.36	0.64
2	3.14	–	0.23	0.44
3	7.13	0.99	0.61	1.18
4	4.46	1.75	0.32	0.95
5	5.68	–	0.59	1.64
6	3.91	–	1.09	1.40
7	9.25	–	0.88	2.64
8	17.22	–	0.65	4.06
9	11.22	–	0.27	1.16
10	7.00	–	0.42	0.74
11	–	2.56	0.95	1.22
12	17.87	–	0.93	3.07
Mean rate	7.59	2.02	0.52	1.25

NOTES: All rates per 100 vehicles. Dashes indicate not applicable.

Intersections with similar violation rates were grouped and their characteristics examined. Intersections were considered to have similar violation rates if their rates were within plus or minus 1.5 of one another. This range was chosen arbitrarily based on the researchers' judgment.

The intersection groupings by overall violation rate for each MOE are displayed in Table 5. As an example, for the NOSTOP MOE, 9 of the 12 intersections were combined into

TABLE 5 INTERSECTION GROUPINGS BY OVERALL VIOLATION RATE FOR EACH MEASURE OF EFFECTIVENESS

Measure of Effectiveness	Group I	II	III	IV
NOSTOP	1, 9	2, 4, 6	3, 10	8, 12
NRTOR	1, 11			
RUNRED	1, 4, 10	11, 12	3, 5, 8	2, 9
TOTVIOL	1, 10	3, 9, 11	5, 6	8, 12

four groups, with each group having NOSTOP violation rates within ±1.5 of one another. As is readily apparent, not all intersections were included in the groupings. This was particularly the case with the NRTOR MOE. A comparison of the information in Tables 1, 4, and 5 yields the following observations:

- Of the four groups of the NOSTOP MOE overall rates, three groups (I, III, IV) had low AADT volume levels in common with higher violation rates (rates greater than or equal to 7.00), and all groups within themselves had a similar number of approach lanes. Only one group, Group II, had medium and high AADT volume levels associated with lower violation rates. These results suggest that low AADTs and the number of approach lanes could be correlated with high NOSTOP violations.
- Although similar NRTOR violation rates occurred for Intersections 1 (2.28) and 11 (2.56), these intersections did not have similar characteristics.
- Intersections with similar RUNRED violation rates were combined into four groups; however, there were no intersection characteristics that dominated every group. It should be noted that Group IV had the lowest RUNRED violation rate with high AADTs on two-lane approaches for each intersection. These results suggest that no single characteristic with all approaches combined for an 8-hr period have an effect on RUNRED violations.
- Looking at all four groups for the TOTVIOL violation rate, the nine intersections were characterized by low, medium, and high AADT volume levels, one- and two-lane approaches, all three signal locations, all land use types, and all jurisdictions. No patterns were evident except that Group I had the lowest violation rates with low AADTs in common, while Group IV had the highest violation rates with mostly medium AADTs. These results suggest that low violation rates are associated with low AADTs, while higher violation rates are associated with medium AADT volume levels.

Number of Approach Lanes

The violation rates by the number of approach lanes were calculated for an 8-hr period per intersection and are shown in Table 6. Some intersections had four approaches with two lanes, four approaches with one lane, or a combination of one- and two-lane approaches.

The mean rate for all MOEs indicated that one-lane approaches had twice as many violations as two-lane approaches, except for the NRTOR violation rate. This trend was not consistent, however, for intersections individually. A further examination of the NOSTOP rates revealed that one extreme value skewed the results, and when it was removed, the mean rate for one-lane approaches became 9.84 compared to the previous value of 5.89 for two-lane approaches.

The RUNRED mean violation rate indicated twice as many violations for one-lane versus two-lane approaches. Upon further examination of each intersection individually, this trend was not consistent.

Looking at the overall TOTVIOL violation rates for one- and two-lane intersection approaches, the one-lane approaches had a higher violation rate with the exception of two intersections. One had an approach with a downhill grade of 7 percent. Thus, vehicles tended not to stop completely before they turned right (NOSTOP violation). This approach also had low AADT volume levels. The other intersection also had low AADT volume levels, good sight distance, and the majority of its violations were NOSTOP. Thus, both intersections had geometric conditions conducive to high NOSTOP violations and low AADT volume levels, thus less chance for conflicts.

Intersection Jurisdiction

The violation rates calculated by intersection jurisdiction included all four approaches for an 8-hr period. The results

TABLE 6 VIOLATION RATES BY NUMBER OF APPROACH LANES

Intersection	One Lane NOSTOP	NRTOR	RUNRED	TOTVIOL	Two Lanes NOSTOP	NRTOR	RUNRED	TOTVIOL
1	10.45	1.91	0.38	0.68	16.51	2.86	0.34	0.56
2	–	–	–	–	3.14	–	0.23	0.44
3	87.42	–	1.66	4.49	0.49	0.99	0.31	0.36
4	–	–	–	–	4.46	1.75	0.32	0.95
5	–	–	–	–	5.68	–	0.59	1.64
6	3.91	–	1.09	1.40	–	–	–	–
7	6.11	–	0.83	1.78	19.69	–	1.61	10.94
8	17.22	–	0.65	4.06	–	–	–	–
9	11.95	–	0.24	2.12	11.12	–	0.27	1.08
10	9.96	–	0.00	2.67	4.44	–	0.45	0.56
11	–	–	–	–	–	2.56	0.95	1.22
12	19.31	–	1.01	2.66	16.68	–	0.77	3.73
Mean rate	11.56	1.91	0.86	2.21	5.89	2.03	0.41	0.95

NOTES: All rates per 100 vehicles. Dashes indicate not applicable.

TABLE 7 JURISDICTION VIOLATION RATES

	Mean Violation Rates			
Jurisdiction	1[a]	2[b]	3[c]	4[d]
Fairfax Co.	11.94	–	0.38	1.33
Montgomery Co.	17.87	2.56	0.94	1.78
D.C.	4.96	1.72	0.36	0.79
Arlington Co.	6.06	–	0.82	1.74

NOTES: All rates per 100 vehicles. Dashes indicate not applicable.
[a]NOSTOP.
[b]NRTOR.
[c]RUNRED.
[d]TOTVIOL.

TABLE 8 SIGNAL LOCATION VIOLATION RATES

	Mean Violation Rates			
Signal Location	1[a]	2[b]	3[c]	4[d]
Post corner	4.83	1.72	0.51	0.94
Overhead spanwire	7.44	–	0.63	1.50
Cantilever arm	10.34	2.56	0.55	1.43

NOTES: All rates per 100 vehicles. Dashes indicate not applicable.
[a]NOSTOP.
[b]NRTOR.
[c]RUNRED.
[d]TOTVIOL.

showed that Montgomery County, Maryland, had the highest NOSTOP, NRTOR, RUNRED, and TOTVIOL mean violation rates, whereas the District of Columbia had the lowest rates (Table 7). Fairfax County had the second highest NOSTOP mean violation rate, and Arlington County had the second highest mean violation rates for RUNRED and TOTVIOL. Each jurisdiction has a different law concerning the violation of a red signal indication as summarized below:

- *Maryland*—Drivers are required to exercise "caution" when entering an intersection when the traffic signal is yellow. However, they are not legally bound to stop.
- *Virginia*—Motorists are required to stop at an intersection if the signal has turned yellow and if they have what police call ample time to halt.
- *District of Columbia*—Drivers are legally in violation and subject to a $50 fine if they enter the intersection when the signal is yellow and if they had ample time to stop. The fine for running a red signal is $75, the stiffest penalty in the region.

Traffic officials of all three jurisdictions indicated that the yellow interval is generally the same (4 sec) in all jurisdictions (*7*).

The jurisdictions' different laws may have affected the violation rates. The District of Columbia had the lowest violation rates and also the stiffest penalties in the region. On the other hand, Montgomery County had the highest violation rates with a lesser red signal violation penalty (i.e., to only exercise "caution" when entering an intersection when the traffic signal is yellow). Arlington County and Fairfax County, Virginia, had greater violation rates than D.C., but lower than those of Montgomery County. This could be a result of Virginia's lesser violation penalty compared with D.C's. The collection of enforcement data was not within the scope of this study, thus no conclusions can be drawn concerning the role of existing enforcement levels.

Traffic Signal Location

Of the three traffic signal locations, the cantilever arm signals had the highest mean violation rates for the NOSTOP and NRTOR (Table 8). The overhead spanwire signal location had the highest RUNRED and TOTVIOL mean violation rates. The post corner signal intersections had the lowest mean violation rates for all MOEs. When overhead spanwire and cantilever arm intersections were combined, they had mean violation rates of 8.29, 2.56, 0.60, and 1.47 for the NOSTOP, NRTOR, RUNRED, and TOTVIOL violation rates, respectively. These rates were all greater than the post corner signal locations. This could be due to the overhead spanwire locations having better visibility than post corner locations, thus giving drivers a better view of the signal and an ability to react to conflicting traffic appropriately.

Time-of-Day Comparisons

The NOSTOP mean violation rate was highest during the nighttime hours, second highest during the off-peak hours, and third and fourth highest during the morning and evening peak hours, respectively (Table 9). These mean violation rates indicate that the NOSTOP violations occurred more often during the off-peak hours. The NRTOR mean violation rate was also highest during the nighttime hours, with the off-peak hours second, evening peak hours third, and morning peak hours fourth. The RUNRED mean violation rate indicated that the evening peak hours had the highest violations. The morning peak hours were second, with off-peak and nighttime hours third and fourth, respectively.

With all the violations combined (TOTVIOL), the nighttime hours produced the highest overall mean violation rate. The off peak was second, with evening and morning peak hours fairly even. To examine these results further, each individual intersection MOE violation rate was compared to the different 2-hr time periods.

At 7 of 11 intersections, both the nighttime and off-peak hours had the greatest NOSTOP violation rates compared to the peak hours. The other four intersections had the second highest NOSTOP violation rates during the peak hours.

Only four intersections prohibited turning on red at any time during the day. Two intersections had the greatest violation rate during the nighttime hours, while the other two intersections were greatest during the peak periods. Overall (all four intersections combined), the highest violation rates occurred at nighttime. However, no time period dominated the NRTOR violation rates.

An examination of each intersection RUNRED violation rate indicated that seven intersections had the highest violation rates during at least one peak period (morning or evening). Three intersections had both peak periods with higher rates than the off-peak periods. These results strongly suggest that most of the intersections had the highest RUNRED violation rates during the peak periods.

The TOTVIOL mean violation rates suggested that all violations combined occurred more often in the nighttime and off-peak hours. Eight out of the eleven intersections with nighttime

TABLE 9 TIME-OF-DAY VIOLATION RATES

Inter- section	NOSTOP				NRTOR			
	Morning[a]	Evening[b]	Off Peak[c]	Night[d]	Morning[a]	Evening[b]	Off Peak[c]	Night[d]
1	–	–	–	12.54	1.97	2.46	2.21	–
2	2.75	2.75	1.78	5.48	–	–	–	–
3	3.35	3.17	17.55	9.43	1.92	0.00	0.89	–
4	4.08	2.99	4.60	14.09	0.56	1.05	2.09	7.23
5	1.65	4.11	5.79	18.01	–	–	–	–
6	3.49	3.50	2.83	–	–	–	–	–
7	8.98	8.58	10.12	–	–	–	–	–
8	15.42	14.38	15.61	39.71	–	–	–	–
9	18.92	6.30	10.18	20.39	–	–	–	–
10	6.80	4.00	11.03	7.45	–	–	–	–
11	–	–	–	–	2.84	2.12	1.72	4.79
12	26.25	10.28	21.95	16.47	–	–	–	–
Mean rate	6.51	5.43	8.54	13.14	1.34	1.61	1.79	5.89

NOTES: All rates per 100 vehicles. Dashes indicate not applicable.
[a]Morning 2-hr peak.
[b]Evening 2-hr peak.
[c]Off peak 2 hr.
[d]Nighttime 2 hr.

observations had the highest violation rates. One intersection was not monitored at night, but it had the highest violation rate during the off-peak hours.

Similarities Among Intersection Characteristics

As previously discussed, intersections were grouped according to similar violation rates. Once these groups were established, other intersection characteristics such as number of approach lanes, land use, signal locations, and AADT volume levels were examined to determine if any relationships existed. The only similar intersection characteristic that emerged was the intersection approach AADT volume level.

The results presented here are based on intersections grouped by their similar overall violation rates (rates calculated for an 8-hr period with all four approaches). It should be noted that these violation rates are not directly related to AADT volume levels (i.e., the violation rates were calculated from the expanded traffic volume counts, not AADT volume levels).

Illustrated in Table 10 is the relationship between each MOE's overall violation rates (high or low) and the AADT volume levels. The NOSTOP MOE resulted in 9 out of 11 intersections extracted into four groups. Six of the nine intersections had high violation rates (greater than or equal to 7.00) while three intersections had violation rates less than 7.00. The combined six intersections with high violation rates had 75 percent of the approaches with low AADT volume levels. The three intersections with low violation rates had 83 percent of the approaches with medium or high AADT volume levels. Thus, the high NOSTOP violation rates were associated with low AADTs and low violation rates with medium and high AADT volume levels.

The NRTOR MOE resulted in one group with two of four intersections. These two intersections did not have similar AADT volume levels. Therefore, no association existed between NRTOR and AADT volume levels.

The RUNRED MOE resulted in four groups. There were 10 of 12 intersections within these four groups. Five intersections had low rates (rates less than 0.50), while five intersections had higher rates (rates greater than 0.50). The low violation rate intersections had mostly medium and high AADT volume levels (60 percent of the approaches), whereas the high violation rate intersections had mostly low AADT volume levels. Thus, these results imply that low AADTs can be associated with higher violation rates, and medium and high AADT's can be associated with low violation rates.

TABLE 10 OVERALL VIOLATION RATES RELATED TO AADT VOLUME LEVELS FOR EACH MEASURE OF EFFECTIVENESS

Measure of Effectiveness	AADT Volume Level Categories		
	Low	Medium	High
NOSTOP	High rate	Low rate	Low rate
NRTOR	*a*	*a*	*a*
RUNRED	High rate	Low rate	Low rate
TOTVIOL	High rate	Low rate	Low rate

[a]No association noticed.

The TOTVIOL MOE resulted in nine intersections with similar violation rates that were placed into four groups. Seven of the intersections had violation rates greater than 1.00 (high rate), and two intersections had violation rates less than 1.00 (low rate). The seven intersections with high violation rates had 50 percent of the approaches with low AADTs. The two low-rate intersections had 75 percent of the approaches with low AADTs. Since the majority of intersections have high rates with low AADTs, this suggests that high rates are more often associated with low AADTs.

Violations Versus Volume Correlations

A useful technique for studying the volume versus violation rate relationship is to establish a correlation between these variables. Descriptive statistics were calculated for the violation rate and volume distributions and included means, standard deviations, and a measure of skewness. The data were aggregated from hourly observations to an 8-hr count by approach. Thus, there were 48 observations or cases. This was done because of the small amount of variance using hourly observations. Based on standard deviation values and skewness, the 48 observations were not normally distributed. For nonnormal data, either a nonparametric test, which is distribution free, may be used or the data may be transformed so that parametric tests may be applied. The use of parametric tests is generally more desirable because they are more powerful than nonparametric tests. Consequently, the data were transformed.

The transformation of data raised a contentious issue. On one hand, some statisticians argue that transforming data is nothing more than "fudging" the data to fit the model and that the implications of transforming data are not fully understood. On the other hand, other statisticians argue that all measurement systems are arbitrary; hence transformed data are just as valid as untransformed data. This latter group has no reservation in using a transformation to normalize data if normally distributed data are required (*8*). Thus, since statisticians have used transformation processes to normalize their data, and a normal distribution is required for parametric testing, it was applied here.

For a transformation to be applied, the skewness measure must be examined. If the data are positively skewed, a transformation is needed that will reduce values in the upper tail by a greater amount than those located in the lower tail. This is accomplished by taking either the square root (fairly moderate transformation) or the logarithm (more radical transformation) for each observation. Both of these transformation processes were applied for the 48 hr observations. The logarithm transformation process gave the better result.

Given in Table 11 are the logarithmic transformations for an 8-hr period by approach. These results indicate low standard deviations versus the mean values for most variables, and the skewness test for normality resulted in all variables falling within the Beta 1 critical limits with 98 percent confidence limits. The NRTOR MOE did not have B1 critical limits, but as the sample size decreases, the B1 critical limits increase. Therefore, the NRTOR skewness value of 0.08 fell within the B1 critical limit. Since logarithmic transformations produced normal data, Pearson's correlations were calculated.

Correlation Analysis Results

The correlation coefficients are presented in Table 12. They ranged from −0.0800 for NRTOR versus RTVOL to −0.6941 for TOTVIOL versus TOTVOL for all 48 observations. These correlations indicate that as traffic volumes increased, the violation rate decreased. A *t*-test tested the null hypothesis. Using the *t*-test, all correlated variables' null hypotheses (i.e., that the population correlation coefficient is zero) were rejected at the 90 percent or greater confidence level, except that of NRTOR versus RTVOL.

If the correlation coefficient is squared, inferences can be made about the total variation explained. For example, right turn volume explained 10.4 percent of the variation in NOSTOP. The THLTVOL explained 30.8 percent of the variation in RUNRED, and TOTVOL explained 48.2 percent of the variation in TOTVIOL. These coefficients of determination indicated that volume is not significant in explaining the amount of variation in the violation rate for NOSTOP but are fairly significant for RUNRED and TOTVIOL.

Additional correlations for violation rates versus volume were calculated by the number of approach lanes (see Table 12). The NOSTOP versus RTVOL had a 5.2 percent decrease in the amount of variance explained by one-lane approaches versus the one- and two-lane approaches combined coefficient of determination (10.4 percent). However, there was an increase of 6.3 percent variance explained between one-lane and two-lane approaches. The correlation coefficient on two-lane approaches is fairly high with a 90 percent confidence level, indicating a stronger association between NOSTOP versus RTVOL on two-lane approaches, as opposed to one-lane approaches.

There was no correlation coefficient for NRTOR versus RTVOL on one-lane approaches since there were only two observations. On two-lane approaches, the correlation coefficient was −0.2313. This correlation was not significant.

The RUNRED versus THLTVOL correlation was the least for one-lane approaches and was not significant. The two-lane approach correlation (−0.6068) was much higher than that for the one-lane approach. The difference in the amount of variance explained between one- and two-lane approaches was 33.8 percent. The two-lane approaches had higher correlations than with both one- and two-lane approaches combined and explained 6.0 percent more variation.

The total violation versus total volume correlations indicated that two-lane approaches had a higher value compared with those of one-lane approaches. These values were −0.6898 and −0.4242, respectively. The one-lane approach correlations were significant at the 95 percent confidence limit while the two-lane approaches were significant at 99.5 percent. It can be concluded that two-lane approaches had a greater degree of association between TOTVIOL and TOTVOL than one-lane approaches, but not with both one- and two-lane approaches combined.

TABLE 11 LOGARITHM TRANSFORMATION FOR AN 8-HR COUNT BY APPROACH

Variable	8-Hr Observations	Mean	Standard Deviation	Skewness	B1 (2%)
NOSTOP	43	0.838	0.361	−0.118	0.71
NRTOR	10	0.280	0.258	0.121	–
RUNRED	46	−0.266	0.340	−0.137	0.64
TOTVIOL	48	0.128	0.389	0.006	0.64
RTVOL	48	0.325	0.333	−0.058	0.64
THLTVOL	48	1.128	0.381	−0.078	0.64
TOTVOL	48	1.214	0.344	−0.062	0.64

NOTE: Dash indicates no table value.

CONCLUSIONS

The violation frequencies and rates in the preceding sections described quantitatively the magnitude of driver noncompliance with traffic signals at signalized intersections as it related to traffic operational characteristics and roadway features.

Considering each MOE separately, the NOSTOP violation rate was greatest on low AADT volume intersection approaches. This was also supported by its rates being highest

TABLE 12 PEARSON'S CORRELATION TABLE FOR VIOLATIONS VERSUS VOLUMES

	48 Observations				One-Lane Approach				Two-Lane Approach			
Correlated Variables	NOSTOP RTVOL	NRTOR RTVOL	RUNRED THLTVOL	TOTVIOL TOTVOL	NOSTOP RTVOL	NRTOR RTVOL	RUNRED THLTVOL	TOTVIOL TOTVOL	NOSTOP RTVOL	NRTOR RTVOL	RUNRED THLTVOL	TOTVIOL TOTVOL
No. of observations	43	10	46	48	21	2	19	21	22	8	27	27
Pearson's correlations	−0.3222	−0.0800	−0.5551	−0.6941	−0.2279	–	−0.1731	−0.4242	−0.3391	−0.2313	−0.6068	−0.6898
R**2	0.1038	0.0064	0.3081	0.4818	0.0519	–	0.0300	0.1800	0.1150	0.0535	0.3682	0.4758
t-test	Reject	N.reject	Reject	Reject	N.reject	–	N.reject	Reject	*Reject	N.reject	Reject	Reject

NOTES: R**2 = coefficient of determination. Reject = rejected at 5%, 2.5%, and 0.5% levels. N.reject = not rejected. *Reject = rejected at 10% level. Dashes indicate sample size too small.

during nighttime and off-peak hours (low volumes during these time periods). When correlated with right turn volumes, the NOSTOP violation rate had significant correlations for all approaches combined and for two-lane approaches. These results may be attributed to a lesser risk of conflict events (low traffic volume levels), better sight distances on two-lane approaches, and possibly lower enforcement levels at off-peak and nighttime hours.

The NRTOR violation rate constituted a relatively small sample size, and therefore, no associations were found between it and right-turn volumes. This MOE was found to occur most often at nighttime.

The RUNRED violation rate was highest during the evening peak hours. It was also found that these high rates occurred for mostly low AADT approaches. Relatively high negative correlations indicated that as the traffic volumes increased, the RUNRED violation rate decreased. These results are expected since more conflict opportunities exist during high levels of traffic volumes.

With all violations combined, TOTVIOL resulted in the highest significant correlations, most violations occurred at nighttime, and the highest rates occurred on low-AADT-volume intersection approaches.

These results suggest that driver noncompliance with traffic signals exists at low-volume intersections during off-peak and nighttime hours on one-lane approaches. Does this suggest that driver noncompliance with traffic signals is a significant problem? With all violations combined, the answer is yes. An overall TOTVIOL violation rate of 1.25 vehicles per 100 vehicles is fairly significant with the highest MOE violation rate being NOSTOP. Does this violation type pose potential safety hazards? What can be done to correct it? The answers are the 3 Es, Education, Enforcement, and Engineering.

Efforts should be made to inform the driver, local police, and local traffic engineers that driver noncompliance is a problem and should be addressed. Improvements such as higher enforcement levels at low traffic volume intersections, stiffer violation penalties, and educating the public of what constitutes a traffic signal violation should be considered. Engineering improvements might include removing unnecessary informational, or regulatory control, devices adjacent to intersection approaches, better signal timing and network progression, lighted intersections, and intersection geometric improvements. Not all of these improvements are applicable for every signalized intersection; therefore, the traffic engineer must use professional judgment. It is also recommended that signalized intersections be monitored periodically for driver noncompliance levels. As traffic volume conditions change, further intersection improvements may be justified.

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