Efficacy of Jurisdiction-Wide Traffic Control Device Upgradings

RICHARD W. LYLES, DALE R. LIGHTHIZER, ARIS DRAKOPOULOS, and SANDRA WOODS

ABSTRACT

An evaluation of several jurisdiction-wide traffic control device upgradings in Michigan was undertaken. The upgradings included only signs. A "before-after with control" experiment design was employed in the examination of general accident distributions along with a more detailed distribution of vehicle-vehicle accidents. Results of assessing the overall effectiveness of traffic control device (TCD) upgradings on a jurisdiction-wide basis were mixed at best. The general variability of accident statistics and because most sites in a jurisdiction have only minor, if any, problems, potential positive results tend to be overwhelmed at sites where there may be significant improvements. It is suggested that safety-effectiveness studies are more appropriate at lower levels of aggregation.

Federally supported programs for inventorying and subsequently upgrading traffic control devices (TCDs) within specific local jurisdictions have long been considered effective investments in highway safety. The purpose of such upgrading is to bring all TCDs and their placement into compliance with the Manual on Uniform Traffic Control Devices (MUTCD) published by the FHWA, U.S. Department of Transportation. Although there are numerous studies on the effectiveness of specific devices at specific locations, few have been explicitly concerned with the evaluation (in terms of safety measures) of jurisdiction-wide programs. The study described here was undertaken with the objective of quantifying the safety-related impacts of comprehensive TCD upgradings in several jurisdictions of varying size in Michigan. The upgradings that were included in this program were concerned with signs only.

Michigan has reasonably extensive and reliable machine-accessible accident and related files. Regardless of the jurisdiction, a common accident report form is filed with the Michigan Department of State Police (MSP), coded, and entered in a central system. The report contains a variety of information about the physical description of the accident itself, the involved vehicles, the accident site, the drivers and passengers, as well as other descriptive information. Approximately 12 years of data were used (1972 through 1983).

METHODOLOGY

The basic approach was to select several jurisdictions that had undertaken TCD upgradings and identify their safety-related impacts. The study was based on a "before and after with modified control" experiment design. The use of the modified control consisted of making parallel comparisons for treated and untreated streets within each jurisdiction--the latter being state trunklines (i.e., numbered state routes) ineligible for TCD upgrading project funds. Thus, a control is provided that has the advantage of being internal. Notwithstanding that somewhat different kinds of accidents might occur on the two systems, the impacts of other confounding factors are avoided by using streets that have the same variations in, for example, weather conditions over the analysis period. For each jurisdiction in the analysis, one or more before periods and an after period (all of equal duration) were identified.

The measures of effectiveness (MOEs) were concerned with the distributions and actual numbers of accidents in each jurisdiction. More specifically, the MOEs addressed the following:

1. Distribution of accidents by general type. For example, is there a shift between vehicle-vehicle collisions and vehicle-fixed object collisions? Examination of the before-after statistics for the control streets (state trunklines) would generally establish whether there were shifts among general accident categories. Having established this baseline, the shifts on the treated streets could be examined.
2. Distribution of vehicle-vehicle collisions. For example, is there a shift between multivehicle rear-end and angle collision accident types?

Evidence of the preceding shifts for treated and control streets within jurisdictions is useful information in itself, but there are at least two other aspects of the shift that are important.

3. Total number of accidents that occurred. Given that equal duration before-and-after periods were defined for each jurisdiction, absolute comparisons of the total number of accidents and the number of accidents in various categories can also be made.
4. Severity of accidents. The foregoing information is supplemented by a consideration of accident severity.

The use of trunklines as a "true" control has obvious disadvantages when the treated streets are local; for example, trunklines carry different kinds of traffic, the applicable design standards are different, and vehicle speeds are different. The purpose was to establish a baseline for the more inter-

R.W. Lyles, D.R. Lighthizer, and A. Drokopoulos, Department of Civil and Environmental Engineering, Michigan State University, East Lansing, Mich. 48824-1212. S. Woods, 4660 Kenmore Ave., JHK & Associates, Alexandria, Va. 22304.

esting before-and-after comparisons of the treated streets. The real utility of the control in this experiment, however, is to establish a general trend in accidents between similar time periods. For example, if there was an increasing trend in accidents on state trunklines within a city an increasing trend could be expected in accidents on the local system; if there is more travel on trunklines there should be proportionately more travel on the local system as well; that is, the trends in increasing or decreasing exposure should be similar. Accident types could be expected to be different on the two types of streets--and indeed they were. So, the comparison between the "treated" and "control" groups was a loose one--an attempt to establish a very general trend. As will be demonstrated, the comparison between the before-and-after periods for the trunklines and, separately, for the treated streets was useful.

APPROACH TO DATA ANALYSIS

The approach to data analysis was straightforward and consisted of three basic stages. The first stage was to identify all jurisdictions to be studied and to identify one jurisdiction as a test case to be examined in detail before undertaking the analysis on all jurisdictions. Albion, Michigan, was chosen as the test case based on the average number of accidents occurring there in a year and because 100 percent of the local system had been treated during an upgrading project.

The second stage of analysis was concerned with the examination of the distributions of different characteristics of the accidents occurring in Albion, for example, what age groups were involved. This level of analysis was also directed to identifying any basic differences between accidents on trunklines (control) and those on the local street system (treated). This analysis also provided, in part, the basis for defining different groups of motorists and accidents for which the differential effects of TCDs might be apparent; for example, one group of accidents consisted of those occurring during the day in good weather where the driver of vehicle number 1 (the "at-fault" vehicle) was unimpaired.

The third stage consisted of the actual before-after comparison for treated streets and the comparison between control and treated groups as outlined earlier.

SELECTION OF JURISDICTIONS AND DATA COLLECTION

The selection of which jurisdictions would be analyzed was based on several criteria: the percentage of local streets (i.e., treated as part of the upgrading project); whether the project completion date allowed an adequate after period for analysis; and whether the set of jurisdictions provide for reasonable mixes of population and geographical representation.

Eventually, 13 jurisdictions were chosen ranging in size from Kaleva, which has a population of 450 and less than a dozen accidents per year, through Albion, which has a population of 11,000 and more than 300 accidents per year, to Pontiac, which has a population of 77,000 and 5,000 accidents per year. The percentage of eligible local streets that were treated was 100 for most cities although for Pontiac, the largest city, the percentage was 86.

Although several kinds of data were collected for each jurisdiction, by far the most important was the accident records. Other data, such as project beginning and end dates, jurisdiction population, and so forth, were primarily used in the selection of the sample of jurisdictions to be analyzed. Once the jurisdictions had been identified, all of the accident records for each jurisdiction over the entire time period 1972 to 1983 were obtained from files maintained by the Michigan Department of Transportation (MDOT) and the Michigan Department of State Police (MSP).

Several problems were encountered with the data, including differentiating the effects of the TCD upgrading from general background accident trends across the state, isolating accidents that could realistically be expected to be affected by TCD upgradings, identifying an appropriate control for each jurisdiction, and accounting for general occurrences such as seasonal variation in accidents and user volumes.

DATA ANALYSIS AND RESULTS

The data analysis was done in two fundamental phases: the first phase was concerned with an exploration of the data for Albion, the test city, and the second was concerned with applying the knowledge gained from the Albion investigation to the 12 other cities.

General Description of the Data

The initial examination of Albion data started with a review of the frequency distributions of the several variables available in the accident files. The rationale for this review was to make a basic determination of which "confounding" variables were of concern in order to either (a) eliminate some accidents from the analysis (e.g., accidents occurring in a construction zone) or to (b) provide the basis for data stratification.

The stratification of accidents was achieved by assigning group designations (which were not necessarily mutually exclusive). The purpose of the group designations was not to eliminate accidents, but to stratify them according to certain common characteristics of interest. For example, the reaction of drunk drivers to TCDs may be different from the reaction of nonimpaired drivers, that is, impaired and nonimpaired drivers provide one dimension for group definition.

The final step before beginning the analysis in earnest was the identification of before-and-after periods for each of the test cities. After some experimentation with longer and shorter periods, a basic length of three years was selected.

Although the 3-year periods are equal in absolute length, they do not contain data for the same precise time periods for each city (because of different project time periods). The advantage of the equal before-and-after periods is that both relative and absolute comparisons of the number of accidents occurring can be made.

Basic Analytical Approach

The fundamental analytical approach taken was to compare accident statistics before and after the project was undertaken. The basic statistical technique was chi-square testing to evaluate whether the before-and-after distributions by, for example, general accident type were the same. This was augmented with other testing as appropriate. There was also a before-after comparison for the control (untreated) streets. In general, the analysis proceeded as follows: for a specific variable, a before-after comparison was made for the control streets (state

TABLE 1 Before-After Comparison for MSPAT, All Cities Combined

	STL System[a]				LOC System[b]			
Category	Before	Percentage	After	Percentage	Before	Percentage	After	Percentage
Overturned	10	0.6	10	0.6	26	0.7	14	0.4
Train	(Combined with others)				11	0.3	14	0.4
Parked vehicle	65	3.7	43	2.7	612	16.5	568	16.1
Another vehicle	1,528	87.2	1,412	88.6	2,638	71.0	2,529	71.8
Pedestrian	18	1.0	14	0.9	72	1.9	59	1.7
Fixed object	112	6.4	91	5.7	287	7.7	272	7.7
Bike	17	1.0	18	1.1	69	1.9	65	1.8
Other categories (combined)	3	<1.0	5	<1.0	3	<1.0	2	<1.0
Total	1,753		1,593		3,718		3,523	

Notes: All cities except Pontiac are combined for this analysis. Absolute number of accidents are given and percentage of total in category. Chi-square comparisons of before and after periods: STL: chi-square (6 X 2) = 3.906; p = .563. Chi-square (7 X 2) = 4.619; p = .594. LOC: chi-square (8 X 2) = 4.664; p = .701.

[a]State trunkline (control).
[b]Local (treated).

trunklines, ineligible for treatment) followed by the same comparison for the treated streets. If the data were "well-behaved" and the TCD upgrading was effective, the following results could be expected: for the state trunklines, a net decrease in accidents in all categories would be observed although the before-after distribution would be proportionately the same; for the city streets (the treated group), larger decreases would be accompanied by shifting among the categories. Note that strict comparisons of "treated to control" were not made other than to verify that, indeed, the types of accidents occurring on the two systems were different.

The initial results for Albion were somewhat promising in that overall accident decreases were observed. Subsequently, the analysis was expanded to all cities. In the following discussion the analysis in the second phase is described, beginning with an analysis of the aggregated accidents for all cities except Pontiac.

Much of the discussion refers to two key variables: Michigan State Police accident type (MSPAT) (see Table 1 for categories) and highway accident type (HWYAT), basically types of vehicle-vehicle collisions (see Table 2 for categories).

General Results--All Cities Combined

The first step was to examine all of the cities collectively for the trends in MSPAT and HWYAT. (The exception was Pontiac, which was examined separately due to cost.) The overall analysis provides the broadest possible view of the potential TCD impact. The one shortcoming is that although all time periods have a common time length, the overall before data, for example, will contain data from different "real time" periods. No group stratifications are reported here.

Table 1 gives the overall results for MSPAT. Qualitatively, there appears to be little difference in the percentages of the different types of accidents (shown in parentheses). However, the chi-square statistics indicate that the MSPAT distributions are different on both the local (LOC) or treated system and the state trunklines (STL) or control system, which is counter to the result that would lead to a straightforward interpretation of the TCD upgrading effect. Indeed, based on the relative p-values, the before-after distributions are more similar for the LOC system than for the STL system--the opposite result from one indicating that the TCD upgrading had any effect. It should be noted that the changes in the total number of accidents are somewhat less pronounced than was initially observed for Albion alone.

A note on the use of frequencies rather than rates is appropriate here. The use of some measure of exposure to normalize the comparisons is always desirable. However, taken in the aggregate, as is the case here, an accurate exposure rate for an entire city (plus a breakdown by street types) is difficult at best. Further, the assumption is that ex-

TABLE 2 Before-After Comparison for HWYAT, All Cities Combined

	STL System				LOC System			
Category	Before	Percentage	After	Percentage	Before	Percentage	After	Percentage
Other	277	18.1	243	17.2	435	16.5	417	16.5
Head-on	27	1.8	20	1.4	63	2.4	62	2.5
Sideswipe (same direction)	60	3.9	25	1.8	61	2.3	38	1.5
Sideswipe (opposite direction)	10	0.7	11	0.8	24	0.9	19	0.8
Angle	348	22.8	409	29.0	1,106	41.9	1,147	45.4
Left turn	254	16.6	223	15.8	243	9.2	248	9.8
Right turn	46	3.0	33	2.3	96	3.6	66	2.6
Rear end	442	28.9	413	29.2	456	17.3	392	15.5
Back into	37	2.4	16	1.1	82	3.1	105	4.2
Parking	27	1.8	19	1.3	72	2.7	35	1.4
Total	1,528		1,412		2,638		2,529	

Notes: All cities except Pontiac are combined for this analysis. Absolute number of accidents are given and percentage of total in category. Chi-square comparisons of before and after periods: STL: chi-square (10 X 2) = 32.965; p = .0001; LOC: chi-square (10 X 2) = 30.800; p = .0003.

posure on the trunklines and local system would vary in a similar fashion. Hence, to at least some degree, if exposure increases on the trunklines and there is a corresponding increase in the accident frequency (a constant overall rate), it would be expected that the exposure and the frequency would increase on the local system as well (without TCD upgradings). Therefore, if the upgradings had an impact the increase in frequency should be less (a lower rate). (Although the impact might also be a shift in type or severity of accident as well.) Hence, although the before-after comparison is based on frequency distributions there is a consideration of exposure when the trend is compared with the trends observed on the trunklines.

Furthermore, much of the testing is done with chi-square, which is relatively insensitive to the overall frequency per se. The greater sensitivity is to shifts among, for example, accident categories, which are independent of the absolute number of accidents (overall frequency) or the exposure (rate).

The next variable to be examined was HWYAT, the vehicle-vehicle collision category of MSPAT. It is in this category of accidents that the TCD upgradings could be expected to be most likely to have a positive effect.

Table 2 gives a before-after comparison for all cities (except Pontiac) for HWYAT. A qualitative examination shows that for the STL (control) system, the major shifts in vehicle-vehicle accident types are (a) a decrease in same-direction sideswipes, (b) a relatively sizable increase in angle accidents, and (c) a relatively small decrease in left-turn accidents. This is in the context of an overall decrease in vehicle-vehicle accidents--from 1,528 to 1,412. On the LOC (treated) system, the qualitative review of the percentage changes show a small decrease in same-direction sideswipes (similar to the STL results); a moderate increase in angle accidents (again, similar to STL results); a small increase in left-turn accidents (opposite of and somewhat less than the STL results); a decrease in rear-end accidents (STL had increased very slightly); and an increase in "backing" accidents. This occurred with an overall decrease of from 2,638 to 2,529 vehicle-vehicle accidents. The chi-square comparison of the before-after distributions showed that they were different for both the LOC and STL systems.

The overall results are not particularly enlightening in terms of the effects of the TCD upgrading. There were changes on the LOC system, as well as changes on the STL system. Moreover, the shifts that took place between categories on the two systems were of similar magnitudes, again making it difficult to isolate TCD effects.

The problem just cited was avoided in the next set of analyses, which were concerned with a general examination of selected individual cities.

Results for Selected Cities

Before-After Comparison of General Accident Types (MSPAT)

Table 3 gives the results for Albion, Dundee, East Tawas, Hudsonville, Mackinaw City, Mt. Pleasant, and Pontiac using the MSPAT variable. Several other small cities were not explicitly considered because of the extremely low number of accidents that occurred.

Looking first at Albion, it can be seen that the results displayed in Table 3 indicate that the MSPAT distributions vary for both the LOC and STL systems although the vehicle-vehicle collisions on both decreased between the before-after periods. On a percentage basis, the LOC system experienced a somewhat larger decrease.

Dundee, which is somewhat smaller than Albion, showed somewhat different results. Although there was a difference in the before-after distribution for the STL system, there was less of a difference for the LOC system. The absolute and percentage decreases in vehicle-vehicle accidents reflected this; they were more pronounced for the STL system. Most of the statistics were not calculated for East Tawas, Hudsonville, and Mackinaw City, but the absolute and percentage decreases can be examined. All three towns showed decreases for both systems: for East Tawas the percentage decrease on the LOC system was approximately the same as for the STL system; the percentage decrease was similar for Hudsonville and less (LOC versus STL) for Mackinaw City.

Mt. Pleasant is substantially larger than Albion and, more important, exhibited substantially different results, although the results for the chi-square were similar (distributional differences for both systems); vehicle-vehicle accidents increased.

Pontiac, the largest city in the study, showed results that were similar to the results shown in Albion and Mt. Pleasant as far as the statistical comparison was concerned, but the results were somewhat more favorable in terms of the changes in accidents. Approximately the same number of vehicle-vehicle accidents occurred on the STL system whereas there was a decrease in the number that occurred on the LOC system.

Based on an examination of the MSPAT distributions for the several cities, little consistent evidence exists that the TCD upgradings had either a positive or a negative effect. The results are inconsistent in general.

TABLE 3 Summary of Before-After Comparisons for MSPAT, Individual Cities

	STL				LOC			
	Statistic		Absolute		Statistic		Absolute	
City	Chi-Square	p-value	Change	Percent Change	Chi-Square	p-value	Change	Percent Change
Albion	4.870	.182	256-171	-33	5.232	.156	304-161	-47
Dundee	3.983	.263	109-88	-19	0.970	.809	44-41	-7
East Tawas	-	-	79-58	-27	0.697	0.874	115-83	-28
Hudsonville	-	-	74-67	-9	-	-	122-108	-11
Mackinaw City	-	-	44-27	-39	1.845	.605	69-44	-7
Mt. Pleasant	4.601	.331	876-913	+4	14.685	.012	727-747	+3
Pontiac	17.189	0.16	3,106-3,104	<1	18.862	.009	4,483-4,019	-10

Notes: Absolute change in vehicle-vehicle accidents and percent change; minus sign denotes a decrease. Chi-square is calculated on all possible cells of MSPAT distribution; one cell is a combination. Dash denotes inadequate number of cells with high enough frequency for chi-square calculation.

TABLE 4 Summary of Before-After Comparisons for HWYAT, Individual Cities

City	STL Chi-Square Statistic	STL p-value	LOC Chi-Square Statistic	LOC p-value	Comments
Albion	0.522	.991	8.803	.117	STL: accidents decrease 256-171; LOC: accidents decrease 304-161, higher percent angle, lower percent left turn
Dundee	0.366	.985	0.027	.871	Generally low frequencies; STL: accidents decrease 109-88; LOC: accidents decrease 44-41
East Tawas	0.809	.847	1.283	.257	STL: accidents decrease 79-58, higher percent left turn; LOC: accidents decrease 115-83, higher percent angle, lower percent left turn, lower percent rear end
Hudsonville	6.561	.087	7.341	.290	STL: accidents decrease 74-67, lower percent left turn, higher percent rear end; LOC: accidents decrease 112-108, higher percent "other," lower percent angle
Mackinaw City	2.628	.105	3.625	.459	STL: accidents decrease 44-27, fewer rear end and "other," percents not meaningful; LOC: accidents decrease 69-64, higher percent angle, lower percent left turn, higher percent backed into
Mt. Pleasant	17.982	.021	16.000	.067	STL: accidents increase 876-913, higher percent angle; LOC: accidents increase 727-747, higher percent angle
Pontiac	23.340	.005	38.348	.000	STL: accidents decrease 3106-3104 on a percentage basis, distributions very similar; LOC: accidents decrease 4483-4019 on a percentage basis, distributions very similar

Notes: Chi-squares calculated on distributions of values in HWYAT categories, before and after project. In comments, only shifts on the order of 5 percent or more are noted.

Before-After Comparison of Vehicle-Vehicle Accidents (HWYAT)

HWYAT is a more important variable that allows a more detailed evaluation of vehicle-vehicle accidents. Table 4 gives a summary of the before-after comparisons for the several cities for HWYAT. Examining the chi-square information, it appears that a shift occurred in the before-after distributions for the STL systems for Hudsonville, Mackinaw City, Mt. Pleasant, and Pontiac, whereas there was no shift for Albion, Dundee, and East Tawas. With the exception of Dundee (and to a lesser extent, Mackinaw City), the cities generally show changes in the HWYAT accident distributions for the LOC system.

It is important to note between which categories the shifts in accidents actually occurred; in Albion, for example, there was a higher percentage of angle accidents and a lower percentage of left-turn accidents on the LOC system between the before-and-after systems.

One of the interesting results is that for several of the cities, higher percentages of angle accidents were noted on the LOC system (the exception being Hudsonville where the percentage was lower). In two of the smaller cities and Albion, this was accompanied by a lower percentage of left-turn accidents. This was seen as a potential result of the TCD project.

On the basis of the finding just cited, a review of the shifts in the accident categories was undertaken using a different technique. If the TCD upgradings have a consistent effect (regardless of whether it is favorable or unfavorable) in terms of preventing some types of accidents (and possibly encouraging others), a pattern of categorical shifts should emerge from a review of the different cities. The data in Table 5 represent a summary of HWYAT accident type shifts for the five cities that were studied in some depth. The table is divided into two sections. The first section is a summary for the LOC system in which the table entries are either plus (+), minus (-), or zero (0). A plus indicates that the percentage of accidents in the category increased by 1.5 percent or more between the before-and-after periods; a minus indicates that there was a decrease of 1.5 percent or more; and a zero indicates that the before-after shift was between -1.5 percent and +1.5 percent. Note that these percentages are relative and have no implications for the absolute number of accidents in any category. Angle accidents can then be seen to have increased in the LOC system in four of the five cities analyzed. The only other categories to show such consistent results were "sideswipe-opposite direction" and "right turns," which experienced very little proportional change--all entries were zeroes. Taken alone, this finding would indicate that the TCD effect was a proportionate increase in angle accidents.

The second part of the table is the same type of comparison for the STL system. Again, it is observed

TABLE 5 Summary of Proportional Shifts in HWYAT Categories

HWYAT Category	Pontiac	Albion	East Tawas	Hudson-ville	Mt. Pleasant
LOC system (criterion = change > 1.5 percent)					
Other	0	0	–	+	–
Head-on	0	0	0	–	0
Sideswipe–same direction	0	–	–	+	0
Sideswipe–opposite direction	0	0	0	0	0
Angle	+	+	+	–	+
Left turn	0	–	–	+	0
Right turn	0	0	0	0	0
Rear end	+	–	–	+	–
Back into	0	+	+	0	0
Parking	0	–	+	0	0
STL system (criterion = change > 1.5 percent)					
Other	0	+	–	0	–
Head-on	0	0	0	0	0
Sideswipe–same direction	–	–	–	–	–
Sideswipe–opposite direction	0	0	0	+	0
Angle	0	+	+	+	+
Left turn	0	0	+	–	0
Right turn	0	0	0	–	0
Rear end	0	0	–	+	0
Back into	0	–	0	0	0
Parking	0	0	–	0	0

Note: Given stated criterion: if percent increases +, if percent decreases -, and if no change 0.

that angle accidents increased in four of the five cities (although the city without the increase is different). Other consistent trends for the STL system include a decrease in the sideswipe-same direction category for all cities and little change in head-ons, sideswipe-opposite direction, right turns, backing, and parking.

The increase in the angle category for the STL system as well as for the LOC system indicates that the change was not attributable to the TCD upgrading (or anything else that is characteristic of the LOC system).

Review of the table reveals no consistent trends on one system that are not present on the other. Further, in most instances the results vary from city to city for any given accident category. In short, the systems are consistent only in their inconsistency of shifts among accident categories.

Before-After Comparison of Accident Severity

The last phase of the analysis was the examination of the severity of accidents occurring on the systems in the various cities. Regardless of whether the shifts in accident types could be tracked and attributed to the TCD upgradings, changes in the severity of accidents might be attributable to them. There are confounding factors that must be considered as well; for example, motorists becoming more safety conscious and vehicles becoming safer.

A comment about the coding of accidents by severity is appropriate. An accident can result in a serious injury, property damage, or a fatality, and different numbers of each. However, each accident was assigned a category according to its most serious outcome; for example, if there were three incapacitating injuries and a fatal accident, the accident was recoded as a fatal accident.

Given the preceding discussion, comparisons of all vehicle-vehicle accidents in all cities other than Pontiac were made. The overall indication was that, in general, the before-after severity distributions tend to be different on the STL system--most explicitly when all vehicle-vehicle collisions are considered and somewhat less so when angle or left-turn accidents are considered. They also tend to differ for the LOC system, although they are reasonably similar when only left-turn accidents are considered.

The same type of comparison was made on an individual basis for three cities: Albion, Mt. Pleasant, and Pontiac (Table 6). In each instance all vehicle-vehicle accidents were examined followed by angle and left-turn accidents. For the Albion STL system, it is observed that within the context of an overall decrease in the number of vehicle-vehicle accidents, there is a shift to somewhat more severe accidents [PDOs decrease proportionately (4 percent) while B and C accidents increase] (see table notes for accident severity description). On the LOC system there is a more pronounced shift to more severe accidents in an overall context of a decreasing number of accidents. The trend is similar, but somewhat more pronounced when only the angle accidents are considered. For left-turn accidents there is a decrease in number on both systems, with the STL accidents becoming somewhat more serious and the LOC accidents becoming less serious. It should be noted that sample sizes are quite small for the angle and left-turn separations, and the percentages can vary greatly with only a few accidents.

The results for Mt. Pleasant are somewhat different. For all vehicle-vehicle accidents, the numbers of accidents on both the STL and LOC systems remained nearly constant between the before-and-after periods, whereas on the STL system they became somewhat more serious and on the LOC system they became somewhat less serious (although the latter shift was between the two least serious categories).

The Mt. Pleasant angle accidents increased on both systems, becoming less serious on the STL system and more serious on the LOC system (again the major shift was between PDO and C categories in both instances). STL left-turn accidents decreased whereas LOC left-turn accidents remained the same. However, there was a positive shift on the LOC system in terms of severity and a negative shift on the STL system. Again most shifting was between the less severe categories and sample sizes were small.

Review of the situation in Pontiac is somewhat more definitive in the sense that all of the sample sizes are greater. For total vehicle-vehicle accidents, there was a shift toward more severe accidents on both systems in the context of an overall decrease in accidents on the LOC system. For angle and left-turn accidents, on the LOC system the shift is not great but clearly toward more severe accidents within an overall decrease in the numbers of both types of accidents. The shifts on the STL system were toward more severe accidents in the angle category and less severe accidents in the left-turn category, with little change in the numbers of accidents in both categories. For Pontiac, the chi-square statistic and p-value indicate that the shifts for the LOC system are (a) highly significant for all vehicle-vehicle accidents, (b) moderately significant for angle accidents, and (c) insignificant for left-turn accidents.

SUMMARY AND DISCUSSION

The analysis of several cities in Michigan for the efficacy of jurisdiction-wide traffic control device upgradings yielded inconsistent results. In summary, there is no substantive evidence that TCD upgradings have a consistent, measurable (positive or negative) impact on safety on a jurisdiction-wide basis as measured by a variety of safety (accident) measures.

A summary of the results for each of the several parts of the analysis undertaken follows:

1. Trends in background and descriptive statistics. Accident distribution (by type of crash) were somewhat different for the STL and LOC systems; the biggest difference was in the proportion of the vehicle-vehicle crashes in the angle category. In general, background information was similar for LOC and STL systems, for example, demographic characteristics of the drivers and weather conditions.

2. General trends in accident frequencies. Some city-to-city variation existed in the trends in the numbers of accidents occurring on the LOC and STL systems. For example, in Albion there was a general decreasing trend on both systems, whereas in Pontiac the trend was increasing and then decreasing.

3. Trends in changes in general and specific accident types (MSPAT and HWYAT). Changes occurred on both systems; that is, between the before-and-after periods on both systems changes occurred in the MSPAT and HWYAT distributions. This result was expected on the LOC system but unexpected on the STL system. This points to the general variability of the accident statistics over time, which makes isolation of the effects of specific changes on either system (i.e., the TCD upgrading) problematic.

4. Absolute and proportional changes in the number and type of vehicle-vehicle accidents. Neither absolute nor proportional changes in the overall

TABLE 6 Summary of Severity of Vehicle-Vehicle Accidents, Selected Cities

Accident Severity	STL				LOC			
	Before		After		Before		After	
	Absolute	Percentage	Absolute	Percentage	Absolute	Percentage	Absolute	Percentage
Albion: All Vehicle-Vehicle Accidents[a]								
PDO	215	84	136	80	258	85	126	78
C	27	11	22	13	23	8	19	12
B	11	4	11	6	16	5	11	7
A	3	1	2	1	7	2	5	3
Albion: Angle Accidents[b]								
PDO	40	80	27	71	95	81	55	71
C	8	16	8	21	10	8	11	14
B	2	4	3	8	9	8	7	9
A	0	–	0	–	4	3	4	5
Albion: Left Turn Accidents[c]								
PDO	26	79	15	71	19	70	5	83
C	4	12	2	10	2	7	0	–
B	2	6	3	14	5	19	1	17
A	1	3	1	5	1	4	0	–
Mt. Pleasant: All Vehicle-Vehicle Accidents[d]								
PDO	219	75	211	73	193	76	200	81
C	53	18	44	15	39	15	28	11
B	14	5	25	9	14	6	16	6
A	6	2	9	3	7	3	4	2
Mt. Pleasant: Angle Accidents[e]								
PDO	35	61	60	67	80	67	92	54
C	12	21	12	13	26	22	19	15
B	7	12	12	13	9	8	11	9
A	3	5	5	6	4	3	3	2
Mt. Pleasant: Left Turn Accidents[f]								
PDO	50	81	41	73	29	78	31	84
C	9	15	12	21	5	14	3	8
B	3	5	3	5	1	3	3	8
A	0	–	0	–	2	5	0	–
Pontiac: All Vehicle-Vehicle Accidents[g]								
PDO	2,230	72	2,080	67	3,201	71	2,767	69
C	577	19	633	20	802	18	762	19
B	202	7	265	9	314	7	332	8
A	92	3	123	4	155	3	153	4
F	5	–	3	–	11	–	5	–
Pontiac: Angle Accidents[h]								
PDO	433	62	379	53	731	68	669	65
C	134	19	179	25	201	19	208	20
B	87	13	96	14	105	10	102	10
A	38	5	52	7	40	4	56	5
F	2	–	3	–	5	–	2	–
Pontiac: Left Turn Accidents[i]								
PDO	347	65	376	70	330	61	284	59
C	115	22	88	16	115	21	110	23
B	47	9	51	10	64	12	51	11
A	23	4	21	4	33	6	32	7
F	1	–	0	–	1	–	2	–

Notes: PDO = property damage only, C = possible injury, B = non-incapacitating injury, A = incapacitating injury, and F = fatal. Chi-square calculations did not include the fatal cell.

[a] STL: chi-square = 1.635; p = .441. LOC: chi-square = 3.356; p = .340.
[b] Statistics not calculated, small cell frequencies.
[c] Statistics not calculated, small cell frequencies.
[d] STL: chi-square = 4.671; p = .198. LOC: chi-square = 2.056; p = .357.
[e] STL: chi-square = 1.441; p = .486. LOC: chi-square = 1.921; p = .383.
[f] Statistics not calculated, small cell frequencies.
[g] STL: chi-square = 20.781; p = .000. LOC: chi-square = 8.404; p = .038.
[h] STL: chi-square = 16.569; p = .001. LOC: chi-square = 4.742; p = .192.
[i] STL: chi-square = 4.994; p = .172. LOC: chi-square = 0.900; p = .825.

number of accidents, vehicle-vehicle accidents, or specific categories of vehicle-vehicle accidents yielded any consistent results for either the STL or LOC systems. Indeed, one qualitative comparison of trends in the specific accident categories showed that the trends were the same on both systems.

5. Trends in accident severity. Overall the trends in severity showed that minimal changes occurred among the different accident types, and there was some contradictory information, for example, a trend toward more severity for one type of accident and less severity for another for the LOC system with some STL trends being the same and some opposed, and in addition to city-to-city differences.

A review of this information indicates that the most striking result is the overall lack of consistency in the results whenever a detailed analysis was attempted; this is especially important in view of a general similarity in broad background characteristics.

Does the lack of results (either positive or negative) mean that TCD upgradings should not be undertaken? The answer is at least twofold. First, from the point of view of a jurisdiction's liability for damage suits, and so forth, TCD upgradings are quite important. The relative success or failure here to identify and quantify systemwide changes does not necessarily mitigate against the efficacy of improved TCDs at specific sites.

Otherwise, the failure to arrive at definitive quantitative results is seen as being due to general variability in accidents per se and a host of confounding variables for which no control was possible. Looking at a jurisdiction as an analysis unit has inherent drawbacks, although the TCD upgrading is indeed jurisdiction-wide, many intersections, for example, would probably experience no change in either the placement or the type of TCD present. Additional intersection-related changes might be concerned with relatively minor placement modifications. These are modest changes unlikely to be picked up in a general analysis. What is left then is relatively few changes in a jurisdiction that might be termed changes of substance. The changes in accident frequency at these relatively few intersections are then lost within (confounded by) the overall lack of change at other sites. An additional factor is that many of the TCD changes may be concerned with noncritical signs such as no parking, and so forth.

In summary, it would appear that safety analyses would be better directed toward the consideration of key problem sites in a jurisdiction. Procedures for this type (level) of analysis are well-defined and accepted within traffic engineering. Although the idea of being able to make a sweeping generalization about the efficacy of TCD upgradings for different jurisdictions is appealing, and would indeed be helpful from an agency viewpoint (in terms of resource allocation, for example), the overall variability of the data appears to overwhelm detectable changes at the jurisdiction level.

ACKNOWLEDGMENT

The work described in this paper was funded by a grant from the Office of Highway Safety Planning (OHSP) of the Michigan Department of State Police. The comments of the reviewers on the original draft of this paper are also acknowledged and appreciated.

Publication of this paper sponsored by Committee on Methodology for Evaluating Highway Improvements.