Abridgment

Areawide Impact of Traffic Control Devices

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The Philadelphia traffic signal demonstrations were a particularly effective manifestation of the power-to-the-people mood of the mid-1960s. At such gatherings, neighborhood residents would band together to blockade traffic from a public roadway; their purpose was to secure a traffic signal at a particular intersection. Initially, these demonstrations were spontaneously generated by a traffic accident. However, as they received growing media coverage, demonstrators lost their spontaneity and began to increase in numbers and to create community unrest. In the latter stages of this period, they would often refuse to clear an intersection until installation of a control had actually commenced. Nor was it uncommon to have simultaneous demonstrations at several adjoining intersections.

The city administration was afraid that arresting demonstrators would escalate the relatively minor disturbances into a major confrontation of the 1964 Philadelphia type that resulted in a $4 million loss of private property. The consequence of this policy of acceding to demonstrator's demands was that between 1964 and 1969 two intersections a week were being signalized, three times the normal rate. Of the 364 signals installed during this era, 65 percent were initiated by demonstrations. It became evident after several years that this situation was likely to continue, and therefore a generally acceptable alternative to the traffic signal became imperative. Thus it was decided in late 1967 to use the four-way stop in Philadelphia.

THE FOUR-WAY STOP PROGRAM

Judicious use of four-way stops had proved effective at several problem locations since the early 1960s. However, city traffic engineers were reluctant to use the device on a large scale because it lacked substantive evaluation as a safety device and because by impeding the flow of traffic it conflicted with a basic traffic engineering principle.

In addition, recommended guidelines governing the use of four-way stops needed modification. The 1971 Manual on Uniform Traffic Control Devices (MUTCD) (1) suggested its use at locations with combined approach traffic volumes averaging "at least 500 vehicles per hour for 8 hours of an average day." This would have limited its use in Philadelphia to only those intersections handling more than 9500 vehicles/d. Low-volume intersections, despite the fact that they may have had the most acute accident problems, were therefore excluded from consideration. It should be noted that 60 percent of the traffic signals installed from 1964 to 1969 did not meet the guidelines. Intersection 1 in the following example is ineligible for four-way stop control, even though its accident rate (accidents/10 million vehicles) is twice that of intersection 2.

Intersection	Average Daily Traffic	Accidents/Year	Accident Rate
1	4 000	4	28.4
2	10 000	5	14.2

Furthermore, the MUTCD suggested that four-way stops be used at locations where accident problems were "indicated by five or more reported accidents of a type susceptible of correction by a 4-way stop in a 12-month period." However, although in some states any damage at all constitutes a legal accident, in others (including Pennsylvania) damage must exceed several hundred dollars. Thus a four-way stop (or traffic signal for that matter) is more easily warranted in those states having a more liberal accident definition. These criteria, then, were deemed too restrictive for practical application.

A 1967 study of nearly 300 Philadelphia intersections designated a dangerous intersection as one where the yearly accidents exceed half of the average daily traffic (ADT) in thousands (2). This was the basic parameter, together with good engineering judgment, that was used to establish the need for a four-way stop. A 1970 before-and-after analysis of those initial 57 intersections converted from two-way to four-way stop control indicated that accidents decreased by 87 percent, and personal injuries decreased by 92 percent (3). The four-way stop program has proved successful in reducing the number of yearly new traffic signal installations by 65 percent. Unfortunately, the four-way stops have proliferated over the past 8 years, until by the end of 1976 they controlled some 1800 of Philadelphia's 20 000 intersections.

Although these two studies served to establish the need and effectiveness of the initial four-way stop installations, there remained a critical need for an objective examination of the wide-range effects of the citywide traffic control changes that averaged 5/week over the past 9 years. Initially four-way stop installations, because they were uncommon, may have commanded more respect than the multitudes of such installations do today.

SELECTING THE STUDY AREA

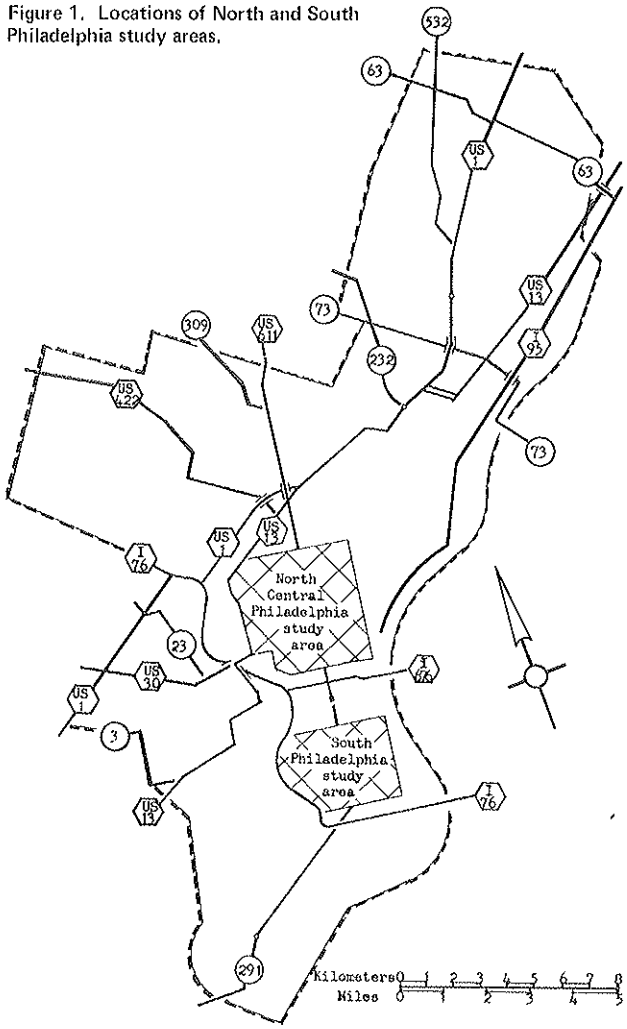
The city of Philadelphia encompasses 336 km^2 (130 $miles^2$). Detailed accident data were available for 1968 through 1976, and our object was to select those areas in which the traffic control device itself was the only variable. Remote sections developing relatively rapidly, and hence experiencing changing traffic patterns, were rejected. Other areas proved undesirable because of the probable influence of varying street widths and vehicle speeds.

Two geographically distinct but geometrically similar areas of the city were finally selected: south Philadelphia and north central Philadelphia (Figure 1). A grid network of cartways 8 m (26 ft) wide with one-lane, one-way street intersections predominates, so all intersections were included in the study. This totaled 449 locations in the southern area and 444 in the northern area. Even though both combined constitute only 10 percent of the total city area, they contain 20 percent of the city's 3300 traffic signals and 1800 four-way stops today. Nine years ago, 40 percent of the study intersections were controlled by traffic signals, and the remainder were two-way stop controlled. Today, 40 percent are still signalized and 20 percent remain two-way stop controlled; 40 percent are now being four-way stop con-

trolled. During the 9 years, 33 study intersections were newly signalized, and 352 intersections were converted from two-way to four-way stop control.

It must be emphasized that none of the 385 traffic signals studied was either interconnected or coordinated with another signal. All comprise two signal heads (green, amber, and red) post-mounted on each of the four intersection corners, thus facilitating two farside indications for each traffic approach and pedestrian indications at each end of the four intersection crosswalks. None of the study installations has pedestrian signals. Stop-sign controlled approaches have both right and left stop signs posted, the right stop carrying a four-way rider for all those intersection approaches where applicable.

Figure 1. Locations of North and South Philadelphia study areas.



TRAFFIC VOLUMES

In the spring and fall of 1973, 1500 manual, vehicle classification, turning movement, intersection counts and one thousand 7-d, 24-h automatic traffic recorder (ATR) counts were conducted in both study areas. Results indicated that

1. Ninety percent of the study intersections have an ADT of 1000 to 9000 vehicles/d;
2. ADT of the 384 traffic signals of both areas is 6700;
3. ADT of the 154 two-way stopped intersections is 4400;
4. ADT of the 198 south Philadelphia four-way stops is 6200;
5. ADT of the 157 north Philadelphia four-way stops is 3600; and
6. At more than 90 percent of the locations studied the minor street accounted for 20 percent more of the total intersection ADT.

A comparison of the 1973 south Philadelphia intersection volumes with the 1960 area traffic study confirmed no area traffic growth. A similar north Philadelphia intersection study revealed that the 1973 volumes were almost identical to those of the earliest recorded citywide traffic study done in 1938! Thus, the traffic volumes in both study areas were indeed static throughout the 9-year study period.

TRAFFIC ACCIDENTS

A total of 19 492 Philadelphia Police Department accident records for 1969 to 1976 were analyzed for the 893 study locations. Sheer magnitude precluded summarization of all but the essential items: date of occurrence, severity (property damage, occupant injury, pedestrian, fatality), type (right angle, rear end, fixed object, sideswipe, pedestrian), and time of day (daylight, darkness).

Accident Severity, Type, and Time

Table 1 summarizes the accident severity, type, and time of day data for each of the three modes of intersection traffic control for both study areas. Figures 2 and 3 illustrate relative impact, and the results indicate the following:

1. One of every 8 intersection accidents involves a pedestrian regardless of the mode of traffic control;
2. Whereas 1 of every 5 accidents at traffic signals and two-way stops in these areas results in an occupant injury, only 1 of every 10 accidents at four-way stops results in an occupant injury;
3. Accidents involving two occupied vehicles (right angle, rear end, and sideswipe) constitute 61 percent of the signal accidents, 67 percent of the two-way stop accidents, and only 46 percent of the four-way stop accidents;

Table 1. Percentages of accidents for each traffic control mode.

Location	Control	Severity				Type					Time		AADT
		Property Damage	Personal Injury	Pedestrian	Fatality	Right Angle	Rear End	Fixed Object	Sideswipe	Pedestrian	Day	Night	
South Philadelphia	Traffic signals	70	18	12	0	26	24	31	7	12	66	34	6700
	Two-way stops	68	20	12	0	51	12	20	5	12	68	32	4400
	Four-way stops	77	11	12	0	23	17	40	8	12	67	33	6200
North Philadelphia	Traffic signals	68	20	12	0	33	23	22	10	12	67	33	6900
	Two-way stops	69	19	12	0	50	10	22	6	12	74	26	4400
	Four-way stops	79	8	13	0	17	17	44	9	13	67	33	3600

4. Right-angle, rear-end, and fixed-object accidents occur in comparable numbers at signals; half of the two-way stop accidents are right angle, but fixed-object accidents predominate at four-way stops by default; and
5. Night driving proves 50 percent more hazardous than day, since a third of the accidents occur at night, which has a fourth of the ADT.

Accident Rates

Table 2 summarizes the accident rates over the 9-year study period for the three modes of intersection traffic control for both study areas (see Figures 4 and 5 for the trends), and the results indicate the following:

1. The two-way stop rates have increased linearly throughout the period, doubling in only 6 years. Reasoning backward from this growth leads to the obviously incorrect conclusion that these rates were 0 in 1960 (some external source has affected the two-way stop accident rates in both areas);
2. The south Philadelphia two-way stop rate is

Figure 2. Accident severity.

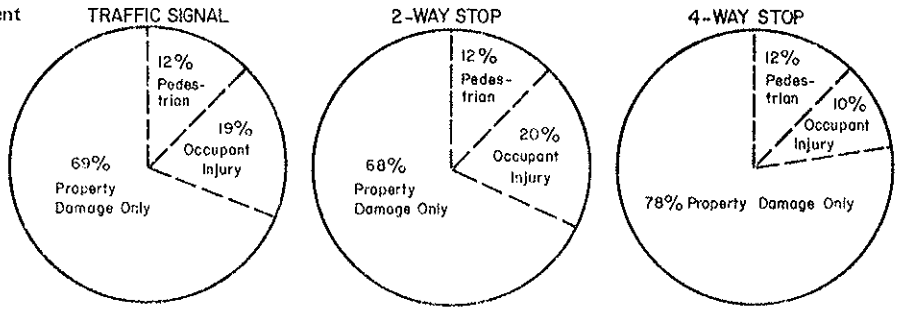


Figure 3. Accident type.

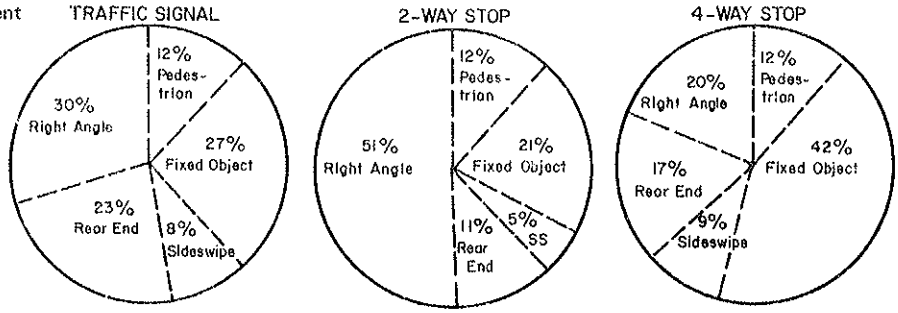


Figure 4. Accident rate for South Philadelphia.

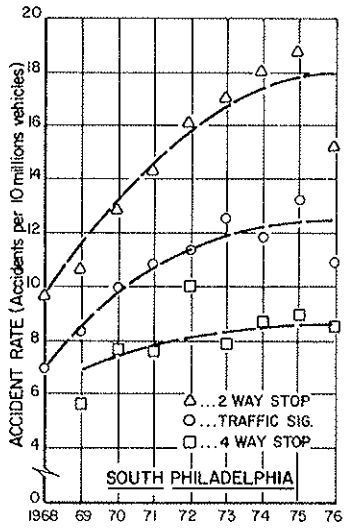


Figure 5. Accident rate for North Philadelphia.

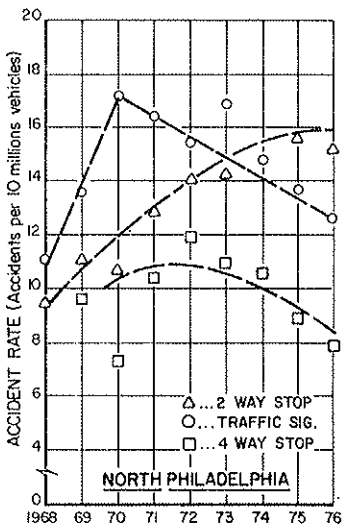


Table 2. Annual accident rate for each intersection control mode.

Location	Control	1968	1969	1970	1971	1972	1973	1974	1975	1976
South Philadelphia	Traffic signals	6.9	8.4	9.9	10.8	11.4	12.6	11.9	13.3	11.0
	Two-way stops	9.7	10.6	12.9	14.4	16.1	17.1	18.1	18.8	15.3
	Four-way stops	—	5.6	7.7	7.6	10.0	7.9	8.7	9.0	8.5
North Philadelphia	Traffic signals	11.2	13.7	17.3	16.5	15.5	16.9	14.8	13.8	12.6
	Two-way stops	9.5	11.1	10.7	12.9	14.1	14.3	16.5	15.6	15.3
	Four-way stops	—	9.7	7.3	10.4	11.9	11.0	10.6	8.9	7.9

Note: Rate = accidents/10 000 000 vehicles.

plateauing at about 18;
3. The south Philadelphia signal rate is plateauing at about 12.5;
4. The south Philadelphia four-way stop rate is plateauing at about 18.5, which is lower today than the other two but higher than they were in 1967;
5. The north Philadelphia two-way stop rate is plateauing at about 16; and
6. For several years the north Philadelphia signal and four-way rates have been on the decline, the latter always 30 percent lower than the former.

BEFORE-AND-AFTER ANALYSIS OF ALL TRAFFIC CONTROL CHANGES

To ensure a definitive evaluation of the before-and-after statistics at all locations where the control mode changed during the study period, we decided to compare the 2-year period both immediately before and immediately after the change. Thus all changes from 1970 to 1974 were evaluated; however, the seven newly signalized locations were insufficient for definitive conclusions.

Results for the 222 two-way to four-way conversions, which the Traffic Engineering Handbook (4) criteria labeled dangerous locations (that is, having an accident rate of nine), indicate the following:

1. Accident reduction conversion results in both study areas were similar;
2. In general, three of every four conversions from two-way to four-way stop control improved conditions, regardless of the before accident rate;
3. Half of the safe two-way conversions to four-way increased accidents;
4. Six of seven dangerous two-way conversions reduced accidents;
5. Total accidents decreased by 55 percent after conversion to four-way stop;
6. Occupant personal injury accidents decreased by 81 percent after conversion;
7. Pedestrian injury accidents decreased by 83 percent after conversion;
8. Right-angle accidents decreased by 83 percent after conversion; and
9. Rear-end, fixed-object, and sideswipe accidents were unaffected.

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Approach to Real-Time Diversion of Freeway Traffic for Special Events

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In Dallas, Texas, on July 4, 1976, freeway traffic bound for a fireworks display was diverted to an alternate arterial route. The object was to validate primary candidate messages and displays resulting from extensive laboratory studies of human factors. Two primary candidate messages were displayed at alternate times on matrix signs located on the Central Expressway. The first message caused 56.2 percent of the traffic to divert and the second 43.8 percent.

Special events at places such as stadiums generate large volumes of traffic and congestion at the site and on adjacent freeways. Practically every driver on the way to a ball game at a major stadium has experienced considerable delay in lengthy queues.

Less congested alternate routes are often available, however, and, if some of the approaching freeway traffic can be diverted to alternate routes, congestion can be reduced. This depends on several factors: (a) An acceptable alternate route must be available; (b) drivers must be made aware of the alternate route; and (c) guidance must be provided along the alternate route so that drivers, once diverted from the primary route (usually a freeway), can progress easily and confidently along the alternate. Research findings in real-time driver information transfer techniques that have been developed from human factors engineering principles are of critical importance to effective route diversion.

The purpose of this study is to develop effective information displays for real-time incident management and route diversion. Extensive human factors laboratory studies are being conducted to develop primary candidate messages and displays that will then be field validated. One phase of the research effort was directed toward route diversion messages and displays for special events. This paper discusses one such study conducted in Dallas, Texas, during a Fourth of July fireworks display at the Fair Park in 1976.

FAIR PARK CHARACTERISTICS

Fair Park, a 97-hm^2 (240-acre) area in south central Dallas, houses the Cotton Bowl and permanent buildings, facilities, and midway for the annual Texas State Fair. In addition it has several cultural buildings such as a music hall, museums, and the Texas Hall of State. Many college and professional football games are played in the Cotton Bowl (seating capacity of 73 000), which is often used for other events and exhibitions such as Fourth of July celebrations.