EVALUATION OF A TRAFFIC ENGINEERING IMPROVEMENT

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Traffic engineers need to evaluate the effectiveness of traffic engineering improvements. Procedures for the evaluation are described in the literature, but few applications are available. This paper discusses the combination of road user consequences, including the effects on air quality, and the procedures for the evaluation of one traffic engineering improvement—a Traffic Operations Program for Increasing Capacity and Safety improvement of an intersection. The evaluation of the intersection improvement indicated that the benefit-cost ratio was 1.9 and that the air quality was improved.

•IN November 1971, a number of improvements were completed at the intersection of Harry and Oliver Streets in Wichita, Kansas. The intersection geometrics before and after the improvements are shown in Figure 1. Funds for the improvements were partially obtained through the Traffic Operations Program for Increasing Capacity and Safety (TOPICS), a cooperative federal, state and local program to improve traffic operations and safety.

Before construction, both Harry and Oliver Streets were four-lane undivided streets with channelized right-turn slots on the west and east approaches. The intersection was controlled with a fixed-time controller and was signalized with 8-in., pedestal-mounted indications on all four corners and an 8-in., four-way signal suspended over the center of the intersection. The speed limit on all approaches to the intersection was 35 mph before and after the improvement.

The construction project included widening 600 ft of each approach to the intersection to provide two through lanes and separate left- and right-turn lanes. The right-turn lanes were designed for continual flow under yield control with the exception of the southbound to westbound movement, which had to move with the southbound movement through the traffic. The signalization was upgraded to provide full traffic actuated control, 12-in. overhead signal indications, and separate signal phases for the left-turn movement. The cost of the construction project including installation of the traffic signals was $274,155.

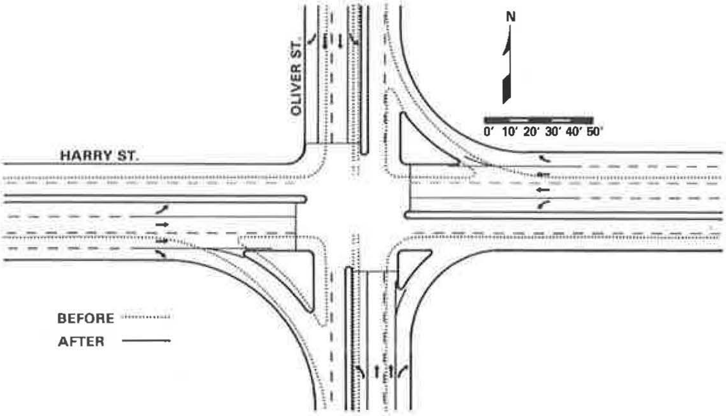
This paper discusses traffic volumes, intersection capacity, vehicular delay, traffic accidents, and air pollution at the intersection before and after the improvements. An analysis of the economic worth of the improvement concerning road user costs and benefits is also discussed.

TRAFFIC VOLUMES

Peak-hour turning movement and 24-hour traffic volume counts were taken at the intersection before and after the improvements. The total 24-hour volume of traffic approaching the intersection was approximately 8 percent greater after the improvement. The increases were approximately equal on all approaches with no single approach exhibiting an increase greater than 10 percent.

Peak-hour volumes increased considerably more than the 24-hour volumes—23 and 29 percent increases in the a.m. and p.m. peak-hour traffic respectively. This is attributed to the congestion at the intersection during the peak periods before the improvements, which encouraged a certain number of motorists to seek alternative routes to their destinations, even though the route through the Harry and Oliver Streets intersection may have been shorter.

Figure 1. Geometrics of intersection of Harry and Oliver Streets.



INTERSECTION CAPACITY

A capacity analysis (1) was conducted to determine the level of service and service volumes (at level of service C) provided by the intersection both before and after the improvements. Table 1 gives the results of the capacity analysis. After the improvements, all approaches were operating at level of service A with the exception of the westbound left turn, which was operating at level of service C. Service volumes after the improvements increased (by approach) approximately 120 percent over the conditions before—from 67 to 222 percent.

VEHICULAR DELAY

Vehicular delay was measured on all approaches to the intersection before and after the improvements. The p.m. peak from 4:00 to 6:00 p.m. was selected for the delay surveys. The before surveys were taken on Thursday, May 27, 1971, and the after surveys were taken on Thursday, April 27, 1972. Because of the limited staff available to conduct the surveys, a sampling procedure was used. Data were collected for three 5-min intervals per hour on each approach and were assumed to be representative samples for the entire hour.

The procedure used to measure delay (2) provides stop-time delay only and does not include time delays due to deceleration and acceleration. The results of the delay surveys indicate that the reduction in average vehicular delay was approximately 48 percent after the improvement. The maximum average vehicular delay observed during one of the 5-min sampling intervals before the improvement was 173.8 sec per vehicle; after the improvement it was 41.7 sec per vehicle.

Figure 2 shows the average vehicular delays by approach. It is interesting that the average vehicular delays were considerably more uniform after the improvements. This is probably attributable to the fully traffic-actuated control system. The increase in average vehicular delay on the east approach was not unexpected because the previous fixed-time control was not able to allocate a green signal in proportion to the traffic demand; therefore, excess green time was given to the east approach before the improvement.

Inasmuch as the delay procedure provided only stopped time, the time delays due to deceleration and acceleration of a vehicle to and from a stop were obtained from another source (3, table A-9) in which the additional time required for passenger cars to stop from 35 mph and regain that speed was 3.94 hours per 1,000 stops.

TRAFFIC ACCIDENTS

The accidents occurring during 1970 and 1972 were studied so that the relative safety of the intersection before and after the improvements could be compared (Table 2).

Table 1. Level of service and service volumes by intersection approach.

Approach	Movement	Level of Service		Service Volume[a]		
		Before	After	Before	After	Change (percent)
North	Thru	—	A	—	850	—
	Right	—	A	—	325	—
	Left	—	A	—	150	—
	All	F	—	429	1,325	+208
South	Thru	—	A	—	850	—
	Right	—	A	—	950	—
	Left	—	A	—	150	—
	All	F	—	606	1,950	+222
East	Thru	A	A	631[b]	650	—
	Right	D	A	416	950	—
	Left	—	C	—	150	—
	All	D	—	1,047	1,750	+67
West	Thru	C	A	559[b]	650	—
	Right	D	A	425	950	—
	Left	—	A	—	150	—
	All	C	—	984	1,750	+78

[a]Service volume at level of service C. [b]Includes left-turn movement.

Figure 2. Average vehicle delay by approach during p.m. peak period.

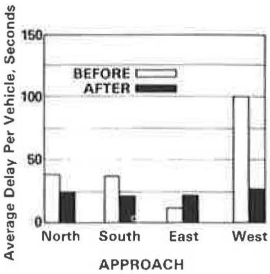


Table 2. Frequency and cost of accidents.

Item	Before	After	Reduction
Annual accident frequency			
Personal injury	16	6	10
Property damage only	22	15	7
Total	38	21	17[a]
Annual accident cost, $[b]			
Personal injury	49,600	18,600	31,000
Property damage only	9,680	6,600	3,080
Total	59,280	25,200	34,080

[a]The change is statistically significant at the 5 percent level of probability with the χ^2 test.
[b]Based on National Safety Council unit cost figures for 1971 of $3,100 for each personal injury accident and $440 for each property damage only accident.

Table 3. Traffic volumes and vehicular delays by approach.

Item	Approach				Total or Average
	North	East	South	West	
Daily approach volume[a]					
Before					
2-hour a.m. peak	889	856	642	632	3,019
2-hour p.m. peak	1,077	1,039	1,488	1,127	4,731
Other hours	5,689	5,821	5,122	5,508	22,140
Total	7,655	7,716	7,252	7,267	29,890
Volume stopped, percent					
Before					
2-hour a.m. peak	(80)	(52)	(71)	(85)	(72)
2-hour p.m. peak	95	67	86	100	87
Other hours	(70)	(50)	(61)	(75)	(64)
After					
2-hour a.m. peak	57	50	49	73	57
2-hour p.m. peak	72	64	68	67	68
Other hours	(50)	(50)	(50)	(55)	(51)
Average delay per stopped vehicle, sec					
Before					
2-hour a.m. peak	(30.2)	(14.1)	(30.8)	(73.4)	(37.1)
2-hour p.m. peak	41.4	19.3	42.2	100.5	50.9
Other hours	(27.7)	(12.9)	(28.3)	(67.3)	(36.5)
After					
2-hour a.m. peak	23.7	27.3	28.5	5.1	21.3
2-hour p.m. peak	35.7	35.1	31.4	41.2	35.9
Other hours	(23.9)	(23.5)	(21.0)	(27.6)	(24.0)

Note: Parenthetical figures are derived based on field observations.
[a]Based on traffic recorder counts and field observations. The traffic stream is assumed to be 100 percent passenger cars.

Table 4. Additional daily motor vehicle operating costs and travel time required (3).

Item	Before	After	Change
Number of vehicles stopped			
2-hour a.m. peak	2,143	1,721	
2-hour p.m. peak	4,116	3,217	
Other hours	14,170	11,291	
Total	20,429	16,229	4,200
Additional travel time required			
Due to stopping, hours[a]	80.5	63.9	16.6
Due to idling, hours			
2-hour a.m. peak	22.5	12.3	
2-hour p.m. peak	62.0	31.6	
Other hours	142.9	75.9	
Subtotal	227.4	119.8	107.6
Total	307.9	183.7	124.2
Additional vehicle operating costs, $[b]			
Due to stopping	250.05	198.64	51.41
Due to idling	26.12	13.76	12.36
Total	276.17	212.40	63.77

[a]From 35 mph, the additional travel time required to stop is 3.94 hours per 1,000 stops (3, Table A-9).
[b]From 35 mph, the additional cost to stop is $12.24 per 1,000 stops (3, Table A-8); and the cost of an idling engine is $114.86 per 1,000 hours (3, Table A-41).

Table 5. Annual costs and benefits of improvement.

Item	Before	After	Benefit or (Cost)
Annual cost of improvement[a]	—	36,379	(36,379)
Annual additional user costs			
Travel time (25 cents per hour)[b]	28,096	16,763	11,333
Vehicle operations	100,802	77,526	23,276
Accidents	59,280	25,200	34,080
Total additional user costs	188,178	119,489	68,689

Note: Benefit/cost ratio = $\frac{68,689}{36,379}$ = 1.9.
[a]Calculated by multiplying the construction costs ($274,155) by a capital recovery factor (crf). The crf is determined by an interest rate (8 percent) and a period of time (12 years). This results in a crf of 0.132695.
[b]From Thomas, T. C., and Thompson, G. I. The Value of Time Saved by Trip Purpose. Stanford Research Institute, Menlo Park, Oct. 1970.

Table 6. Additional daily amounts of air pollutants due to stopping and idling of vehicles.

Item	Before	After	Change
Hydrocarbon (HC) emissions[a]			
At uniform speed (0.71 lb/1,000 vehicle-miles)	4.82	4.82	
Additional HC emissions			
Due to stopping (0.04 lb/1,000 stops)	0.82	0.65	
Due to idling (0.0087 lb/hour)	1.98	1.04	
Total reference HC	7.62	6.51	
Total 1972 HC (×2.3)[b]	17.52	14.97	2.55
Carbon monoxide (CO) emissions[a]			
At uniform speed (25 lb/1,000 vehicle-miles)	170	170	
Additional CO emissions			
Due to stopping (22 lb/1,000 stops)	449	357	
Due to idling (1.19 lb/hour)	271	143	
Total reference CO	890	670	
Total 1972 CO (×2.3)[b]	2,047	1,541	506

[a]Procedures for Estimating Highway User Costs, Air Pollution, and Noise Effects. NCHRP Rept. 133, 1972 (Figs. 18, 20, and 23).
[b]The factor (2.3) is used to convert reference year emissions to average emissions in 1972 and takes into account expected future emission standards, vehicle maintenance practices, and the mix of new and old vehicles expected to be on the highway each year.

During 1970 (before the improvement) of the total 38 accidents, there were 16 personal injury and 22 property damage only accidents. During 1972 (after the improvement), of the total 21 accidents, personal injury accounted for 6 and property damage only for 15: a significant reduction statistically.

Because traffic volumes increased after the improvement, the reduction in the accident rate was even greater with nearly a 50 percent reduction from 3.48 to 1.78 accidents per million vehicles entering the intersection.

ECONOMIC EVALUATION

Traffic volume counts and the vehicular delay study provided the data (or the basis for making the necessary assumptions) for making road user economic evaluations of the improvement.

Table 3 gives the percent of the ADT stopped and the average delay per stopped vehicle before and after the improvement. These data were based on the results of the vehicular delay study described and were determined for the 2-hour a.m. peak period, the 2-hour p.m. peak period, and the remaining hours of the day. Then, by using published unit vehicle operating costs and travel time data the daily motor vehicle operating costs and travel time required were calculated (Table 4).

Table 5 gives a summary (on a yearly basis) of road user and accident costs. Estimated road user benefits are \$68,689 per year. With a calculated annual capital cost of improvement of \$36,379 per year, the benefit-cost ratio for the improvement is 1.9.

ENVIRONMENTAL CONSEQUENCES

Traffic engineering improvements affect the environment principally through their impact on air quality and noise levels. However, the most extensive research (4) on noise levels concluded that it was not possible to model the interrupted traffic flow that would be experienced at an intersection controlled by a STOP sign or traffic signal. Hence, no attempt was made to measure the effects of the improvement on noise levels, although it is expected that noise levels will decrease because fewer vehicles are stopping (approximately 4,000 fewer stops per day).

There is more research available that permits an estimation of the effects of a traffic engineering improvement on air quality. A recent study (5) recommends that emission levels be used as an interim measure of air pollution consequences.

An estimate was made of the amounts of hydrocarbon and carbon monoxide emissions that could be expected if the traffic stream operated at a constant speed of 35 mph. To these amounts were added the emissions resulting from the stopping and idling of vehicles before and after the improvement. As given in Table 6, the improvement reduces hydrocarbon emissions about $2\frac{1}{2}$ lb per day (15 percent) and carbon monoxide emissions about 500 lb per day (25 percent).

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