Simple Types of Intersection Improvements

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Examine any surveillance system, find a concentration of accidents and you will usually find an intersection at the root of the problem. This is not meant to be an earth-shattering statement but a simple truth. And if there were degrees of truth, we would find it near the 100 percent end of the scale in urban areas. For this reason, the simple intersection has not been given the attention it deserves. Just stop and contemplate the number of intersections in this country (it is questionable whether anyone knows how many there are). Visualize how many vehicles might be stopped in the middle of the intersection at any one moment in time waiting for a turn of one kind or another. To put it bluntly, think of the rear-end exposures, unless of course they enjoy the protection afforded by various types of simple traffic engineering improvements.

Of the more than 500 minor improvement evaluation reports being analyzed by the California Division of Highways 380 are considered to be urban in nature. They are classified into 12 types of improvements, 5 of which deal directly with the intersection in one way or another. Table 1 shows a breakdown of the various types and number of locations studied. To further emphasize the problem, of the 1725 locations turned up in the inventory of "hot" spots in complying with Bureau of Public Roads directives, 1275 were found to be in the urban environment and 960 were of the intersection type. Tables 2 and 3 give the information gathered in the inventory and the breakdown by type of project.

To illustrate what simple measures will accomplish, several projects have been chosen, most of which involve some type of left-turn treatment. It is in this area that California can get a high "pay off." Left-turn lanes at intersections without signals reduce accidents on an average of 50 percent. It is this device that will reduce the "rear-end" exposure and provide a comfortable means of making a left turn. There are several ways to accomplish this. To implement many of these, it is necessary on occasion to remove parking on either one or both sides of the street—this is not always easily accomplished. However, it is a price that business people and motorists must pay for safety. Diagrams have been prepared showing experience with several intersections receiving various kinds of median treatment. They are summarized by types and reveal some interesting findings.

Figures 1 and 2 reflect a before and after accident condition at a T-intersection of US 50 and a two-lane street. US 50 is a four-lane highway with average speeds of 45 mph in this area. A left-turn pocket for vehicles entering Wisseman Drive was provided by raised bars and curbing.

In one-year before and after periods, total accidents dropped from 9 to 5

TABLE 1

MINOR IMPROVEMENTS PROJECTS SUMMARY

Type of Improvement	No. of Projects	Change in Accidents (%)
New signals	140	-14
Modified signals	28	-9
New signals with channelization	65	-20
Modified signals with channelization	45	-35
Flashing signals	45	-34
Safety lighting	41	-29
		-60[a]
Delineation	17	-9[b]
Protective guardrail	14	-60
Intersection channelization	53	-34
Reconstruction	30	-30
Signs	22	-53
Miscellaneous	6	+37
Total	506	
Urban	380	
Rural	126	

[a]Night accidents only.
[b]Based on accident rate change.

TABLE 2

SUMMARY OF INVENTORY PROJECTS

Types of Projects	No. of Projects	Improvement Costs—$1,000		
		Total	State	Other
01 New signals[a]	215	4,700	2,700	2,000
02 Modified signals[a]	180	2,000	1,240	760
03 New signals with channelization[a]	115	3,800	2,400	1,400
04 Modified signals with channelization[a]	180	4,050	3,150	900
05 Flashing signals[b]	25	150	130	20
06 Safety lighting[c]	80	800	600	200
07 Delineation	50	200	200	0
08 Protective guardrail	60	1,300	1,300	0
09 Intersection channelization[a]	165	2,600	2,500	100
10 Reconstruction[d]	225	14,200	13,200	1,000
11 Signing and marking[e]	375	1,500	1,480	20
12 Other	55	1,200	1,100	100
Totals	1,725	36,500	30,000	6,500

[a]Intersection locations.
[b]About 90 percent of flashing signals & beacons are at intersections.
[c]About 75 percent of lighting projects are at intersections.
[d]About 30 percent of reconstruction projects include intersections.
[e]About 40 percent of signing and marking projects are at intersections.

Total intersection locations = 1,160

TABLE 3

CALIFORNIA'S THREE-YEAR HIGHWAY SAFETY PROGRAM

Item	Rural		Urban		Total	
	Number	Percent	Number	Percent	Number	Percent
Miles of state highway	12,226	(86)	2,034	(14)	14,260	(100)
Total locations investigated	908	(19)	3,920	(81)	4,828	(100)
Total locations to be improved	450	(26)	1,275	(74)	1,725	(100)
Percent of investigated locations to be improved	50		33		36	
Total intersection locations to be improved	200	(18)	960	(82)	1,160	(100)
Percent of all improvements which are at intersections	44		75		67	

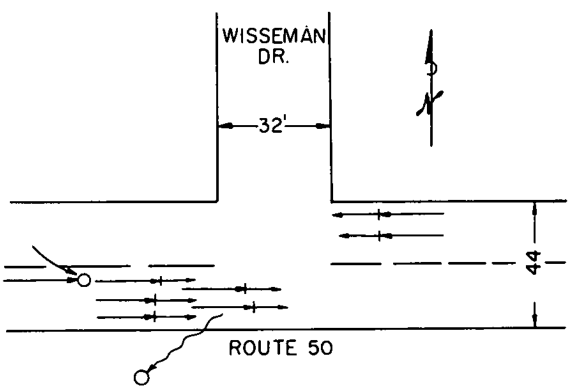

Figure 1. Collision diagram: US 50 and Wisseman Dr. before improvement (1-yr period).

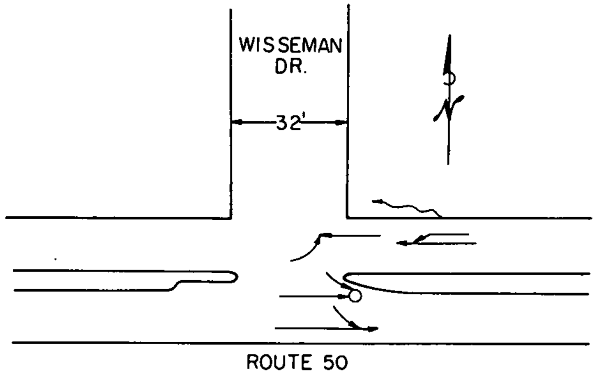

Figure 2. Collision diagram: US 50 and Wisseman Dr. after improvement (1-yr period).

with the accident rate decreasing 0.91 to 0.43 accidents per million vehicles entering the intersection, a 48 percent reduction. Rear-end and approach left-turn accidents declined from 7 to 1. If these intersecting accidents continue, concerning left-turning vehicles from Wisseman Drive, an escape acceleration lane could be provided in the median for this movement.

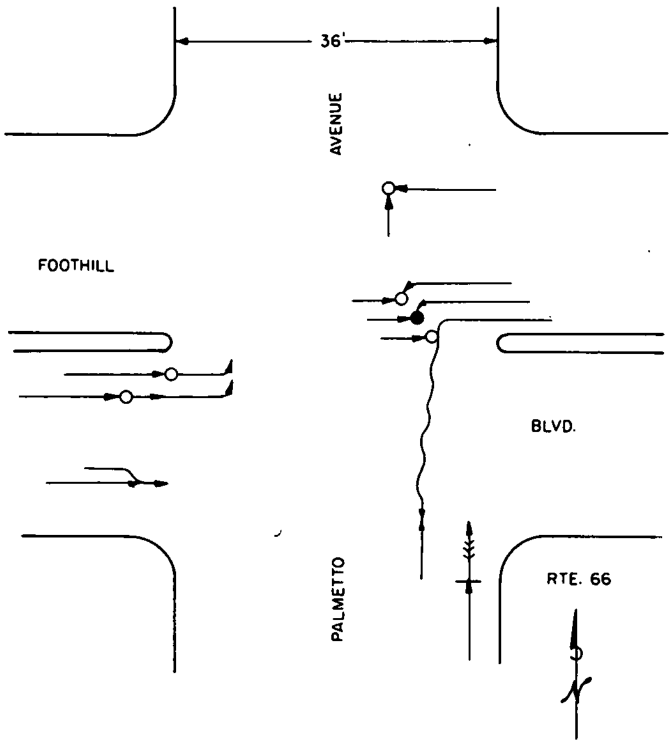

Figure 3. Collision diagram: Foothill Blvd. (US 66) and Palmetto Ave. before improvement (1-yr period).

Because of a rather large number of accidents occurring at the Palmetto Avenue intersection on Foothill Boulevard, the City of Fontana requested that the State make a study for possible signalization of this intersection.

US 66 on Foothill Boulevard is a four-lane highway divided by a 4-ft painted median. Palmetto Avenue is a two-lane city street. After a traffic count, it was decided that there was not a sufficient volume of traffic to warrant the expense of signalization. However, it was decided to use painted channelization to provide refuge for left-turning vehicles which was accomplished by prohibiting parking on one side of this highway to obtain the necessary width for the left-turn lane.

Traffic volumes increased 5 percent from an entering ADT of 15,400 to 16,200 vehicles. Total accidents were reduced from 8 to 1 in equal 1-yr periods before and after the channelization with the accident rate (accidents per million vehicles) dropping from 1.42 to 0.17, an 88 percent reduction. Rear-end and approach left-turn accidents decreased from 5 to 0, indicating a high degree of success for this painted channelization improvement. Figures 3 and 4 show this improvement.

As mentioned earlier, it is not always possible to experience a significant drop in accidents. Sometimes judgment is inaccurate, and another type of improvement should have been made. For example, US 66, on Fifth Street, in San Bernardino, is a 64-ft wide, four-lane highway. Muscott Street, a 52-ft wide, two-lane city street, is the north leg of a T-intersection with the east-west highway. The ADT remained about the same at 16,000 veh/day for the one-year before and after periods.

In the before period (Fig. 5), seven accidents occurred, two of which involved pedestrians. Three were the rear-end type and involved vehicles turning left into Muscott. It was decided that painted channelization on Fifth Street could reduce this hazard.

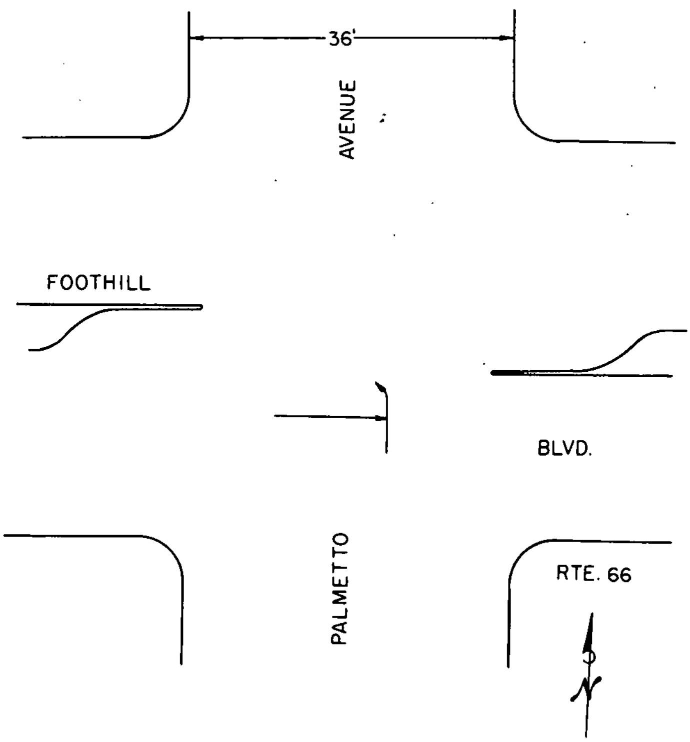

Figure 4. Collision diagram: Foothill Blvd. (US 66) and Palmetto Ave. after improvement (1-yr period).

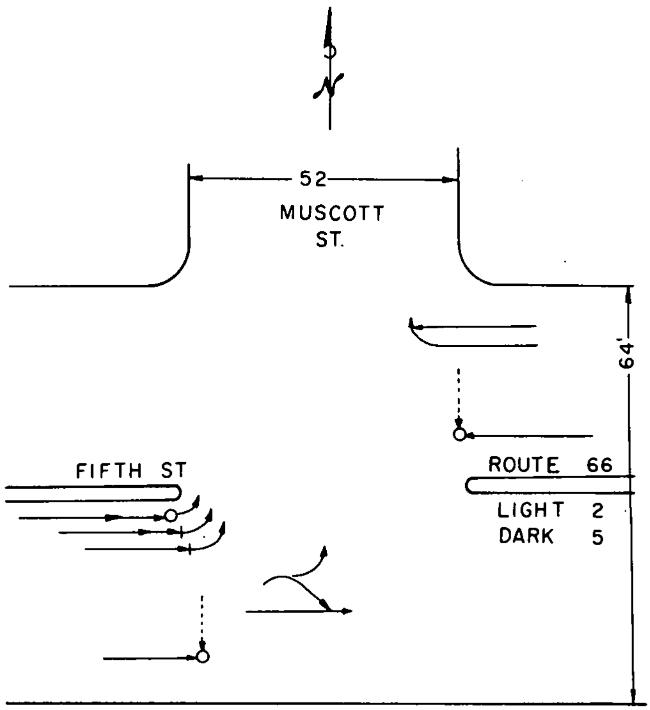

Figure 5. Collision diagram: Fifth St. (US 66) and Muscott St. before improvement (1-yr period).

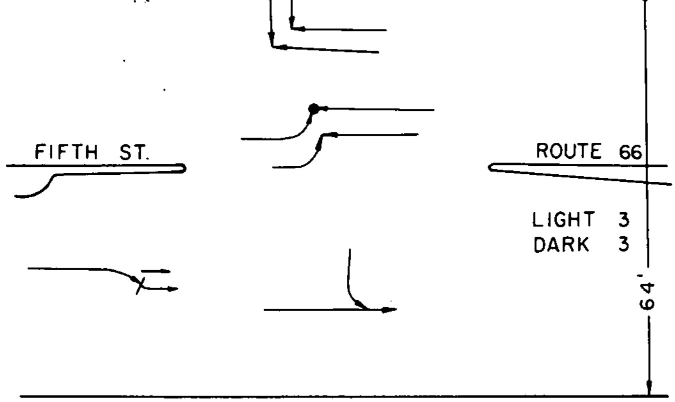

Figure 6. Collision diagram: Fifth St. (US 66) and Muscott St. after improvement (1-yr period).

In the after period (Fig. 6), six accidents occurred, two of which were the approach left-turn type. Both involved vehicles turning left into Muscott.

It appears that 3 rear-end accidents were traded for 2 approach left-turn accidents. However, when a day-night breakdown was made, it was discovered that 5 of the before accidents and 3 of the after accidents occurred at night. Part 2 "Safety Lighting" of the Evaluation of Minor Improvement Study recommends the installation of safety lighting if 4 night accidents occur in 12 months, or 6 night accidents occur in a 24-month period. Since this criterion is satisfied, safety lighting should be considered at this intersection.

US 50 in Stockton has 2 intersections with a one-way couplet. These intersections have been signalized and lighted for many years with a one-lane left-turn movement provided from the State highway. The inside through lane of this four-lane highway was allowed the option of also turning left or going straight ahead at these intersections (relative to the signal phase). The electrical features were not altered appreciably when the optional lane was established.

Entering ADT at Center Street increased 15 percent from 28,700 to 33,100 vehicles with total accidents increasing from 9 to 16 and approach left-turn and rear-end accidents increasing 7 to 9. The accident rate increased from 0.88 to 1.33 accidents per million vehicles.

Entering ADT at El Dorado Street increased 19 percent from 31,200 to 37,100 vehicles with total accidents dropping from 19 to 13 and approach left-turn and rear-end accidents from 12 to 6. The accident rate decreased from 1.67 to 0.96 accidents per million vehicles. Neither of these intersections experienced statistically significant

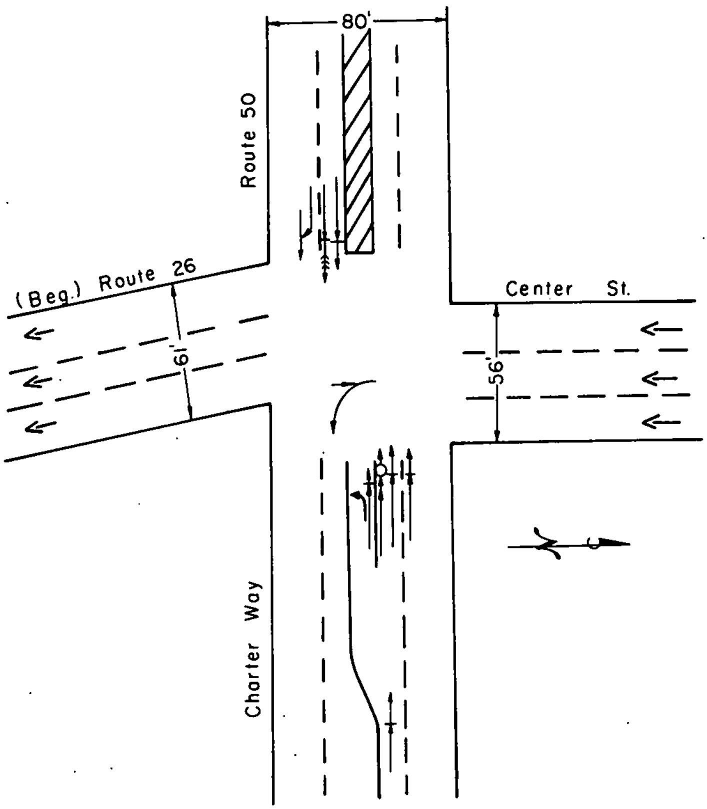

Figure 7. Collision diagram: Charter Way (US 50) and Center St. before improvement (1-yr period).

total accident changes thus indicating these changes could have occurred by chance. Figures 7, 8, 9 and 10 are before and after collision diagrams of these intersections.

A portion of the accident problem stems from the fact that when a vehicle in the optional lane wants to turn left and is waiting for the green arrow, it effectively reduces the highway to only one lane in this direction when the through traffic has a green indication. (The city police have been ticketing these drivers waiting for the green arrow for blocking traffic.) A better solution would be to add an additional through lane thus giving two mandatory left-turn lanes and two through lanes.

Something that may be unusual to some but which has been found very successful for years is the two-way left-turn lane through minor intersections. This treatment is reserved for locations where there are numerous private openings of low volume, and long blocks usually having low volumes entering or leaving the side streets. Where volumes are heavy, either at private drives or public streets, normal channelization is used.

To solve some problems at intersections, more drastic action is necessary. On what was formerly US 101 (Figs. 11 and 12) near San Diego, 5 intersections were blocked off by curbing across the median. Engineers are sometimes fearful that closing some openings would aggravate problems at others. In this case, 10th through 14th Streets were closed to left turns, thus forcing all vehicles to turn left at 9th Street and 15th Street which were signalized. The highway had an ADT of approximately 31,000 vehicles during both the before and after periods. Total accidents decreased

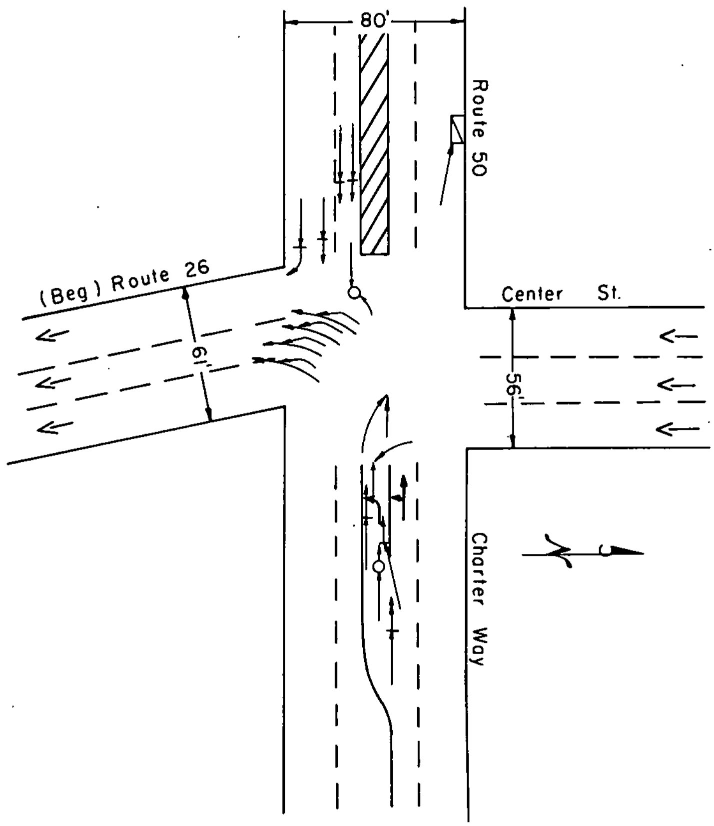

Figure 8. Collision diagram: Charter Way (US 50) and Center St. after improvement (1-yr period).

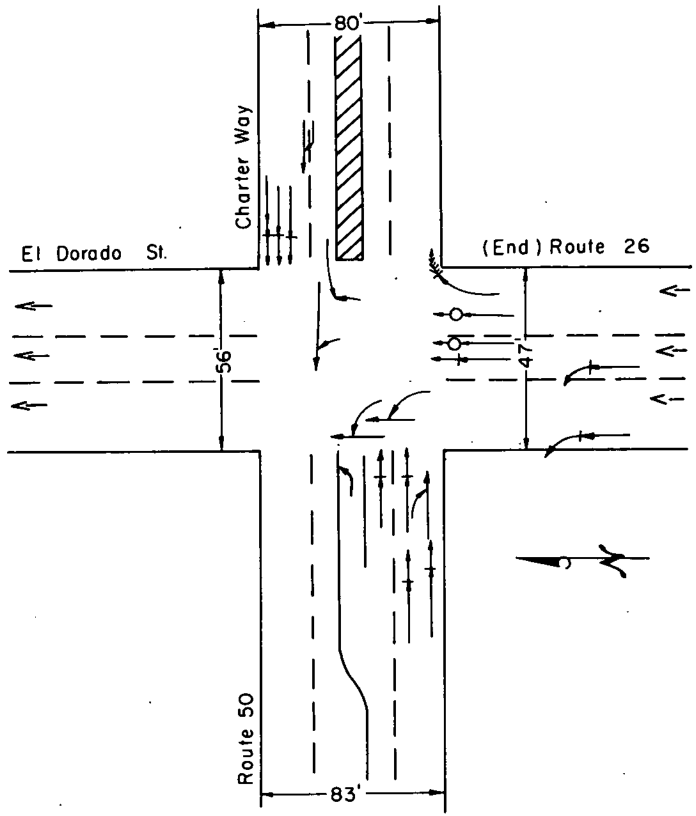

Figure 9. Collision diagram: Charter Way (US 50) and El Dorado St. before improvement (1-yr period).

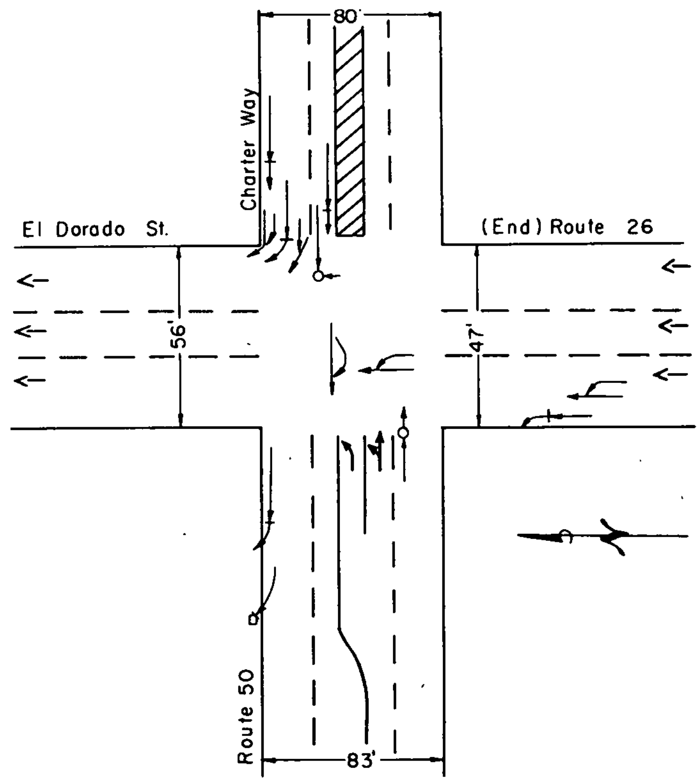

Figure 10. Collision diagram: Charter Way (US 50) and El Dorado St. after improvement (1-yr period).

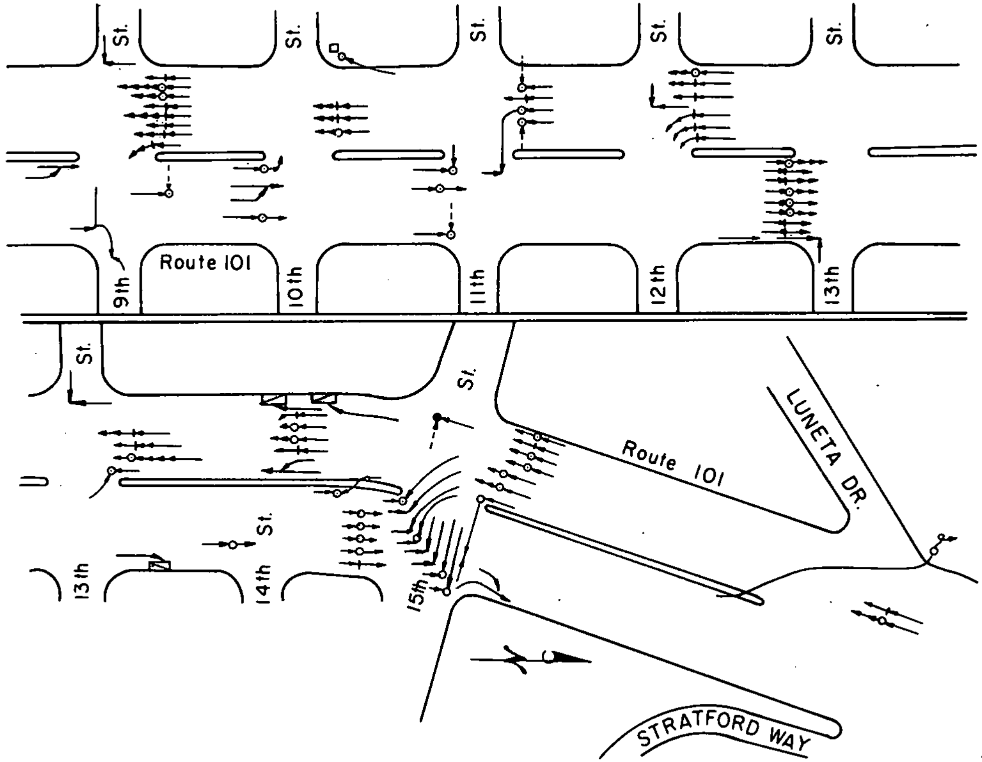

Figure 11. Collision diagram: US 101 in Del Mar before improvement (1-yr period).

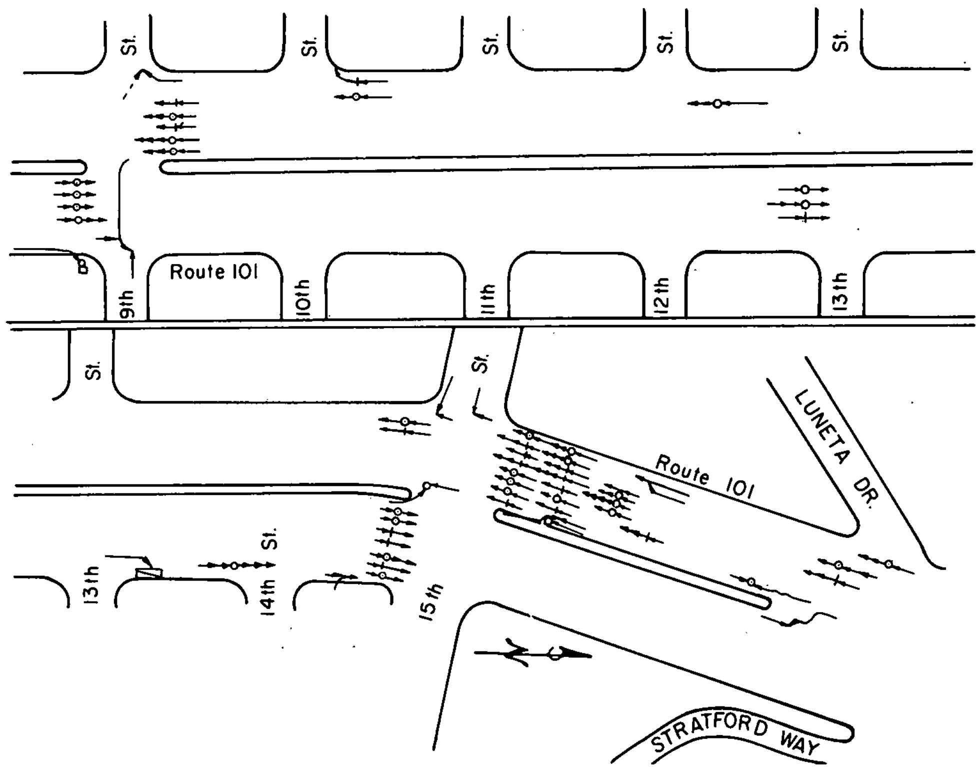

Figure 12. Collision diagram: US 101 in Del Mar after improvement (1-yr period).

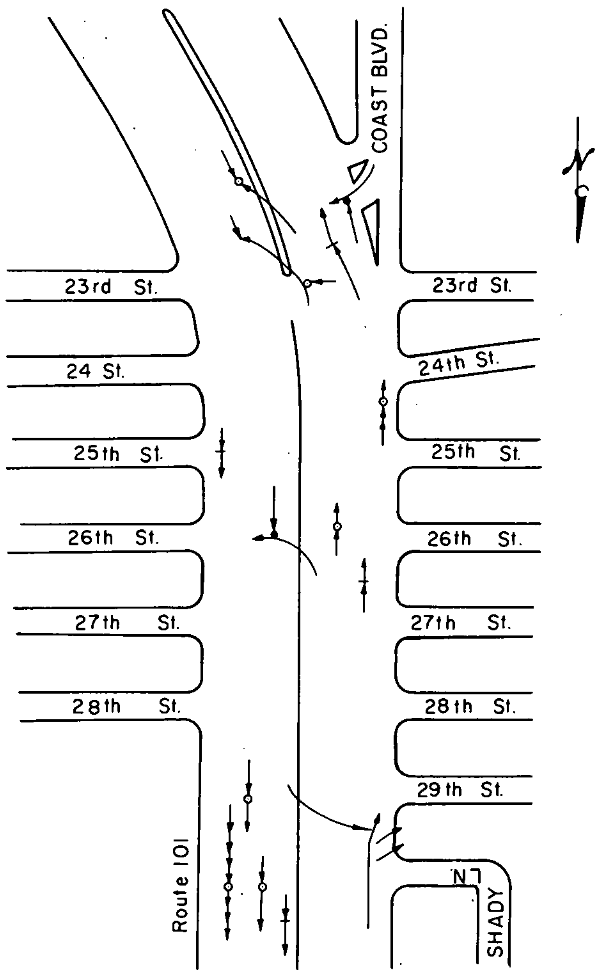

Figure 13. Collision diagram: US 101 in Del Mar before improvement (1-yr period).

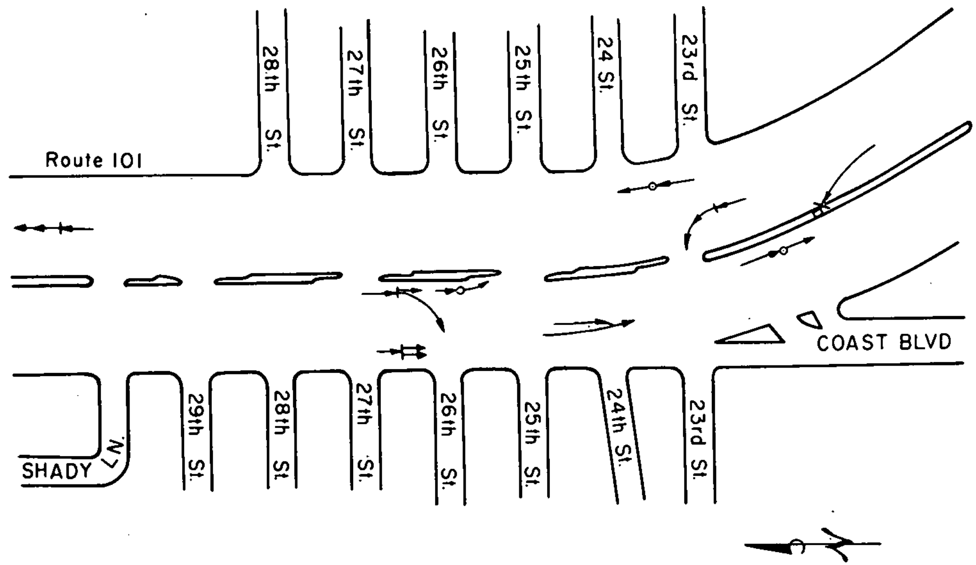

Figure 14. Collision diagram: US 101 in Del Mar after improvement (1-yr period).

from 83 to 60 with rear-end and approach left-turn accidents dropping from 56 to 50 and crossing accidents dropping from 16 to 3. There was one fatal accident and 40 injury accidents (75 injured) in the before period with 35 injury accidents and 47 people injured in the after period.

At another series of intersections (Figs. 13 and 14), every other block was closed in the median. This was also on US 101 in the same area as the previous example. There was a total of 7 intersections with 3 of them closed in the 1-yr after period. The ADT was the same as mentioned before with total accidents decreasing from 14 to 9 on this four-lane highway. Rear-end and approach left-turn accidents dropped from 10 to 7. Fatal accidents dropped from 2 (2 killed) to none while injury accidents dropped from 7 (17 injured) to 3 (4 injured).

Table 4 summarizes data at 40 unsignalized intersections with a breakdown of the types of channelization used to provide the protection for the left-turning vehicles. The methods used are paint, raised bars with paint, and curbs. The number of accidents are shown on the first line, the accident rate on the second line and the percent change in accident rate on the third line of the after period. The "S" indicates the change is significant at the 0.10 level of the χ-square test.

Total accidents and rear-end accidents were reduced significantly in all three types with raised bars and curbs yielding greater reductions than painted channelization. Lesser and insignificant reductions are noted in the left-turning accidents.

Table 5 is a rural-urban breakdown of the 27 painted channelized intersections. As might be suspected, much greater accident reductions are noted at rural intersections. Although rear-end accidents again were reduced significantly in both groups, urban crossing or broadside accidents were significantly increased. Perhaps drivers used the painted areas as a normal path in these heavier traffic conditions. Also, there is a possibility that these urban intersections did at the time meet the capacity requirements for a traffic signal.

TABLE 4

LEFT-TURN CHANNELIZATION

(Unsignalized)

			Projects				Accident Description															Million Vehicles	Equivalent PDO (EPDO)	Severity Index (SI)
								Accident Type								Severity			Lt. Cond.					
								Single Vehicle			Multiple Vehicle								a/	a/				
			Total No.	Improved	Worsened	No Change	Years of Experience	Ran off Road	Other	Sub-Total	Left Turn	Rear End	Crossing	Other	Sub-Total	PDO	Injury	Fatal	Day	Night	Total Accidents			
Painted	Before	No. of Accidents	27				$31\frac{2}{12}$	11	4	15	37	68	27	10	142	84	71	2	98	59	157	134.5	522	3.3
		Rate						0.08	0.03	0.11	0.28	0.51	0.20	0.07	1.06	0.62	0.53	0.01	1.09	1.33	1.17		3.88	
	After	No. of Accidents	27	2^S	0	25	$31\frac{2}{12}$	16	2	18	24	17^S	37	10	88^S	64	40^S	2	58^S	48	106^S	134.1	316	3.0
		Rate						0.12	0.01	0.13	0.18	0.13	0.28	0.07	0.66	0.48	0.30	0.01	0.65	1.08	0.79		2.36	
		% Rate Change						+50	-67	+18	-36	-75	+40	0	-38	-23	-43	0	-40	-19	-32		-39	
Curbed	Before	No. of Accidents	7				10	1	6	7	4	36	6	8	54	44	15	2	38	23	61	68.8	146	2.4
		Rate						0.01	0.09	0.10	0.06	0.52	0.09	0.12	0.78	0.64	0.22	0.03	0.83	1.00	0.89		2.12	
	After	No. of Accidents	7	3^S	0	4	10	3	1^S	4	4	4^S	10	3	21^S	22^S	3^S	0	18^S	7^S	25^S	77.7	40	1.6
		Rate						0.04	0.01	0.05	0.05	0.05	0.13	0.04	0.27	0.28	0.04	0	0.35	0.27	0.32		0.51	
		% Rate Change						+300	-89	-50	-17	-90	+44	-67	-66	-56	-82	-100	-58	-73	-64		-76	
Raised Bars	Before	No. of Accidents	6				9	5	2	7	11	60	6	11	88	54	40	1	67	28	95	66.4	300	3.2
		Rate						0.08	0.03	0.11	0.17	0.90	0.09	0.17	1.33	0.81	0.60	0.02	1.51	1.27	1.43		4.52	
	After	No. of Accidents	6	4^S	0	2	9	6	0	6	5	3^S	13	4^S	25^S	18^S	12^S	1	18^S	13^S	31^S	69.6	96	3.1
		Rate						0.09	0	0.09	0.07	0.04	0.19	0.06	0.36	0.26	0.17	0.01	0.39	0.56	0.45		1.38	
		% Rate Change						+12	-100	-18	-59	-96	+111	-65	-73	-68	-72	-50	-74	-56	-69		-69	
Total	Before	No. of Accidents	40				$50\frac{2}{12}$	17	12	29	52	164	39	29	284	182	126	5	203	110	313	269.7	968	3.1
		Rate						0.06	0.04	0.11	0.19	0.61	0.14	0.11	1.05	0.67	0.47	0.02	1.12	1.24	1.16		3.59	
	After	No. of Accidents	40	9^S	0	31	$50\frac{2}{12}$	25	3^S	28	33^S	24^S	60^S	17^S	134^S	104^S	55^S	3	94^S	68^S	162^S	281.5	452	2.8
		Rate						0.09	0.01	0.10	0.12	0.08	0.21	0.06	0.48	0.37	0.20	0.01	0.50	0.73	0.58		1.61	
		% Rate Change						+50	-75	-9	-37	-87	+50	-45	-54	-45	-57	-50	-55	-41	-50		-55	

a/ Assume 2/3 MV for Day and 1/3 MV at night for rate calculations.
"S" Indicates change is significant at the 0 10 level using the Chi-Square Test.

TABLE 5

LEFT-TURN CHANNELIZATION
(Painted)

			PROJECTS				ACCIDENT DESCRIPTION																
								ACCIDENT TYPE								SEVERITY			LT. COND.					
								SINGLE VEHICLE			MULTIPLE VEHICLE								a/	a/				
			Total No.	Improved	Worsened	No. Change	Years of Experience	Ran off Road	Other	Sub-Total	Left Turn	Rear End	Crossing	Other	Sub-Total	PDO	Injury	Fatal	Day	Night	Total Accidents	Million Vehicles	Equivalent PDO (EPDO)	Severity Index (SI)
Urban	Before	No. of Accidents	12				12 16/12	4	4	8	18	34	14	5	71	43	35	1	45	34	79	67.4	259	3.3
		Rate						0.06	0.06	0.12	0.27	0.50	0.21	0.07	1.05	0.64	0.52	0.01	1.00	1.53	1.17		3.84	
	After	No. of Accidents	12	1^S	0	11	12 16/12	6	2	8	14	11^S	26^S	8	59	43	23	1	33	34	67	66.7	187	2.8
		Rate						0.09	0.03	0.12	0.21	0.16	0.39	0.12	0.88	0.64	0.34	0.01	0.74	1.54	1.00		2.80	
		% Rate Change						+50	-50	0	-22	-68	+86	+71	-16	0	-35	0	-26	+1	-15		-27	
Rural	Before	No. of Accidents	15				18 4/12	7	0	7	19	34	13	5	71	41	36	1	53	25	78	67.1	263	3.4
		Rate						0.10	0	0.10	0.28	0.51	0.19	0.07	1.06	0.61	0.54	0.01	1.18	1.13	1.16		3.92	
	After	No. of Accidents	15	1^S	0	14	18 4/12	10	0	10	10	6^S	11	2	29^S	21^S	17^S	1	25^S	14	39^S	67.4	129	3.3
		Rate						0.15	0	0.15	0.15	0.09	0.16	0.03	0.43	0.31	0.25	0.01	0.55	0.63	0.58		1.91	
		% Rate Change						+50	0	+50	-46	-82	-16	-57	-59	-49	-54	0	-53	-44	-50		-51	
Total	Before	No. of Accidents	27				31 2/12	11	4	15	37	68	27	10	142	84	71	2	98	59	157	134.5	522	3.3
		Rate						0.08	0.03	0.11	0.28	0.51	0.20	0.07	1.06	0.62	0.53	0.01	1.09	1.33	1.17		3.88	
	After	No. of Accidents	27	2^S	0	25	31 2/12	16	2	18	24	17^S	37	10	88^S	64	40^S	2	58^S	48	106^S	134.1	316	3.0
		Rate						0.12	0.01	0.13	0.18	0.13	0.28	0.07	0.66	0.48	0.30	0.01	0.65	1.08	0.79		2.36	
		% Rate Change						+50	-67	+18	-36	-75	+40	0	-38	-23	-43	0	-40	-19	-32		-39	

a/ Assume 2/3 MV for Day and 1/3 MV at night for rate calculations.
"S" Indicates change is significant at the 0.10 level using the Chi-Square Test.

Additional study has revealed that painted left-turn channelization reduces accidents as much if not more than physically protected intersections (raised bars and/or curbs) on highways where the zoned speed is 55 mph or greater.

One more type of improvement involving a signal is the complete removal of the normally used refuge island to protect a left-turn signal head. In one urban area roadway having four lanes with left turns at all signalized intersections, the problem was two-fold. Motorists were running into the islands and the snow plows (it was in a heavy snow area) were hitting the islands. This highway handled peak-day traffic of over 50,000. The removal of the islands necessitated the use of long mast arms for signal support. After data are not yet available, but it appears that accidents will be reduced and snow-plowing operations simplified.

CONCLUSIONS

The intersection should and will come in for more attention particularly where more effort can be devoted to reducing delay at signalized intersections. Pay-off in accident reduction may be great with separate turning lanes but simpler treatment such as relocating bus stops from the near to the far side, liberal restriction of parking near intersections, and proper control of driveways near intersections, may also help. Unfortunately, no before and after information was available at this time.

Addendum

PHOENIX, ARIZ.

A simple intersection improvement example is shown in the before and after collision diagrams (Figs. 15 and 16) for a pavement widening project in Phoenix. A factual study of the accident patterns identified a clear need for left-turn channels on 32nd Street. There was also considerable traffic delay and congestion. It was determined that four lanes of traffic plus a left-turn channel were needed.

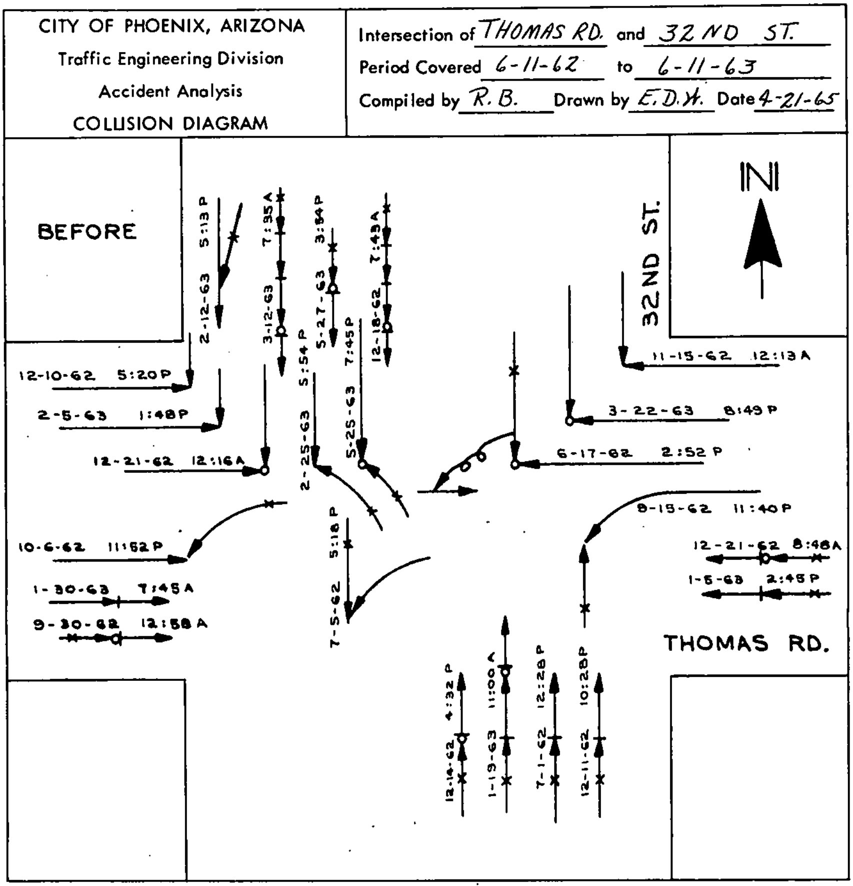

Figure 15.

It is important to understand that the foundation of much of the Phoenix major street system, to this day, is the old 16-ft wide concrete pavements installed in 1919. These have been slightly widened from time to time over the years. However, 32nd Street was essentially a narrow, two-lane road in both directions before this improvement.

The project was combined with several others to be included in a contract for street resurfacing and sealing and other bottleneck projects. Combining these projects re-

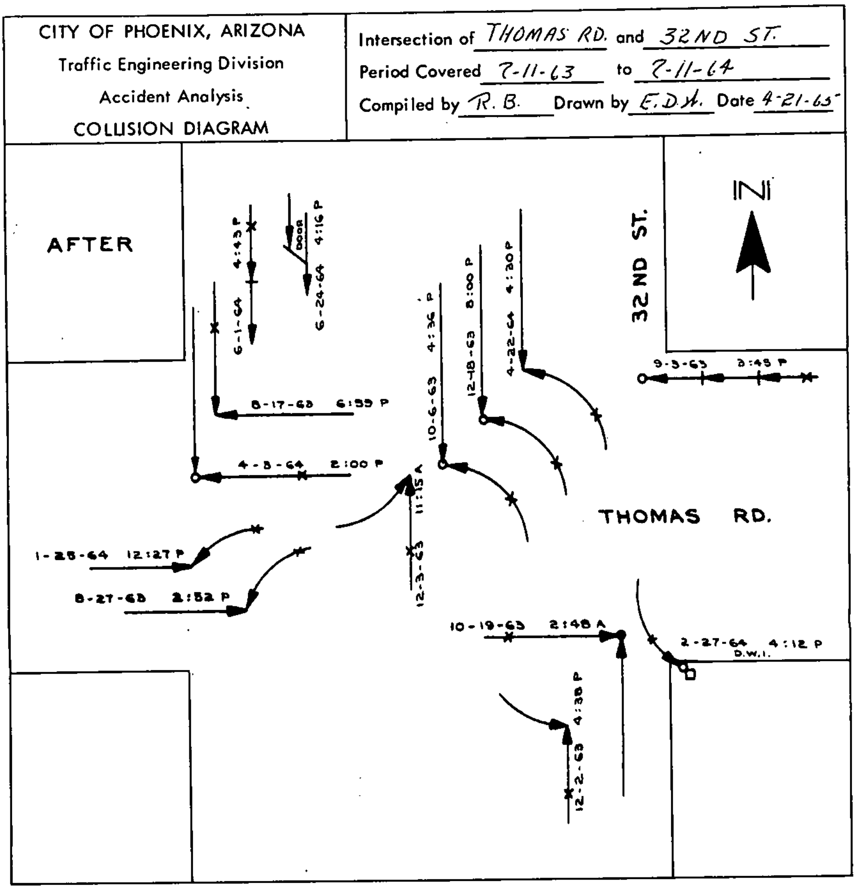

Figure 16.

sults in construction savings, because the contractor is already doing work in nearby streets or intersections, and in this way, avoids duplicating moving-in and moving-out costs. The total cost of this improvement was $900.

Figures 15 and 16 demonstrate the effectiveness and economy of the bottleneck elimination program in reducing accidents and relieving congestion. This is a program that provides relatively great returns for relatively small investments.