TRAFFIC MOVEMENT AND THE ADEQUACY OF ROADS IN THE VICINITY OF TUCSON

by

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Major Professor, Date

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PREFACE

The increase in highway accidents during the past few years, resulting from the increased use of the automobile and from other causes, demands the attention of every thoughtful person of the nation. The following tabulation shows the number of fatalities due to highway accidents in the United States during the past five years. In addition

Year		Fatalities
1932	-	29,451
1933	-	31,363
1934	-	36,000
1935	-	37,000
1936	-	37,500

to the number of deaths on the highway in 1936, there were more than 1,000,000 persons injured, and property worth approximately $2,000,000,000 was destroyed.

Widely diversified viewpoints have been expressed as to the best methods of handling this ever-increasing traffic problem. Some say it can be controlled by a rigid enforcement of traffic laws; others are of the opinion that education as to correct and reasonable driving practices will correct the situation; and still others believe the

highways can be made safe through engineering design. Experts in the field of traffic control incorporate all three of these corrective methods in their recommendations; no single one can be successfully used without the aid of the other two.

In cooperation with the United States Bureau of Public Roads, the highway departments in the majority of the forty-eight states have entered upon a thorough study of highway conditions and of the character and volume of traffic thereon. This study, which is termed the Highway Planning Survey, is divided into three branches: the Inventory Survey, Traffic Survey, and Financial Survey.

The Inventory Survey consists of the recording of all physical features of the State and county roads, namely, width of right-of-way, road surface, pavement surface, type of surface, sidewalks, fences, pipes, culverts, bridges, railroad crossings, topography and culture along the roads.

Under the Traffic Survey not only is the density information recorded, but information is obtained as to type of vehicle, weight of vehicle, residence of occupants, and origin and destination of the vehicle on that particular trip.

The Financial Survey is an economic study, through which the relation between the sum of all highway revenues and expenditures and the total of all revenues and expendi-

tures will be revealed. It will indicate the extent to which counties, State, and cities should be able to pay for future highway development.

Through this Highway Planning Survey, the highway departments will be able to institute a long-time planning program for the refinement of the highway system as a whole.

Heretofore most articles concerning traffic engineering that might have been of interest to the general public have been published in technical magazines with which the average layman very seldom comes in contact. Moreover, engineering articles have been too technical to hold the interest of most people, who read for the enjoyment of reading. After all, the engineer in this line must have the support of the public if anything is to be accomplished.

This paper consists of a review of the local road system in the vicinity of Tucson. Emphasis is placed on the facilities of the system affecting the factors of safety and efficiency in the regulation of highway traffic movement.

INTRODUCTION

Population Growth and Advanced Highway Design

The population of Tucson and the metropolitan area has increased from 43,639 in 1930 to 75,000 in 1936.[1] Along with this constant growth in population, as new residential areas are developed, the available highway facilities must be extended and improved. Advanced social standards demand advanced engineering standards with respect to highway planning. As in automobile design, the incorporation of safety, beauty, and comfort is fast becoming an important factor in selling better roads to the public.

In the near future construction will begin on the improvement of one mile of U. S. Highway 80, just north of the Tucson city limits. The completion of this so-called "Miracle Mile" will give Tucson the latest in highway design. The over-all width of right-of-way will be 135 feet, consisting of two 30-foot paved roadways, separated by a 38-foot landscaped central parkway and lined on each side with an additional 10-foot parkway and 6-foot concrete sidewalk. The estimated cost of the project is in the neighborhood of $250,000.

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1. Tucson Chamber of Commerce Report, December 1936.

The "Steady-flow"[1] principle of uninterrupted highway traffic has been employed in the design of the "Miracle Mile." "Steady-flow" means that the movement of the main body of traffic will not be disturbed or broken up by the entrance of traffic from intersecting streets. Under this system provisions are made for street-crossing without right-angle intersections and without grade separation. Cross-road intersections are made indirectly. (See Figure 1.)

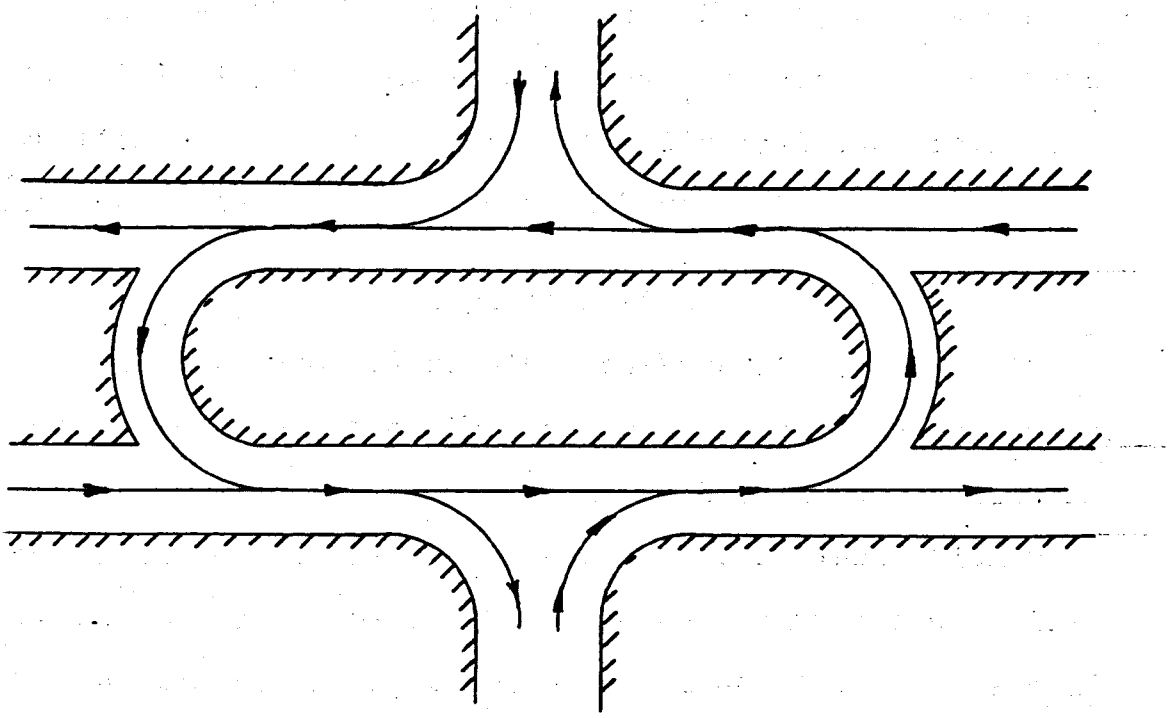

Figure 1. Indirect Crossing on Steady-Flow Principles

All traffic entering the thoroughfare must move in the same general direction as existing traffic. A motorist

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1. Fritz Malcher, The Steady-flow Traffic System, Harvard University Press, 1935.

wishing to cross the street will no longer have to face traffic moving in two directions before entering the intersection. Thus, not only is safety accomplished, but beauty, convenience and, in the end, economy to the motorist and adjacent property owners result.

Anything that adds contentment and happiness to the lives of the people of a community is a contribution to the wealth of that community. Upon completion, the "Miracle Mile" will be the finest stretch of highway in Southern Arizona. This improvement is only the beginning of the transformation of the roads in the vicinity of Tucson into an adequate system of well designed highways.

Highway System

A map (Figure 20) showing the highway system of the Tucson area accompanies this paper. The road layout is rectangular in plan, except where it is broken by the natural irregularities of water channels and mountains. Within an area of 430 square miles there are approximately 60 miles of paved county roads, 32 miles of paved state and federal aid roads, and about 400 miles of unpaved county roads.

As the past ten or fifteen years have constituted a period of road building and highway extension into newly developed rural areas, the next ten years will probably be occupied in improving and modernizing the existing system to meet present and future needs.

TRAFFIC MOVEMENT

Flow Map

From traffic counts furnished by the Arizona Highway Planning Survey, an approximate traffic flow map was constructed for the Tucson district. This map shows the relative distribution of vehicles per day for the main arteries leading into and out of the city. The figures shown at various points are the total actual count at those points. Because of the large percentage of tourist and sight-seeing traffic on the rural roads around Tucson, recreational areas and points of scenic and historical interest are located on this map. (See Figure 19) The diminishing width of bands on the more heavily traveled roads demonstrates, to a certain extent, the collection and distribution of the traffic volume leading to and from the city.

Adequacy of Pavement Widths

Until about a year ago all rural pavements (see Figure 20) were from sixteen to twenty feet in width. The state highway engineers realized the inadequacy of these narrow widths on the state routes adjacent to the city and proceeded to widen South Sixth Avenue to fifty-six feet, providing two lanes for moving traffic in each direction and one eight-foot lane for parking on either side. The

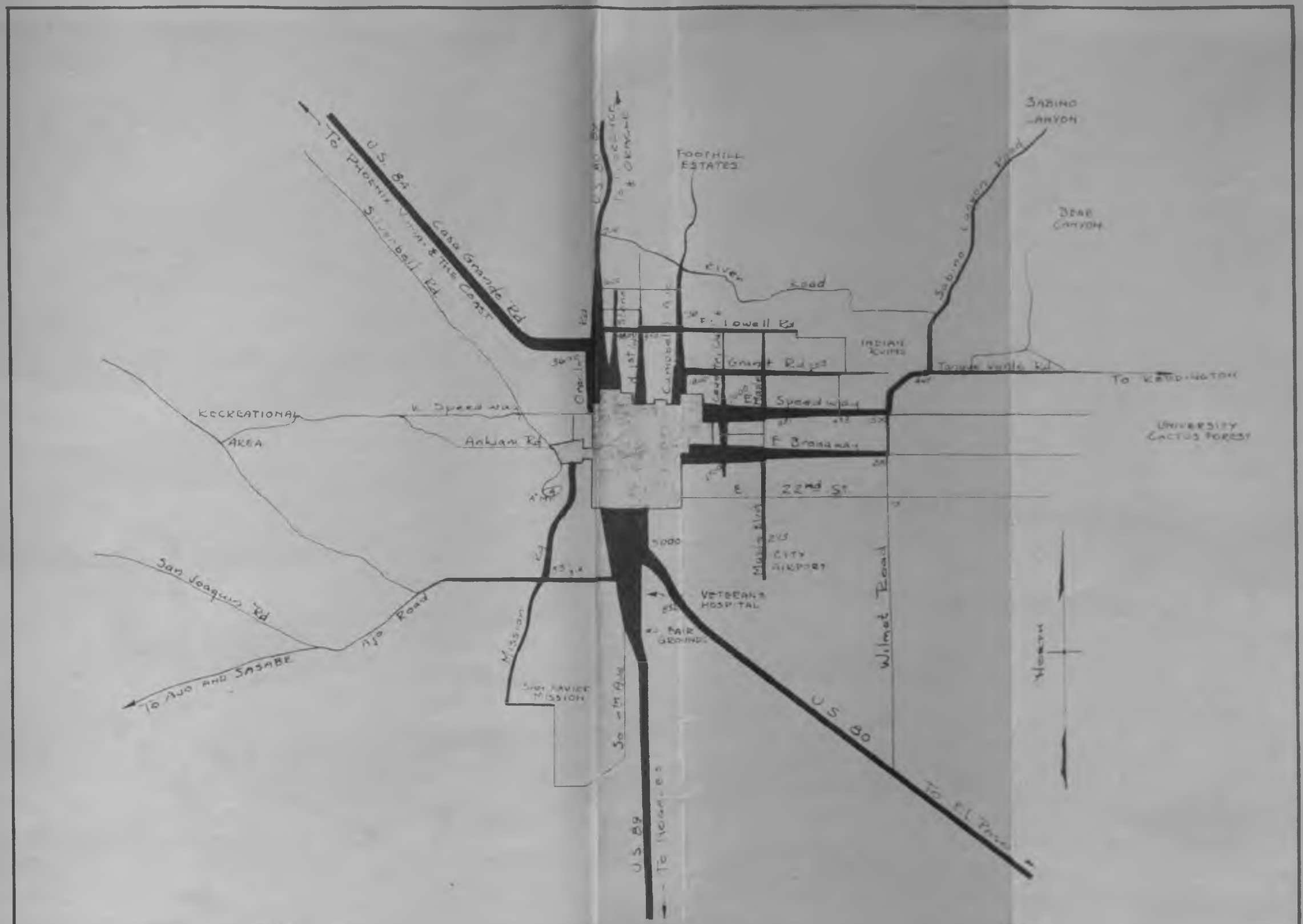

Fig. 19 FLOW MAP OF MOST IMPORTANT ROADS OUTSIDE OF THE CITY LIMITS
Width of band indicates relative 24 hour volume
Figures indicate count at that point

CITY OF TUCSON

TUCSON AIRPORT

U.S. 84

CASA GRANDE HIGHWAY

SILVERBELL ROAD

FLORENCE HIGHWAY U.S. 80-89

NORTH CAMPBELL

HACIENDA DEL SOL

RIVER ROAD

SABINO CANYON

BEAR CANYON

RUTHRAUFF

PASTIME PARK

ROGERS ROAD

PRINCE ROAD

WETMORE ROAD

LOWELL ROAD

GLENN AVE

GRANT ROAD

PIMA AVE

EAST SPEEDWAY

WEST SPEEDWAY

5TH ST

EAST BROADWAY

TANQUE VERDE ROAD

SPEEDWAY

BROADWAY

22ND ST.

OLD SPANISH TRAIL

EAST

ORACLE ROAD

STONE AVE

FIRST AVE

PARK AVE

MOUNTAIN AVE

CAMPBELL AVE

TUCSON BLVD

COUNTRY CLUB

BOULEVARD

MAPLE

THOMBAU

SWAN ROAD

GOLF LINKS

FLD TP.

AVIATION

BEVERLY

SWAN

HARRISON ROAD

DEMOSS PETRE

ANKLAM

SAHUARO PARK BLVD.

HELPMATE

SAN JOAQUIN

AJO HIGHWAY

SILVER LAKE

SAN JUAN TRAIL

MAIL ROUTE

INDIAN SCHOOL RD

SOUTH CAMPBELL

IRVINGTON ROAD

BENSON HIGHWAY U.S. 80

DREXEL ROAD

WILMOT ROAD

MISSION ROAD

SAN XAVIER

6TH AVE EXT.

NOGALES HIGHWAY U.S. 89

S. 6TH AVE

S. 4TH

S. PARK

LEGEND

- Paved Roads
- Dirt Roads
- Suggested By-Pass
- Railroad

N

Fig. 20

PIMA COUNTY HIGHWAY SYSTEM

TUCSON VICINITY

Scale 1" = 1 Mile

Drawn by G.B. Houston

improvement of the state highway on the north side of Tucson will soon be under way.

It is the writer's belief that a twenty-foot pavement may be ample to care for traffic up to five thousand vehicles per day, when the highway is in open country on state routes; but when a volume of two thousand vehicles per day exists within the first two or three miles outside the city and where the class of travel is so varied, as it is around Tucson, twenty feet is inadequate. The variety referred to

Figure 2. U. S. Highway 80 (South Sixth Ave.) 1½ miles south of Tucson city limits. Pavement is fifty-six feet wide.

is a mixture of tourist, sight-seeing, pleasure, and every-day business traffic.

Tucson is located in the center of that area of Arizona that attracts hundreds of winter visitors every year.

The southern coast-to-coast highway (Broadway of America) passes through this city. A good part of the local traffic may be attributed to the above-mentioned facts. If the city of Tucson is to continue to attract tourists, health-seekers, and winter visitors, it must lend its support to the development of the road system used by these visitors. The influx of visitors every year has contributed a great deal to the exceptionally good business conditions enjoyed during the depression years. It is a good policy for a community such as Tucson to endorse any plan for improving the roads adjacent to its boundaries, because an adequate road system is one of the very best forms of advertising a city can have. Highways, like other things, will never be perfect; there will always be room for improvement. Of course local resident traffic should be considered first, but the reason for mentioning the tourist traffic is that it has been so conspicuous in the past few years. From observations on three different occasions, the writer estimates that foreign traffic on the main county arteries into the city constitute about twenty per cent of the total traffic carried. The observations, shown in Table I, were made while driving along the highway. Two of the counts were made on Sunday, while the third was made in the middle of the week, on Wednesday.

The United States Bureau of Public Roads made a study

TABLE I

Road	Day	Time (P. M.)	Traffic		
			Foreign	Local	Total
East Broadway	Wed.	5:15 - 5:45	37	122	159
East Speedway	Sun.	4:00 - 4:30	24	96	120
Anklam Road	Sun.	4:15 - 5:15	16	23	39

of foreign traffic on all federal aid roads in the Western States in 1929 and found that the daily foreign car miles on Arizona highways were 38.5 per cent of the total.[1] Therefore, even though local studies have been rather limited, the foreign traffic on the local roads is well worth considering.

Tucson is not an industrial city but a winter and health resort. The estimated income from tourists with an average length visit of four months during the year is $4,000,000. The University of Arizona, located in Tucson, has an enrollment of 2500 students, of which approximately 2000 are from out of town.

In studying the habits indulged in by the different types of traffic, it was found that even though traffic volumes are small the prevailing speeds warrant pavement widths greater than twenty feet. In the two-lane high-

1. L. E. Peabody, "Western States Traffic Survey," Public Roads, March, 1932.

Figure 3. A Drive through Tucson Recreational Area

way no provision has been made for the accommodation of overtaking vehicles other than the use of the unpaved shoulder. Following is a tabulation of capacities for a single lane of moving traffic at different speeds (Table II). These listed capacities would apply under ideal conditions, when the speeds of all the vehicles are the same. Under actual conditions, when the speeds of the different vehicles range from 15 to 45 miles per hour, the capacity is greatly lowered.

The intermingling of this fast and slow traffic lowers the factor of safety of travel on a two-lane highway. Not only is there a tendency for the fast driver to take unneces-

TABLE II

STREET CAPACITIES AS AFFECTED BY SPEED[1]

Miles per hour	Safe interval between cars	Cars/hour per traffic lane
5	5 feet	1380
10	11	2100
15	18	2430
20	27	2580
23.5	33	2600
25	37	2595
30	49	2520
35	65	2340
40	88	2080
45	120	1760

(Average car length is fourteen feet.)

1. Malcher, op. cit., Los Angeles County Regional Planning Commission.

sary chances in passing slower cars, but fast travel, even when the road is absolutely clear, is inadvisable because of the unevenness of the paved surface. Less care is taken in setting paving grades on rural roads than on city streets. Then, too, as paving ages, small irregularities due to failures of subgrade are formed; this same condition may be found to exist on city streets but it is not so noticeable there because of speed restrictions.

Figure 4 is a view taken on East Broadway, at the city limits, illustrating a bad feature of a two-lane pavement. The car on the right was on the pavement until the car in the center of the picture approached and the driver sounded his horn. The central car appears to be turning to the left onto a side street, which is just ahead, but in reality, upon approaching the slower vehicle, the driver realized that he could not pass to the left because of another vehicle approaching from the opposite direction; therefore, he immediately slammed on his brakes, blew his horn,

Figure 4

and tried to pass to the right of the slower car. Upon hearing the confusion from behind, the driver of the slower car turned off the pavement, thereby adding to the confusion. The other car then swerved back to the left as the picture was snapped. Incidents such as this happen every day on the more heavily trafficked streets; they could be avoided with a three- or four-lane pavement.

East Broadway, East Speedway, and North Campbell Avenue are streets that carry a peak hourly flow of about six hundred vehicles. Unless reasonable speeds are enforced this is too much traffic for roads with but a single lane in either direction. Widening of these streets would carry a social as well as an economic value. The trend of population growth lies in the directions followed by these roads and improvements thereon would be fulfilling or tending to fulfill the future needs of the community.

By-Pass Road for Through Traffic

Of late it has come to the attention of city officials and business men that a portion of the traffic congestions so often encountered in down-town Tucson could be eliminated by providing a by-pass road for the truck traffic that passes through the city. The idea of utilizing existing streets on the west side of the city was resented by the inhabitants. Of course such a scheme could only be temporary, for as the traffic continued to increase new facilities

would have to be provided. After much controversy, the proposal was dropped for the time being, as the opposition was too great. The freight and trucking companies objected on the ground that their depots were established along the present main highways through town and that any changes in routing necessitating the moving of these depots would entail too great an expense.

Part of the truck traffic is encircling the city by way of East Speedway on the north and Wilmot Road on the east. The drivers have found that they can save time and trouble by taking this indirect route and avoiding unnecessary delays from congestion on the heavily trafficked downtown streets.

Truck traffic which finds it necessary to enter the city to deliver and take on cargo should be provided an entrance of its own. The use of the main thoroughfares for such traffic lowers the factors of safety, efficiency, and appearance of the most important part of the street system.

The large map (see Figure 20) at the end of this thesis shows (heavy broken line) a suggested route, the location of which might furnish an interesting study for the possible future development of a by-pass road. The writer does not have at hand the necessary data from which to estimate the cost of such a project; nevertheless, a few advantages offered by this route are discussed in the following paragraphs.

The distance through the city would be shortened by approximately one and one-quarter miles. This by-pass would begin on U. S. Highway 84 at a point one and one-half miles west of its junction with U. S. 80 and 89. Instead of crossing the Southern Pacific Railroad grade-separation at this point, the by-pass would continue in a southeastern direction paralleling the railroad tracks. At a point just outside the city limits, there is a junction of the Southern Pacific main line with the old El Paso and South-Western railroad; at this point the road would bear to the south and parallel the E. P. and S. W. tracks until it intersects South Sixth Avenue about a quarter of a mile north of the present junction of U. S. Highways 80 and 89. The approximate length of this proposed by-pass is five and three-quarters miles as compared to seven miles over the regular route through the city's main arteries. The saving in mileage on the suggested route over the easterly route (Speedway and Wilmot Road) is approximately five and one-quarter miles.

At no point on the proposed new road would there be a railroad crossing. This, from the standpoint of safety, is a desirable feature.

Not only would through traffic be accommodated but farm traffic from that area adjacent to Highway 84 northwest of Tucson would be provided a more direct road into the city.

Several improved streets, namely, West Speedway, West Fifth Street, and West Congress Street, would provide possible access to the business district for those who may wish to enter the city.

Approximately one-half of the land traversed by this route is entirely undeveloped and the other half is occupied by the lowest class dwellings.

After considering all possible routes through and around the city, this one west of the city appears to be the most feasible.

Although Tucson is still a small city and the through traffic has not reached a dangerous magnitude, now is the time to look ahead and plan for that traffic which may reasonably be expected in the future. The popularity of the southern coast to coast route through Tucson is increasing from year to year.

TRAFFIC SIGNS

Uniform Signs a Necessity

Too much emphasis cannot be placed on the necessity for uniformity of highway traffic signs, since an efficient control of traffic must be considered from a national rather than a local viewpoint. Similar colors, shapes, and locations with respect to traveled road surface tend to eliminate confusion in the mind of the vehicle operator.

Fig. 5

Standard 24-inch hexagonally shaped sign as recommended by the Bureau of Standards and the Bureau of Public Roads.
Location: City streets

Fig. 6

24-inch diamond shaped sign. No set standard.
Location: County roads

It is high time the city and county highway departments cooperate with the state highway department to use some sort of uniform code. The state officials follow the plan recommended by the United States Bureau of Public Roads. In order to illustrate the great lack of uniformity of the three systems, there has been included a set of photographs of the various types of signs encountered by the author while driving over the roads in and around the city of Tucson.

Fig. 7

Fig. 8

Standard 18-inch hexagonal signs, illustrating different types of placement and difference in heights from ground.

The lack of uniformity is noticed mostly in the use of stop signs. Both the county and the city street officials have standardized stop signs as to color. The county has seen fit to use black letters on a yellow background while

the city uses black letters on a silver or an aluminum background. In the majority of cases the county signs are home-made; this accounts for the variety of shapes. On the other hand those signs placed by the city are bought ready-made except for the color scheme.

Fig. 9

18-inch hexagonal stop-sign on county road. Non-standard color-scheme and placed too close to the ground.

Fig. 10

Standard diamond shaped warning sign as recommended by the United States Bureau of Public Roads. Standard in shape, color, and position relative to roadway.

In 1932 a very exhaustive study was made by the United States Bureau of Public Roads and National Bureau of Standards on the comparative visibility of standard luminous

and non-luminous highway signs. The following conclusions involving the determination of the relative value of the ground colors and the legibility of the respective legend colors and design were made:

> "All evidence deduced and analyzed points to the definite conclusion that the standard yellow background with black design color, under all conditions which might reasonably be expected to obtain on either a city street or upon a rural highway, is much superior to black on white or white on black. Not only has this been demonstrated to be true as to readability of the legend but the yellow background is more arresting to the average observer, is more conspicuous by contrast with the average natural or artificial background, and, therefore, has a greater signal value than the other backgrounds or combinations. Moreover, by adopting a definite shade and hue, such as is covered by the specifications of the American Association of State Highway officials in rule 53 of the sectional committee on colors for traffic signals of the American Standards Association, it may be possible by legislative act or otherwise to prohibit the use of this distinctive shade for advertising or for purposes other than official road signs upon the highways controlled by State or other properly constituted authorities."[1]

Figures 5, 6, 7, and 8 are photographs of the different types of signs to be found on the city streets and county roads around Tucson. Figure 5, the standard type used by the United States Bureau of Public Roads, is probably the best. The signs shown in Figures 7 and 8 are also standard and are the most extensively used in the city.

The signs in Figures 6 and 9 are off-brands. Evidently the county has not had the funds to replace such signs. To

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1. F. W. Mills, Public Roads, Government Printing Office, September 1933.

my knowledge the county has not used a single standard stop sign, except where a county road intersects a state highway. The sign of Figure 6 is most often encountered on the county roads in the vicinity of Tucson.

Figures 10 and 11 show that there has been no attempt to distinguish one type of road legend from another by the shape of the sign.

Fig. 11

A diamond shaped sign used for street marking

From observation of these different types of signs on the county highways, the point to be emphasized is the necessity of adopting standard shapes for the different legends. The general shape of a traffic sign should convey a definite message to the driver.

On the majority of the main thoroughfares adjacent to

the city, the cross streets are marked with diamond shaped signs. As many of the stop signs and all caution signs are of this same shape, the appearance of these signs fails to convey any meaning whatsoever to most motorists. On the other hand, visiting motorists who are used to signs whose shapes are meant to help deliver the warning printed thereon will become confused at this non-standardization and may disregard all warning signs.

Fig. 12

Defaced warning sign

Maintenance of Traffic Signs

There should be a periodic inspection of all traffic signs; those that have weathered or have been defaced in any way should be replaced immediately. Figure 12 is an illustration of what can happen to traffic signs. This particular sign, which immediately precedes a dangerous dip and

curve through the Rillito River on the Tanque Verde road, has been weathered by nature and stoned and shot at by vandals to the point where it has become a hazard rather than an aid to traffic.

SAFETY HAZARDS

The demands for highway improvements, in the past, have over-taxed the ability of the country to meet them; therefore, very little attention has been given to many of the refinements relating to highway design and operation which contribute to the general safety of the motorist. There is always the danger of encountering the unexpected, especially since the speeds attainable by the present-day automobiles are so much greater than they were when the roads were built.

Alignment

The alignment on most of the county highways in the

Figure 13. Curve on Silverbell Road with sight distance less than 300 feet

vicinity of Tucson is very good. At present the county highway department is engaged in a project involving the elimination of dangerous curves on the Silverbell Road. Figure 13 illustrates the type of curve being dealt with. Figure 14 shows a cut that is being made in the process of eliminating just such a curve as shown in Figure 13, thereby increasing the sight distance and safety in vehicular operation.

Figure 14. Increasing sight distance by side-hill excavation

Profile

North and east of the city the profile of the roads follows very closely that of the natural ground over which they are located. Much has been done in the past few years

to eliminate dips in the road, which were originally built to convey drainage water from one side of the road to the other. A few of these dips still exist, not only on the minor roads but even on more heavily traveled roads, such as East Speedway, East Broadway, North Stone Avenue, and the main United States highways near Tucson. On the main roads the small number of dips encountered is really the only discomfort to the motorist, so far as horizontal and vertical alignment is concerned. Farther from the city, in the foothills, where traffic is less dense, the hazards from alignment and profile are greater. Vertical curves are not so well-rounded as are those on the outskirts of towns. The surfaces on these roads are too good for the profile and alignment, because a clean, smooth surface induces speedy travel. On East Speedway, about ten miles from Tucson, there are a series of vertical curves over which, to most people, it is a pleasure to drive. Young folks especially love to take this so-called roller-coaster road at high speed. About three years ago a young girl was killed and several of her companions injured when driving over this road at approximately fifty-five miles per hour. After reaching the summit of one of these curves the front wheels evidently left the ground and the driver lost control of the car, turning it over and causing injuries and death to its occupants.

The River Road, north of the city, is another road that

is exceedingly dangerous to the careless driver. Figure 15 is a view of a dip in the road where it crosses a dry sand-wash. The author was driving along this road at thirty-five miles per hour and did not notice the abrupt break in the grade until the car was within about ten feet of the dip. It was supposed that this dip would be as well-rounded and smooth as the ones that had preceded it farther back in

Figure 15. Dangerous dip.

the road. This dip was so bad that it jerked the wheel out of the driver's hands and turned the car to the right into the sand-wash. The tracks made by the deflected car may be seen beside the road in front of the vehicle. Serious accidents could happen from such lack of maintenance. Usually, warning signs are placed on either side of a hazard such as this, but none exist at this location.

Intersections

In providing for heavier and speedier traffic the simple intersection of two strips of pavement is no longer adequate. Figure 17 illustrates the type of enlarged intersections now being built at the junctions of the heavier trafficked county pavements, and at the junctions of the county and state pavements, replacing that type of intersection illustrated in Figure 16. Improving the intersections in this way eases the flow of traffic from one road to the other. The necessity of encroaching upon the lane of opposing traffic flow is eliminated. The abrupt turn to the right, which works a hardship on both the driver and the mechanical equipment of the vehicle, is replaced by a long sweeping turn with a radius of 30 to 40 feet. Improvements such as this go a long way toward increasing the efficiency of the existing pavements.

On Ft. Lowell and Grant Roads there are several intersections where box culverts were built on either side of the intersecting streets to carry the drainage and irrigation waters under these roads. The head-walls built on either end of these culverts tend to restrict the useable roadway width. On top of the walls, concrete posts with pipe railings have been built. To a person driving on the road, the service width appears to be bottle-necked at these points, although the head-walls are about 32 feet apart and

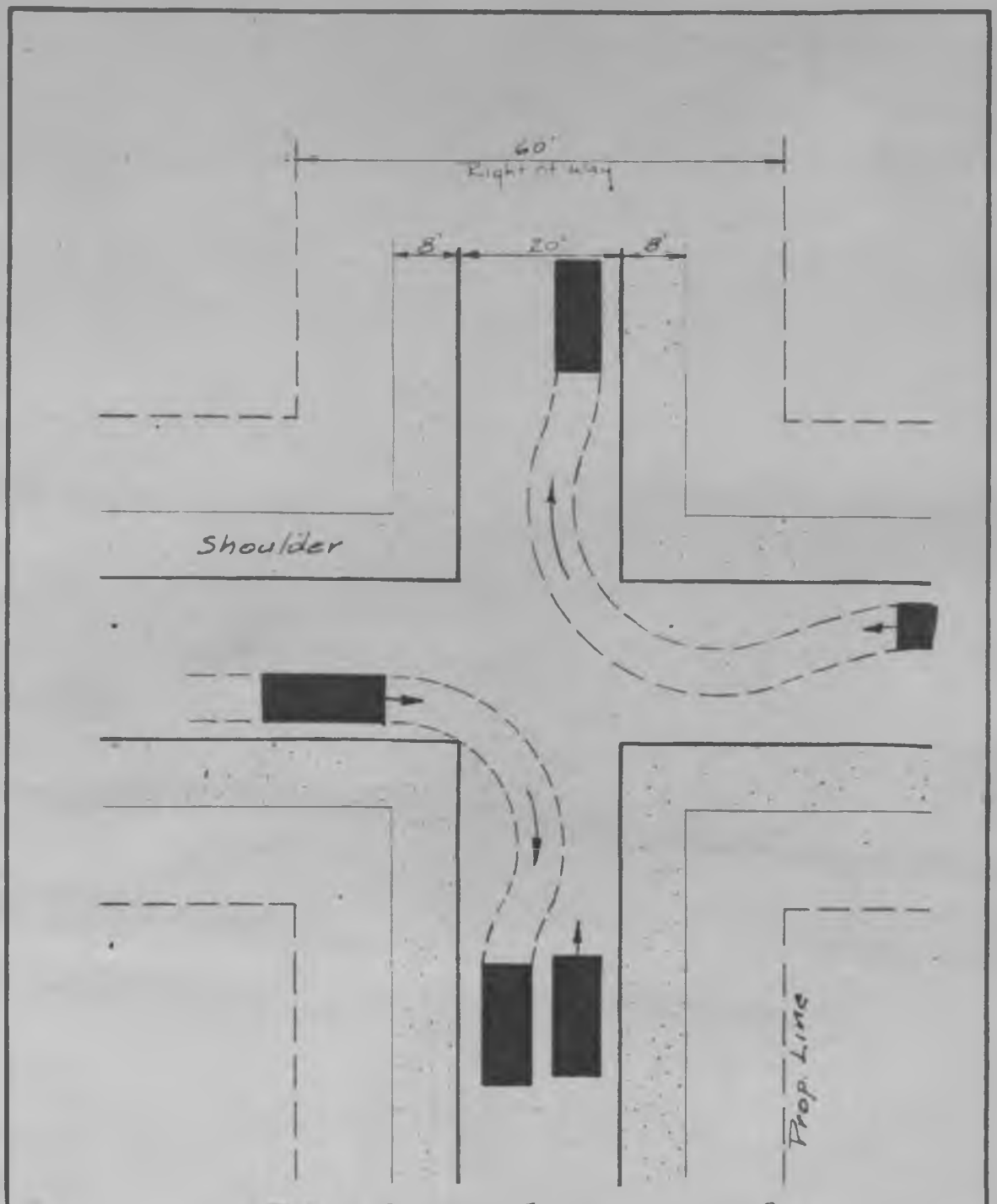

Fig. 16 Simple Intersection of 2 pavements, indicating the usual paths of vehicles

Scale $\frac{1}{2}$"=10'-0"

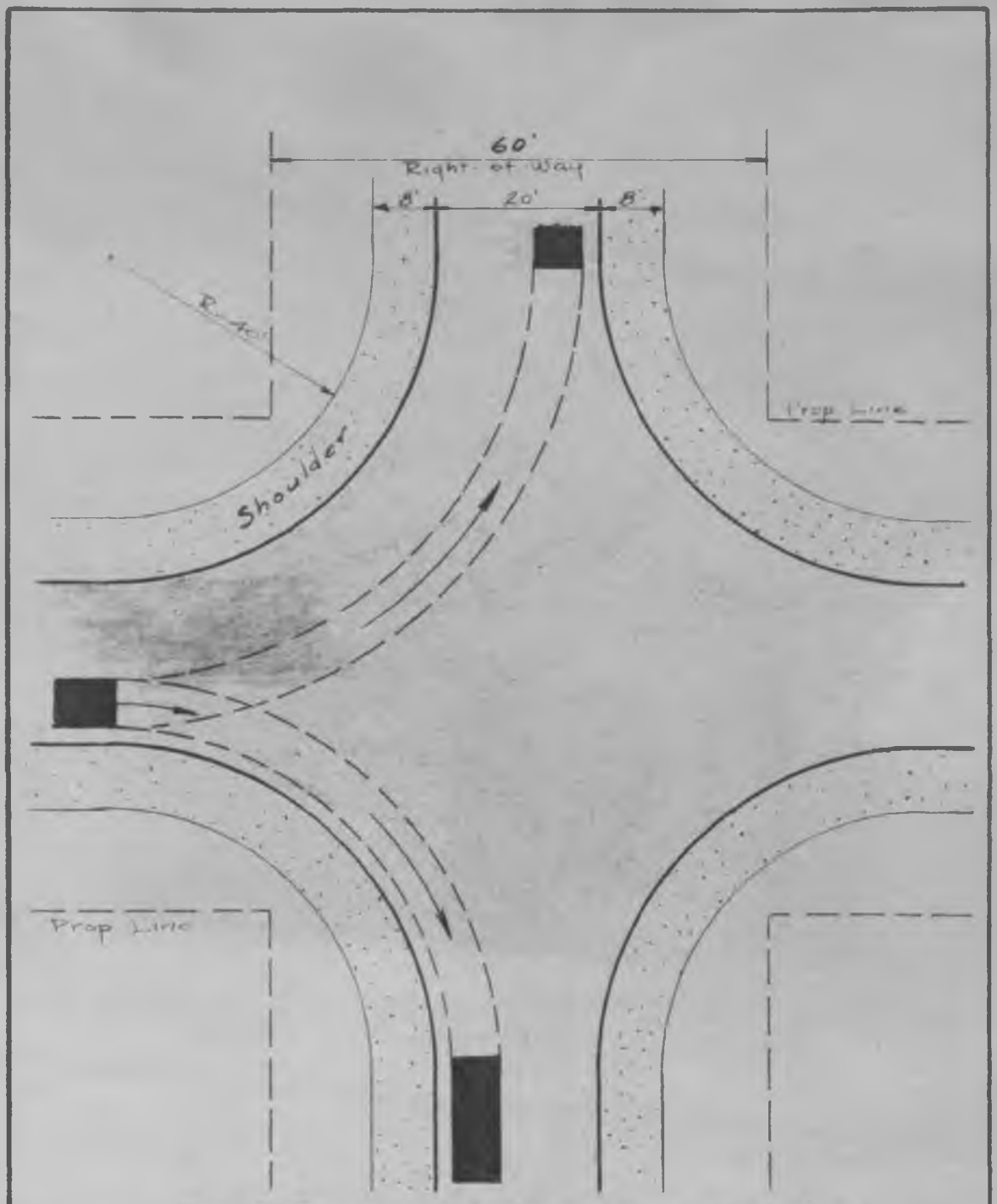

Fig. 17 Improved Intersection indicating the probable paths of vehicles.

Scale ½"=10'-0"

the pavement is 20 feet wide. Evidence of the contribution of these railings toward automobile accidents is seen by examining the broken rail and post shown in Figure 18. These culverts should be lengthened now before any greater damage is done to vehicle operation. Lengthening will have to be done in the future when increased traffic volume necessitates the widening of the road.

Figure 18. Head-walls of Box Culvert tend to restrict roadway width

Since 40 per cent of all accidents in 1936 on Arizona highways, of which the location was known, occurred at intersections, it is believed that the intersection is the most frequently encountered potential hazard of the highway system. Therefore, it is the highway engineer's responsibility

to reduce the accident hazard at intersections through rational design.

TRAFFIC COUNTS AS A FACTOR IN HIGHWAY IMPROVEMENT

In the past, the traffic count has been greatly underrated by many highway engineers. Mr. M. W. Torkelson, Director of Regional Planning, Wisconsin State Planning Board, in a report made before the American Road Builders' Association in 1936, stated that the probable maximum use of traffic counts in his state was to serve as a guide for the location of bill-boards and gasoline filling stations.[1] Mr. Torkelson went on to state that the real use of traffic counts is in the correlation of the existing traffic facilities with the population they serve, thereby becoming useful in estimating the capacity necessary to serve the needs of future population.

In view of the many improvements needed on the roads in the vicinity of Tucson, and since the county highway funds are mostly derived from the gasoline tax revenue imposed upon users of these roads, traffic counts should be utilized in forming a basis for a fair order of road improvement. The advisability of any highway improvement program is determined by an analysis of the social, economic, and educational benefits derived from such a program. In

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1. American Road Builders' Association, 1936 Convention Proceedings.

the analysis of these visionary benefits, traffic counts and the study of traffic origin and destination play a large part. Using traffic counts furnished by the Arizona State Highway Planning Survey, a table showing the vehicle miles traveled over some of the paved roads in the Tucson Area has been compiled.

TABLE III

COMPARISON OF VEHICLE MILES ON PAVED ROADS

Road	Length (miles)	Total Car-miles/day	Max. car-miles/day per mile	Ave. car-miles/day per mile
E. Broadway	4¾	3670	1800	775
E. Speedway	4½	4750	2100	1055
N. Campbell	2¾	2950	1500	1072
N. First Ave.	3	2250	1000	750
Wilmot Road	1	150	150	150
Maple Blvd.	4	1350	395	337
Ft. Lowell	4	1825	550	456
Country Club	1½	950	834	475
Grant Road	3	1400	600	466
N. Stone Ave.	1½	1600	1200	1066
Sabino Canyon	7	2100	470	300
Total car miles/day		22995		
Total mileage considered		37		

The writer considered only those roads to the north and east of the city, because it is in these directions that the population has been moving for the past 16 years.

Of all the roads listed, East Speedway and East Broadway, the two heaviest trafficked roads, have the poorest surfaces. In a program for improvement, East Broadway is placed at the top of the list, ahead of all others. The reasons for this are few, but well-founded.

First of all, abutting on Broadway are the most highly valued residential subdivisions adjacent to the city, with the exception of the Catalina Foothills Estates. The largest winter resort hotel in Southern Arizona is located on this road, two and one-half miles from the center of the city. The municipal golf-links, municipal baseball park, state sahuaro park, aviation field, and all residential areas to the north are easily accessible to East Broadway traffic.

In view of the fact that Broadway leads directly east from the heart of the city, it is logical to assume that, if it were to be improved to a condition where increased speeds and increased capacities might be served, it would draw a portion of the eixsting traffic on East Speedway and other streets between Speedway and Broadway. It is the most direct route out of the city. As mentioned before, the prevailing speeds on East Broadway warrant its improvement. Not only would property values be increased, but property

development would be speeded up. People would not be so hesitant in investing in high priced residences on this road. In other words such an improved road would lend confidence to those persons who are well-to-do and who wish to build homes in the vicinity of Tucson.

The recreational facilities mentioned draw people from all over the city and a well-designed road leading to such facilities is the best publicity for the promotion of better roads.

In considering the type of improvement for East Broadway, probably any improvement in the surface of the pavement would suffice so far as enticing traffic from neighboring thoroughfares is concerned, but as to increasing property values and the development of new areas, the incorporation of beauty is a necessity. For this reason, the center parkway principle in highway design is most favorable. There is nothing about the simple highway ribbon of two-lane width that is inviting to the motoring public, but where the highway with the center parkway with roadside planning exists, it will be found that the motorist will go out of his way to travel over such a road. Also, with the center strip, safety is assured to a greater degree; the possibility of head-on collisions is eliminated. Although, to the writer's knowledge, there have been no fatal accidents on the road in question, its hazardous condition should be remedied before

there are any.

In addition to the increase in property values, through an improvement in the pavement grade and pavement surface, there would be effected a direct saving to the motorist due to a decrease in vehicle operating costs. According to studies made by Professor John A. Oakey, of Columbia University, indications were that the vehicle operating costs varied from five and one-half cents ($0.055) on low type pavements to five cents ($0.05) on intermediate, and four and one-half cents ($0.045) on high type pavements.[1] The pavement on East Broadway falls in the low type class.

From the table on page 30 it is seen that Broadway is used to the extent of 3670 car-miles per day. This amounts to 1,339,550 car-miles per year. Using Professor Oakey's figure of five and one-half cents per mile, the total operating cost over this road is approximately $74,000 per year. If the pavement were improved to the high type, thereby decreasing the operating costs to four and one-half cents per mile, there would be a direct saving to the motorist of approximately $14,000. This direct saving and the estimated benefits to the property owners and the community as a whole justify the improvement of East Broadway. Of all the major thoroughfares around the city of Tucson, East Broadway and

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1. American Road Builders' Association, 1936 Convention Proceedings, pp. 831-36.

East Speedway are the only ones on which the paved surfaces are inadequate to meet the needs of traffic. The main reason for choosing East Broadway as the most feasible of the two to improve is its location with respect to the center of the city.

CONCLUSION

In the past, political influence has played too great a part in the development of highway systems. As with any other governmental decision, the location of highways and the improvement of existing ones should be based on the principle of the greatest good for the greatest number. Who knows better than the experienced highway engineer which location is the best, what improvements are necessary, and what mistakes made in the past must be corrected? More and more people are realizing the true responsibility of the highway engineer, and are giving him more of a free hand in the application of engineering principles in design and construction. In the last five years the importance of traffic studies in connection with highway design has been recognized in combatting the evils of highway accidents and promoting convenient and efficient highway travel.

The basis for improvement in the past has been to take care of increasing volume of traffic. Safety, beauty, and comfort have appeared, and these factors will continue to grow as important elements in future design. Small communities and governmental sub-divisions, such as Tucson and Pima County, should utilize the knowledge gained through experience by the larger cities and counties.

The big difficulty in highway development, not only in the Tucson area but in the State as a whole, is in its financing. It must be remembered that there are three parties that benefit through highway improvements--the community, the property owner, and the motorist. It is only fair that all three contribute their share to the cost of such improvement. The motorist alone cannot afford to pay the total cost. Therefore if the progression of highway development is to advance to that point of perfection already achieved by the automobile in design and operation, highway revenues must increase and must continually be made available.

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