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ENVIRONMENTAL FACTORS AS CAUSATIVE AGENTS IN

MOTOR VEHICLE INTERSECTION COLLISIONS

DISSERTATION COMMITTEE

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CHAPTER I

INTRODUCTION

An Overview

Ever since the automobile was invented, man has managed to find innumerable ways in which to kill or injure himself through the use of this great achievement in science and technology. As the number of vehicles on the road has increased, so has the number of accidents, and, although the death and injury rates have fluctuated somewhat, there is no question that the automobile has created a monumental environmental health problem. Tremendous efforts have been made to reduce the number of accidents, as well as their severity, but, as yet, these efforts have met with little success. Most of the emphasis in the past has been placed on the driver as the primary causative factor. Only recently researchers have begun to consider the multiple cause approach, and in particular the role of the environment as a primary contributing factor.

Death and injury statistics, such as those compiled by the National Safety Council (Table 1) (1), have been collected and presented to the public annually with relatively little effect on altering people's

TABLE 1

U.S. DEATHS AND INJURIES FROM

MOTOR VEHICLE ACCIDENTS - 1971

Classification	Total
Deaths	54,700
Bed disabling injuries	1,284,000
Non-bed disabling	
With activity restriction	1,196,000
Without activity restriction	1,071,000
Permanent impairments	170,000

attitudes and reducing accidents. This contention has been supported by Whitlock (2) who observed that despite the enormity of these figures, road-death and injury rates have astonishingly little impact on the general population. For the most part, each new record has received only brief notice in the press, and the majority of readers, after expressing perfunctory concern, have remained indifferent or apathetic.

As the annual number of accidents has continued to mount, so have the costs. The National Safety Council (1) estimated that in 1971, motor vehicle accidents cost the United States approximately $15.8 billion of which $5 billion was in property damage and $10.8 billion was in injuries including wage loss as well as medical expenses.

Accidents which have resulted in death and injury have received most of the publicity to date, however, the less severe and far more numerous property damage accidents have contributed heavily to this country's financial loss. Accidents involving property damage have increased 35 per cent since 1966, and the average dollar amount has increased from $489.82 in 1968 to $842.04 in 1971 (3).

Since the invention of the automobile, and the occurrence of the first motor vehicle accident, researchers have compiled and analyzed voluminous statistics pertaining to injuries and fatalities. Even with this mountain of available data, investigators have been unable to develop effective solutions to the automobile accident dilemma. Americans have been talking about traffic safety since the turn of the century - yet there has been very little scientific proof about the causes and cures of accidents. Opinions and slogans have been relied on extensively, including attempts to frighten people into being more careful (4).

As late as 1965, less than $10 million a year was being spent on research aimed strictly at highway safety with some national direction (4). With the passage of the National Highway Safety Act in 1966, safety research increased considerably, but accomplishments in the area of accident prevention were still minimal. The seriousness of this state of ineffectiveness was further complicated by the considerable importance of road safety research to the economic welfare of any country. The philosophy of the Road Research Laboratory's investigators (5) was that if large sums of money were to be spent on the road and traffic system, that these funds should be spent as effectively as possible. Research on traffic safety should contribute substantially to this end.

The limited success of safety research in this country has been primarily a result of the philosophy toward automobile accidents. One probable reason for such a poor showing in the area of motor vehicle accident research is that the problem of traffic safety has not been dealt with effectively, because it has not been defined effectively; for over half a century, traffic safety has been seen primarily as a problem of individual behavior, when in fact, it should have been considered as a problem of public health (6).

As a public health problem, traffic safety can be treated in an epidemiological frame of reference. Accidents as a problem of health to populations conform to the same biologic laws as do disease processes and regularly evidence a comparable behavior (7). By implementing this epidemiologic approach, investigators could then define specific causes and search for individual solutions in an effort to decrease accident occurrence.

Before potential solutions can be investigated and recommended, it is first necessary to determine specific causes of the motor vehicle accidents. The term accident itself has been a very misleading one. In common usage, the word accident has been used to imply an event over which one has no control (8). Halsey (9) agreed that accidents were not accidents at all in the literal sense of the word; they do not simply "befall." A more definitive word representing the contact between two automobiles or an automobile and a fixed object would be collision. In an attempt to reduce automobile collisions, injuries and fatalities, agreement first has to be reached that collisions do not happen by chance or at random, but rather, they are caused by specific sets of circumstances, which in many cases are predictable and can be altered to reduce motor vehicle collisions.

As has been the general rule in the past, automobile collisions have been described as having one specific cause, and any further investigation has not been deemed necessary. The major source of motor vehicle collision information available to accident researchers has been the traffic accident records compiled by the states and municipalities. A major handicap in identifying accident-causing factors has been the inadequacy of this prime source of data: the accident records system (10).

In most cases, the official record of a traffic collision has consisted of a one or two page report form which was completed by the investigating officer, either at the scene of the collision or shortly afterward. Traditionally, the principal objective of the police officer in accident investigation has been to find which operator was at fault (11). Assessment of fault has been of primary concern in settling insurance claims, and more in-depth investigation has not been deemed necessary. Responsibility for this deficiency in the investigative process should not have been placed on the police officer, but rather, on the entire system of data collection. The failure of some form of local, state or national data collection program has been one of the principal reasons for the inability of safety researchers to reduce automobile collisions and provide a safer system in which motor vehicles could be operated.

To further emphasize this problem of data collection, Taylor (12), in a sample of 14 police accident reports from different states, observed that almost total emphasis for accident causation was placed on driver failure. The state of Oklahoma has been employing a system of cause assessment of a similar nature. Table 2 lists the choice of causes available to an accident investigation officer, as well as the number of collisions attributable to each cause for the year 1971. According to these statistics, 83 per cent of all traffic accidents were caused by human error, while 14 per cent of the collisions were listed as having other causes, and only 3 per cent were attributed to vehicle failure. No other possible causes were even listed (3). Similar findings were reported in a study by the Stanford Research Institute, whose researchers reported in "U. S. News and World Report" (13) that 90.6 per cent of all automobile accidents were caused by improper driving, while another 7.4 per cent were attributable to the drinking driver. Only 2 per cent of the accidents were reportedly caused by other factors, these being 1.7 per cent from faulty brakes and 0.3 per cent due to improper lights. No other causes were listed or discussed. The results of this study are presented in Table 3. Once again, these data were based on information obtained from police accident reports.

With this type of multiple choice accident cause selection, it is clear how the National Safety Council arrived at figures such as 90 per cent of all traffic collisions having been caused by a failure of the part of the drivers, or simply, human error. Taylor (12) has pointed out that this figure is not necessarily false, but rather, that the statement has no meaning. There have been too many accidents where driver errors and impairments could not be clearly separated from other equally important contributing factors.

TABLE 2

NUMBER OF MOTOR VEHICLE COLLISIONS BY CAUSE

FOR OKLAHOMA - 1971

Official Cause	No. of Collisions
Failed to yield	13,217
Following too closely	9,220
Unsafe speed	9,762
Improper turn	8,488
Improper lane change	2,421
Improper movement	5,376
Unsafe vehicle	2,025
Left of center	1,820
Other violations	2,645
Pedestrian actions	527
Other	9,447
Total	64,948

TABLE 3

PERCENTAGE OF MOTOR VEHICLE COLLISIONS BY CAUSE*

Causative Factor	Percentage of Collisions	
Improper driving	90.6	
Speeding, too fast for conditions		18.1
Failed to yield right of way		18.4
Ignored a stop sign		3.1
Disregarded a traffic signal		3.7
Drove in wrong lane, left of center		5.5
Overtook another car improperly		3.8
Made a turn improperly		4.7
Followed too closely		13.3
Other driver errors		20.0
Driver had been drinking	7.4	
Faulty brakes	1.7	
Improper lights	0.3	

* These data were obtained from the National Safety Council.

The lack of the accident data gathering system in the United States caused Segal (11) to suggest four valuable objectives of scientific collision investigation:

a) the improvement of mass data systems,

b) the development of quality control techniques on the mass data systems,

c) the establishment of causal hypotheses for verification by statistical and experimental techniques, and

d) the uncovering of faulty design and operating practices too subtle for detection by other methods.

Collision researchers have been unwilling to accept the single cause explanation for the hundreds of thousands of automobile collisions occurring in this country each year. This new philosophy toward accident causation has best been stated in <u>The State of the Art of Traffic Safety</u> (8). The highway transportation system of the United States has continued to be one of the most complex systems in our society. Safety has been but one of its several requirements, the proper treatment of which has required an understanding of a wide variety of social, economic, political, psychological, legal and physiological, as well as engineering factors related to the highway, the vehicle and the driver. The system is characterized not only by its complexity, but also by the high degree of interconnectedness and interdependence of these many factors.

Smith (4) supported this hypothesis of a systems failure due to the inseparable interaction between the vehicle, roadway and the driver in every traffic situation. As a result of this relatively recent change to the concept of a systems approach to automobile accident investigation, the idea of a single cause has been replaced by one of numerous contributory factors. A contributing element has come to mean any feature of the system, the variation of which will alter the risk of an accident (7).

An equally important concept is that a set of contributing factors or exceptional combination of circumstances has to be acting at any instant in order for a collision to occur (14)(15). This set of circumstances or contributing factors acts upon one or more of the three major variables of the transportation system with the occurrence of numerous accidents as the result. These three variables are the driver, the vehicle and the environment. Of these three, the driver has traditionally been credited as the source of almost all accidents. Only recently, safety researchers have begun to look beyond this superficial reasoning and initiated a procedure of investigating the entire system as it really exists, and the manner in which it functions in automobile accident causation.

Driving involves the performance of a complex perceptual-motor skill with the driver responding to and interacting with a large set of stimuli (8). However, in the commonly used simplistic approach to accident causation, the driver culpability theory was and still is often accepted. In other words, there has been a tendency to blame the driver for inefficiencies and breakdowns in the system, and especially for accident occurrence. A quite different point of view has come to be called the driver overload theory which is a multiple factor theory of accident causation (16).

Human error has been employed to cover up a multitude of causative factors. An accident may have, according to the official interpretation, been the result of a driver failing to yield at a stop sign; however, the driver's action may not have been a cause by itself, but rather, the result of some other set of circumstances. Therefore, these other variables have really caused the collision, not simply the driver's response to them, which was the only explanation appearing on the police report.

To more fully understand this hierarchy of causative factors, a common classification scheme, using three reasonably distinct phases of driver action, has been established. These phases included perception, judgement and action. Taking them separately, an accident may result where a driver fails to perceive, or incorrectly perceives, a situation. For example, accidents are more likely to occur where there are a number of things the driver has to see and pay attention to at the same time, such as at a busy intersection. The driver's view may be obstructed, making it impossible for him to see a potential hazard or at least to see it in its true perspective (15).

Utilizing the systems approach, accidents have been shown to be the result of a complicated series of events where the driver has consistently been labeled the sole causative agent. In fact, there may be a multiplicity of causes for every accident, revolving around the driver, the vehicle and the environment. Since these accidents are known to occur where the driver is presented with a large amount of data to evaluate, and where it is necessary for him to make many decisions at once, it is logical that one of the most likely locations for accidents to occur would be at intersections.

The Department of Transportation, through use of multidisciplinary accident investigation teams has stimulated much research into the underlying causes of motor vehicle accidents. They have organized their research around the three primary factors already mentioned: the driver, the vehicle and the environment. Investigation by these teams has shown that vehicle failure has not been a primary factor in more than a small percentage of collisions. While the driver still remains the dominant factor, in-depth investigation has indicated that environmental factors play a key role in accident causation. Instead of the 15 per cent of all accidents which have commonly been attributed to the highway, the portion of the total accident problem in which the highway bears some share of the responsibility may well be three times as great, and it may even be larger (17).

The continued occurrence of automobile collisions has indicated a failure by the road facility, vehicle and vehicle operator separately or jointly (18). The driver has been responsible for many collisions through his actions, but in most cases, it has been his driving environment which determined those actions and therefore deserves at least partial responsibility for causing the collision. In addition, it is a well known fact that environmental factors play an important role in increasing the severity of the collision or the injuries sustained by those involved.

Human Factors

Human variables have already been evaluated to some extent. Accidents have traditionally been blamed on the driver, and although he is in control of the car's movement, there are other considerations, some obvious, some subtle, to which the operator has to react in determining what driving maneuvers to execute. In fact, the driver's actions which bring about an accident may not be causes at all, but rather results, results of the driver's interpretation of environmental conditions which are the actual causes. This is not to be construed to mean that the motor vehicle operator is never at fault, but, in fact, that many times he is not the primary or sole cause.

Drinking drivers have always been a problem, and many programs, such as the Alcohol Safety Action Program, have been instituted to limit this contributing source of over half of the automobile fatalities. These programs have met with some success, and they have assisted in the reduction of the number of motor vehicle accidents. Other areas of action such as driver education, driver training, licensing and examination procedures have also helped, but not sufficiently to note any marked decline in the number of automobile collisions which occur each year.

Vehicle

The second area of concern has been the vehicle. Repeated studies (3)(13) have indicated that vehicle malfunction has been responsible for collisions only about 3 per cent of the time. The condition of the vehicles involved in accidents has overwhelmingly been judged by investigating officers to have been "apparently normal," although, the percentage of defective components have been found to have increased with the age of the vehicle (3). Efforts have been made to reduce vehicle component failure by increasingly strict inspection and registration programs. Once again, this has failed to produce any significant reduction in the number of vehicle collisions.

Most of the research centered around the vehicle has involved safety equipment to lessen the severity of injuries received in collisions. Stress has been given to those aspects of the vehicle which, through modifications or additions, would reduce the effects of collision on a car's occupants. This has not been aimed at accident prevention, of course, although, it is a sensible approach to injury control (19). At the same time, automobiles have been designed with larger, more powerful engines which can attain higher speeds and increase the chance of injury, should a collision occur.

This type of approach has been consistent with the past philosophy concerning accidents. Much research has been devoted to limiting injury severity and providing better emergency treatment, but for the most part, accident prevention has received little attention. Vehicle and human factors researchers seem to have resigned themselves to the occurrence of large numbers of accidents and have been primarily concerned with limiting fatalities and severe injuries. This situation has brought about the necessity for a new philosophy, centered around accident prevention, rather than around severity reduction.

Environment

The third area of consideration is the environment. Until recently, the environment, as a potential cause of motor vehicle accidents, has been relatively neglected. This seems rather unusual, since the highway, after all, is the only variable in highway safety under full control of public officials (20).

Environmental conditions have been shown to be directly related to the manner in which the driver operates his vehicle. The immediate surrounding conditions of the road user often affect his behavior, and are therefore important when considering road safety and traffic flow (21).

Environmental factors have always been present and influence traffic conditions, as well as traffic accidents. These factors have contributed to highway safety in several important regards. Safe transportation has required, in addition to a properly functioning vehicle and operator, an accommodating roadway which permits the driver-vehicle combination to traverse it without incident. This has demanded that the environment provide not only a roadway surface compatible with the vehicle-driver combination, but also the information needed by the operator to maintain himself on his desired path. In this view, the environment has been understood to consist of: the physical elements of the roadway itself and all other physical entities on the roadway which affect the safety of movement of the vehicle; the informational factors which provide the vehicle operator the information on his location on the road and the instructions for his continued travel; and a special set of informational factors concerned with traffic control (8).

Multidisciplinary Accident Investigation Research

Due to the dissatisfaction with the simplistic approach to accident causation, the United States Department of Transportation instituted the Multidisciplinary Accident Investigation Program. This in-depth investigation of collisions included a careful analysis of the basic elements of a collision:

a) human factors,

b) vehicle factors and

c) environmental factors.

The three phases of the traffic system failure were also examined:

a) pre-crash,

b) crash, and

c) post-crash (22).

Approximately, 16 of these teams were established in major cities and research centers across the country. Since their inception, they have provided the Department of Transportation with in-depth information on thousands of automobile collisions. These teams reported that vehicle failure was rarely the cause of accidents. Their findings pointed out that the human factor was still the predominant one, but that environmental factors played a key role as contributory causes in a far greater proportion of these collisions than had been previously suspected.

In a study of 31 fatal automobile accidents, the Boston University team (23) included among its conclusions and observations that multiple-accident locations indicated road deficiencies which aggravated the human factors, and that trees and poles were often close to the pavement. In another study, the Indiana Unviersity team (24) found that in at least half of the 22 vehicular accidents attributed to driver error, environmental factors contributed an added load to the system in which the driver erred. The Southwest Research Institute team (25) found that, in 53 accidents, 65 road defects and hazardous conditions were observed which had directly caused, or significantly contributed to, producing the accident or injury.

The University of Miami team (26) observed that there were few safety engineering standards currently established and those few were thinly spread among other standards. Further, they recommended that a manual of minimum safety engineering standards be developed on a national level. A study conducted at the Georgia Institute of Technology (27) illustrated the need for remedial programs to improve the roadway environment due to the fact that environmental deficiencies were reported in 62 out of 100 cases investigated. In another study, a greater correlation was observed at the University of Miami (28) where it was found that in 29 of 40 cases, some form of traffic engineering hazard, as related to the accident, was noted. Boston University investigators (29), in a study of fatal collisions, concluded that there was a contribution to auto fatalities of poor highway illumination, curbing design, standard pole construction, lane demarcation and median barriers.

Further study of these and other factors leading to the refinement of our present laws and design standards may serve effectively to minimize highway fatalities. The U.C.L.A. team (30) concluded their report with the statement that, at the present time, the state of the art of environmental analysis needs a great deal of specific information concerning individual cases.

All of these data were not employed to prove that environmental factors caused all motor vehicle accidents, but rather, to show that environmental factors play a significant role, both as a contributory cause and as a severity increasing factor.

At the time of this writing, most accident research and the resulting safety standards have been directed toward selected vehicular factors. As pointed out earlier, this philosophy concedes the occurrence of the accident and has as its thrust, injury control through improving the crash worthiness of the vehicle. The environmental factors which may have contributed to accident causation have been virtually ignored.

Due to the lead time required by manufacturers to effect design changes, the life span of the vehicle after manufacture, and the reluctance of regulatory authorities to require post-production addition of safety equipment, improving highway safety through vehicular modification is, at best, slow. On the other hand, minimization of the environmental factors in accidents has as its philosophy the prevention of the accident. Logically, contributory environmental factors can be identified and eliminated in a much shorter time frame.

Clearly, more in-depth research is necessary to isolate these specific hazards and remedy them in an effort to decrease the public health problem identified as motor vehicle accidents.

CHAPTER II

LITERATURE REVIEW

The Transportation System

At locations where the roadways are wide and straight and where traffic volume has been low, accidents have been rare. Unfortunately, urban areas, by nature, have not met these criteria. The urban transportation problem has become more complicated, with increased congestion, and, as would have been anticipated, an increased number of motor vehicle collisions. The difficulty of the driving task has continually increased, as is evidenced by unusually high urban accident rates. These increased rates have paralleled an increase in the severity of environmental conditions. As greater demands have been placed on driver ability, human error has increased disproportionately (31). One of the essential causative factors, at least in urban accidents, has been the failure of the transportation system itself. Drivers, subjected to constant stress and conflict, with complicated decisions and maneuvers to make, have misjudged or misinterpreted environmental conditions or hazards with the inevitable result of an avalanche of motor vehicle accidents, injuries and fatalities.

Within any urban area, driving conditions vary from one location to another, but accident rates have always been consistently high at intersections. Table 4 illustrates the increase in the number of inter-

TABLE 4

PERCENTAGE OF TRAFFIC ACCIDENTS BY

INTERSECTION/NON-INTERSECTION*

Year	All Accidents			
	Intersection		Non-intersection	
	Number	Percentage	Number	Percentage
1968	24,682	41.6	34,602	58.4
1969	22,513	35.3	41,308	64.7
1970	27,820	41.9	38,637	58.1
1971	32,528	50.1	32,400	49.9

* Data obtained from the Oklahoma Department of Public Safety.

section collisions in Oklahoma City from 1968 to 1971 at which time they finally surpassed non-intersection collisions (3).

Intersections have been defined as the area shared by two or more roads. The primary operational function of the intersection is to permit a change in travel route. Because of this, the intersection becomes a point of decision. The motorist has to decide on one of the available alternative choices. Thus, an intersection presents the driver with added tasks not required at non-intersection points on the road (18).

All intersections have not been equally dangerous with equally high accident rates. The number and type of accidents at these locations have been strongly influenced by the type of intersection, the individual details of design, the volume of traffic and the control devices used (15). For example, Taylor (32), in the early 1930's found that three-way intersections consistently had lower accident rates than four-way intersections.

Staffeld (33), in a study conducted in the early 1950's observed similar results. This was reasonable since intersections represent pairs of discontinuities which present additional hazards to highway travel (8). The more complicated the intersection, the more hazardous and the higher the number of automobile collisions. Therefore, if intersections were simplified, the conflicts reduced and the hazards removed, the number of accidents could be reduced considerably.

Two alternative approaches to solving the problem of urban transportation have been put forth as a result of the annually increasing traffic volume and the already over crowded city streets. The first approach, which actually contains many different possibilities, has come to be known as mass transportation or mass transit. High-speed mass transit systems, such as commuter railroads, subways, or even monorails, could be built relatively easily and inexpensively to relieve the congestion and keep the cities from choking (34).

Most cities have been reluctant to invest in such a major departure from the American philosophy of each individual driving his own automobile, so the second alternative, that of modifying and improving our present transportation network, has gained more popular acceptance. For an urban road network of a given capacity, which has been subjected to a certain demand level, it is theoretically possible to exert direct control over these complex flow patterns in such a manner as to optimize some index of performance. The capacity of the network could be regulated or increased by:

a) modification of existing roads,

b) construction of new roads,

c) use of smaller or more efficient transport units and

d) the direct control of traffic movement (35).

Many traffic researchers have focused their attention on various design aspects of the urban transportation system with particular emphasis on intersection operations. By making traffic movements more fluid and by creating fewer conflicts and reducing confusion at these intersections through the use of improved signs and signal devices, it was thought that intersection traffic accidents could be reduced by a significant amount.

Day and Time Relationships

Two of the first environmental factors which received study were day and time relationships. Collisions did not occur randomly throughout the week, but rather, they peaked during the Friday-Saturday time period. As may be seen in Table 5, an average of about 13.1 per cent of the

TABLE 5

PERCENTAGE OF TOTAL ACCIDENTS BY DAY OF WEEK*

Year	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.
1968	13.5	13.4	13.5	13.2	16.8	18.0	11.7
1969	13.5	12.5	14.2	13.4	17.4	17.1	11.9
1970	14.0	13.2	13.2	14.3	17.1	17.1	11.1
1971	13.6	13.4	14.3	13.9	17.3	16.7	10.8
Annual Average	13.6	13.1	13.8	13.7	17.2	17.2	11.4

* Data obtained from the Oklahoma Department of Public Safety.

accidents have occurred on each of the days Sunday through Thursday, while the rate rose to 17.2 per cent for Friday, and the same for Saturday. Table 6 shows an even more pronounced increase in the per-

TABLE 6

PERCENTAGE OF TRAFFIC FATALITIES BY DAY OF WEEK*

Year	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.
1968	10.8	9.8	10.5	12.8	12.5	22.5	21.1
1969	10.8	9.5	12.2	12.8	16.4	19.8	18.5
1970	9.2	9.6	12.4	14.8	15.8	20.6	17.6
1971	10.3	10.0	9.3	15.2	17.2	21.3	16.7
Annual Average	10.3	9.7	11.1	13.9	15.5	21.0	18.5

* Data obtained from the Oklahoma Department of Public Safety.

centage of fatalities during this 48-hour time period, which carried over to Sunday, mainly due to early morning collisions. Figures 1 and 2 on the following page illustrate these findings.

Table 7 illustrates the frequency of occurrence of accidents under different lighting conditions. These data appear to show that the occurrence of accidents in the dawn/dusk period has been in proportion to the amount of time while those lighting conditions existed. The difference between the daylight and darkness figures is believed to be due to the small number of vehicles on the road after dark. A more detailed study of similar data for 1972 (36) (Table 8), showed approximately the same findings. It is a recognized fact that there is a higher accident rate

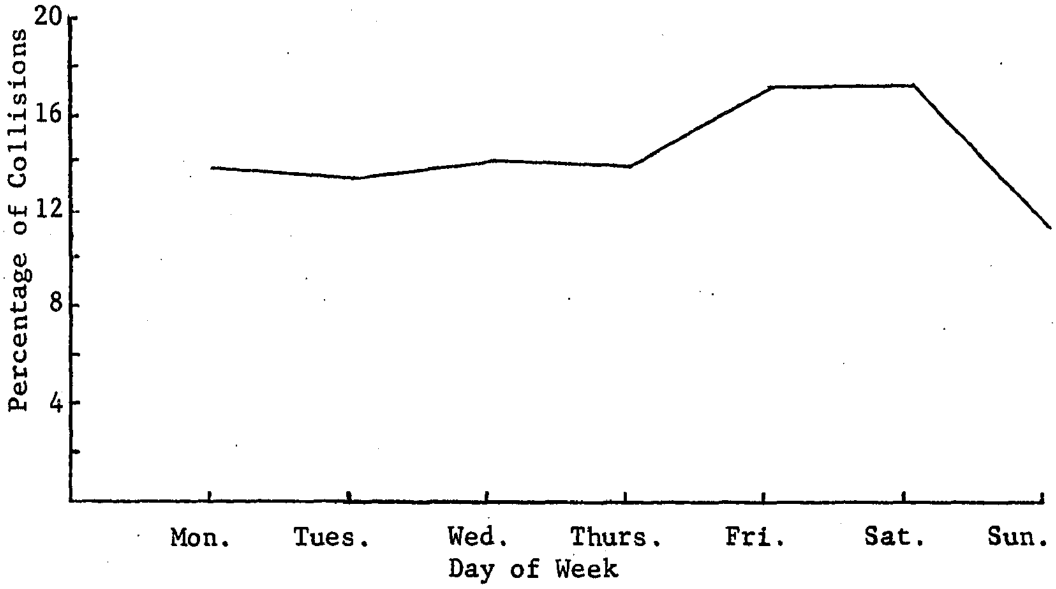

Figure 1. Percentage of accidents by day of week.

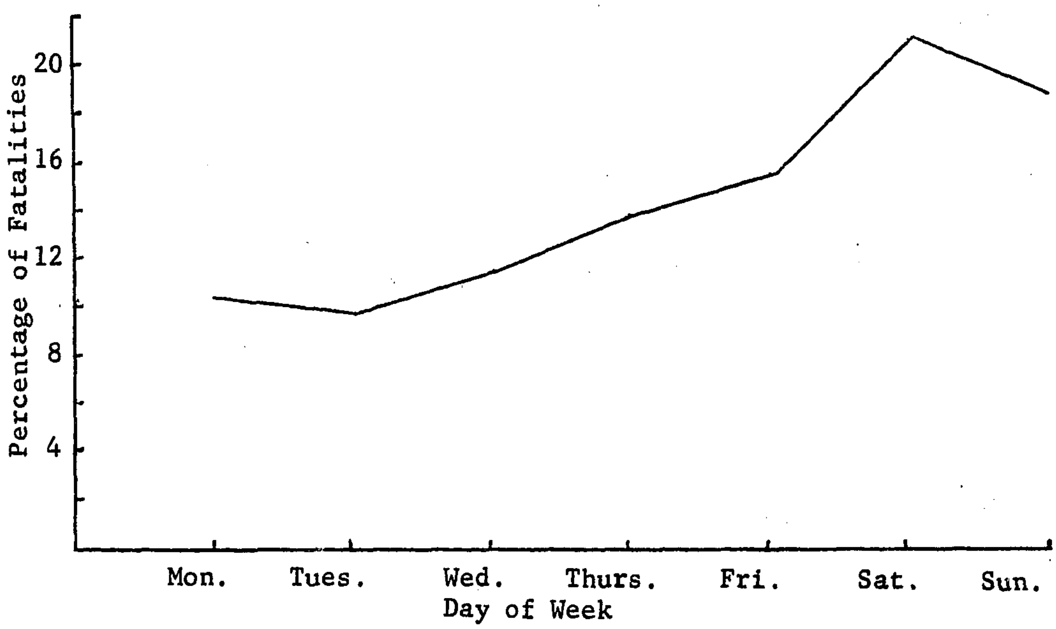

Figure 2. Percentage of fatalities by day of week.

TABLE 7

PERCENTAGE OF TRAFFIC COLLISIONS BY LIGHT CONDITIONS*

Year	Daylight	Darkness	Dawn/Dusk, Etc.
1968	69.5	22.1	8.4
1969	69.8	22.3	7.9
1970	71.2	20.8	8.0
1971	71.5	20.8	7.7
Annual Average	70.5	21.5	8.0

* Data obtained from the Oklahoma Department of Public Safety.

TABLE 8

PERCENTAGE OF TRAFFIC ACCIDENTS BY LIGHT CONDITIONS - 1972

Light Condition	All Accidents	Fatal Accidents	Non-fatal Injury Acc.
Daylight	12,388	35	2,079
Dawn or dusk	543	5	113
Darkness	3,583	41	928
Not stated	61	0	45
Totals	16,575	81	3,165

after dark, based on actual vehicle miles traveled by the smaller number of motor vehicles operating during this time period. No data were available on the number of vehicle miles driven in Oklahoma City after dark; therefore, this relationship could not be studied more precisely. The lighting condition is just one environmental factor that has affected accident occurrence.

As shown in Table 9, accidents have also occurred with different

TABLE 9

PERCENTAGE OF OKLAHOMA TRAFFIC ACCIDENTS BY TIME OF DAY*

Year	12:00 3 AM	3:01 6 AM	6:01 9 AM	9:01 Noon	12:01 3 PM	3:01 6 PM	6:01 9 PM	9:01 Mid.
1968	6.3	2.6	10.7	13.3	16.9	25.4	14.8	10.0
1969	5.7	2.4	10.6	12.8	17.3	26.3	15.2	9.7
1970	5.4	2.3	10.4	13.4	18.0	26.6	14.5	9.4
1971	5.0	2.2	10.5	13.6	18.2	26.4	14.6	9.5
Annual Average	5.6	2.4	10.5	13.3	17.6	26.2	14.7	9.7

* Data obtained from the Oklahoma Department of Public Safety.

frequencies at different times of the day. There has been a general trend of increasing accident rates from before dawn through the evening rush hour, and then a gradual decline from then to the early morning hours. Figure 3 shows a detailed summary of accident occurrence by time of day and day of week combined, for the year 1972. The peaks are in line with data already discussed.

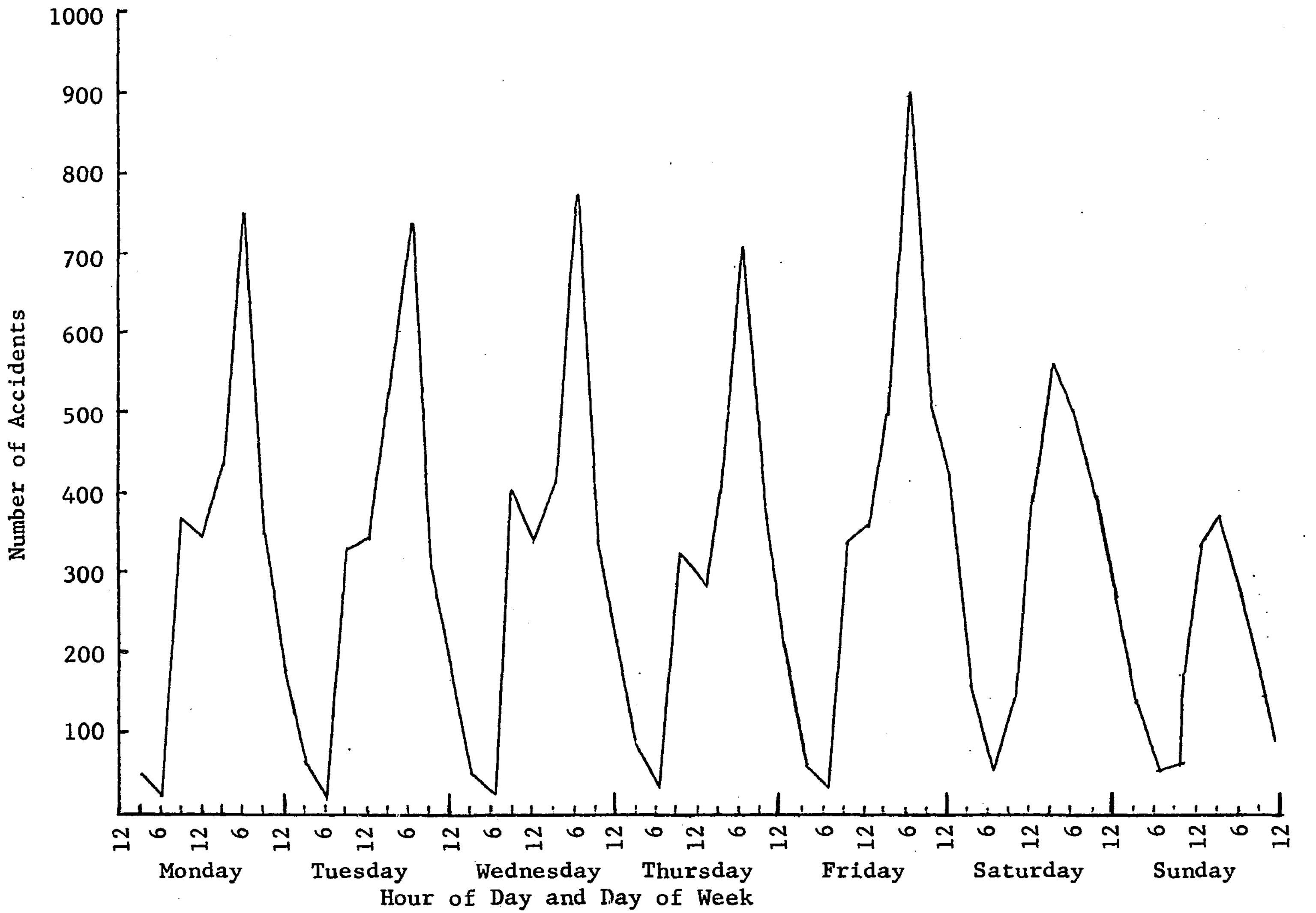

Figure 3. Number of accidents by time of day and day of week.

All of the afore mentioned data clearly indicate that accidents have occurred most frequently when the number of vehicles on the roads was large. Traffic volume, especially with regard to intersection collisions was also an important determining factor.

Traffic Volume

When there were few vehicles on the roads, collisions were much less frequent. As city streets have become more crowded, particularly at intersections, the number of collisions has increased rapidly. This relationship between increasing volume and increasing collisions has not been linear.

Although it is known that collisions are related to traffic volume, Vey (37), in the 1930's, discovered that the number of accidents per million vehicle miles increased with volume up to about 7,000 vehicles per day, then decreased with further increases in volume. The results of this study were later substantiated by Raff (38), who found a similar relationship with a break in the curve at slightly under 9,000 vehicles per day. At traffic volumes greater than these values, it was found that congestion reached a point where vehicle movement was slowed considerably and the number of accidents declined.

Researchers found that this relationship is further complicated by intersection and road design. Millard (39) observed that congestion was rarely due to a lack of road capacity, particularly at junctions where conflicting traffic movements produced approximately 70 per cent of London's traffic accidents. In a related study, Jorgensen (40) noted that Connecticut highways which met modern design standards had lower accident rates than those of all highways in the same traffic volume groups. If intersections were designed safely to limit conflicting movements, large traffic volumes could be handled with relatively few collisions.

Pavel (41) suggested that, in order to obtain a realistic picture of traffic conditions at any particular time, several flow parameters were relevant. These were:

a) number of vehicles per unit time,

b) vehicle density on the street section supervised,

c) average vehicle speed,

d) vehicle categories,

e) vehicle presence and

f) the degree of occupancy of a street.

The central problem confronting urban transportation planners has been of moving large volumes of traffic through a system of streets and intersections. Too often, these streets and intersections have been and continue to be antiquated and in need of major repairs and renovations. Many methods have been developed to control and guide the masses of vehicles through these street systems, while reducing the number of collisions at the same time.

One-Way Streets

One-way streets have a number of characteristics which would enhance highway safety. First, there are fewer points of potential conflict at intersections. Second, with no opposing traffic, the chances of head-on and sideswipe accidents are virtually eliminated. Third, turning vehicles can be passed, thereby reducing the possibility of rear-end collisions. Fourth, and perhaps most important, signals can be timed for progressive movement, reducing the number of stops and keeping the vehicles in orderly groups, with well defined intervals between groups for pedestrian and vehicle crossings (15).

One-way streets have been used with a great deal of success in Oklahoma City. By designating alternating downtown streets as one-way, either north or south, not only have there been fewer accidents, but traffic flow has improved greatly, allowing much faster access to, and egress from, the downtown area.

Other major cities have employed one-way streets extensively, particularly where old and narrow streets were not able to accommodate large volumes of two-way traffic. However, one-way streets were not always possible, so other methods had to be devised to control conflicting traffic on two-way streets. In most cases, these have not been extremely successful in limiting automobile collisions, as evidenced by the large number of high density accident intersections.

Speed Limits

Speed was once thought to be a prime factor in accident causation, and has been clearly demonstrated to be a definite injury severity increasing factor. In every case for which information was available, the imposition of a speed limit in an urban area was followed by a reduction in serious injuries in other areas (5); however, its relation to accident causation was far more complicated. Speed limits have been imposed on most roadways as a safety feature, but this action itself has contributed to the cause of many collisions, as a result of a lack of forethought on the part of those who determined the speed limits.

The problem which arose from establishing speed limits was that their values were of an arbitrary nature, often providing drivers with a false sense of security and safety, simply because they were driving below the speed limit. It was found that, all too frequently, drivers thought that, just because they were driving at a slow rate of speed in vehicles they presumed to be in good condition, they were safe. Actually, these people produced more accidents than the faster drivers.

For speed limits to be effective at both providing an even traffic flow and preventing accidents, it is necessary that they be set according to environmental circumstances. Any speed limit is reasonable only for the roadway and traffic conditions for which it is set. Since this has been generally for fair weather and off-peak volumes, it has been unreasonably high for extreme weather and traffic conditions, and low for more favorable conditions. Speed limits based on studies of the prevailing speeds, the character of the road, the extent and character of development along the margins of the roadway and the accident history of the roadway have tended to reduce the spread in speeds, from the highest to the lowest, and thereby have resulted in a smoother traffic flow. This smoother flow has resulted in a reduction of accidents (15).

The traffic engineering handbook recommended four basic factors to be considered in establishing speed limits: prevailing vehicle speed, physical features of the road, accident experience and traffic characteristics and control (42). Variable speed limit signs have been in use for some time; however, their use has been largely limited to turnpikes and school zones. Utilizing signs of this type on other urban streets would most likely have a beneficial effect on traffic flow as well as accident reduction.

Auxiliary Lanes

In addition to regulation of speed, the creation of auxiliary lanes has aided greatly in establishing a smoother traffic flow through intersections. One of the fundamental causes of traffic difficulties has been the difference between the speeds of vehicles operating in the same lane. Since at most intersections it is necessary for the drivers to slow down to turn off the roadway, and equally necessary to make the turn at a slow speed, special provisions have to be made for these functions (9).

Normally, the first concern of engineers in providing lane channelization has been to aid those drivers in making a left or right-hand turn. The advantages of such a system also include better flow for through traffic and protection from drivers who have to deviate from the average traffic speed to turn onto or off of a roadway (42). Rear-end collisions have traditionally been the most numerous at intersections, particularly with regard to the through traffic. The number of this and all other types of collisions have been reduced by redesigning intersections to include some form of auxiliary lane configuration.

A study conducted by Thomas (43) in Denver involved a section of Federal Boulevard which contained 48 intersections, 12 of which were traffic signal-controlled. Accident records were compared for the years 1961 and 1963, those immediately preceding and following the channelization project. As left-turning motorists were removed from the through lanes, the through traffic was able to move smoothly along the street, as evidenced by the 52 per cent decrease in rear-end accidents at previously non-channelized intersections. There was also a savings of $151,200 in accident costs for the year 1963.

In a similar study in Arizona, Crossette and Allen (44) showed the value of painted channelization and signal synchronization. Painted channelization was installed throughout the study section of roadway to provide a 16-foot painted median and four 12-foot travel lanes. As a result, traffic volume in this 14-block distance was increased 19 per cent from 17,800 to 21,100 vehicles per day. Total accidents were reduced 41 per cent from 100 to 59 the next year and injury accidents were decreased a total of 58 per cent.

Left turn lanes have been designed in several different ways. Medians have been used to separate left turn lanes from oncoming traffic, as have curbings and other channeling devices. The most common type has been simply an extra lane with pavement markings indicating left turn only. At more complicated or highly traveled intersections, lane channelization has not been the entire solution to left turn and rear-end accidents. As left turn accidents and the problems of left turn flow increased, the second stage of left turn protection usually involved the installation of left turn signal phasing (45). A study in Los Angeles County examined comparative accident experience of intersections with special left turn lanes in the median but no special signal phase, and intersections with both features. The results indicated that the turning accident rate at those without the special signal phase was three times as great as the rate at intersections having both (46).

Provision of a special left turn phase in the traffic signal sequence has brought about a longer delay at the intersection for through traffic. Surveys have indicated that most drivers were willing to accept an additional 3-to 5-second delay at an intersection for the safety and convenience of a left turn phase (45).

Right turn channelization has also been employed to a lesser extent, particularly at intersections with a high traffic flow and pedestrian movement. These right turn lanes have often been employed in conjunction with signs allowing motorists to make a right turn on a red light, further improving intersectional traffic flow. Accidents under these conditions were far fewer than would be expected based on right turn traffic volume.

These special turning lanes have been found to reduce delays, rear-end collisions, and turning accidents, and they have added to roadway capacity at intersections. The separation of left turning traffic into a distinct lane, clearly indicating the intent of those vehicles, has eased the danger of the crossing and diverging conflicts (18).

Roadway Markings

Roadway markings have been employed primarily for one specific purpose, to provide channels within which a motor vehicle could operate without coming in contact with another motor vehicle. Many colors have been used to signify different conditions to motorists. Conner (47) found that from both motorist surveys and scientific experiments, color was the one factor that motorists first noticed and recognized in road markings. As a result, entire lanes have been painted at some locations to indicate exit ramps or slow dangerous areas. The use of colored pavement has been somewhat experimental. The most common uses of pavement markings has been as center lines and lane dividers, and less frequently, as road edge markings.

Lane markings have been very effective in reducing accidents of all types. Although few studies have been done in this area, Prisk (48) reported that placing lane lines on the roadways of the Pentagon network resulted in a 33 per cent reduction of accidents.

The effectiveness of pavement markings is directly related to their visibility. In daylight, under normal conditions, the lines are usually quite visible, but after dark, or when the pavement is wet, they often become invisible. As a result, many types of paints and plastics of a reflective nature have been studied.

To reduce the risk of accidents, traffic engineers in Cleveland installed thermoplastic lane marking stripes containing reflective glass beads. The expected life of the thermoplastic was between 3 and 6 years, depending on street traffic volume and pavement type. One year after installation on a length of heavily traveled roadway, the thermoplastic markings were clearly visible, while on a similar length of roadway, the paint had almost entirely worn off. The perma lines were considerably more expensive, but it was estimated that if they lasted four years, they would be economically competitive with paint (49).

Wet pavement has always made it difficult to see markings on the roadway. The heavier the rain, the more obscured these markings have become. After much experimentation, the State of Florida Road Department (50) has applied waterproof glass beads to mark 15,000 miles of center lines and 8,000 miles of edge lines. The difference between these beads and the older type became more and more outstanding as the water on the pavement was increased. When the pavement was flooded, the waterproof bead line remained visible, while the standard line was ineffective as a marking.

In England (51), 80 to 90 per cent of their road lines have been marked with a similar thermoplastic material, which has superior visibility characteristics. In West Germany, where a reflectorized plastic material was applied cold, it was found that this material not only lasted as long as the thermoplastic, but it was not as sensitive to temperature changes (52). Unlike England and West Germany, engineers in the Netherlands (53) found paint, including reflectorized glass beads, to be adequate for their roadway conditions; however, they also advocated the use of thermoplastic strips.

In several studies, including one by Basile (54) of the Kansas Highway Commission, road edge markings, which were not used as extensively as lane markings, have been shown to be an equally valuable safety feature, and have proven quite effective in preventing motor vehicle collisions. The Kansas study included some 20 sections of Kansas highway, totaling approximately 200 miles, and showed a 21 per cent reduction in total accidents, a 26 per cent reduction in personal injury and a 59 per cent reduction in fatalities, attributable to pavement edge markings of two-lane highways of 20-foot width or more.

Other types of pavement markings, including arrows and printed instructions, have also been used. When these markings were of a high visibility material, they were effective in reducing motor vehicle collisions.

Signs and Signals

Signs and signals have been among the most important segments of the intersection, and have been commonly grouped together as traffic control devices. They have traditionally served in three basic capacities: as warning devices, regulatory devices and information guides. Their objectives are to promote an orderly traffic flow, reduce accidents, permit the safe movement of cross traffic and cost less than grade separation. They should never invite accidents (55).

As the transportation system has become more crowded and complex, the number of road signs has increased drastically. The objectives of these signs are to promote traffic flow and enhance safety. In many cases, the opposite has been true, and improperly placed or worded signs have confused drivers and contributed to the causation of a large number of traffic accidents. When road signs are unintelligible, the driver hesitates - and a hesitating driver is a hazard (56). Hulbert (57) noted that humans could learn to negotiate even complex systems, providing certain basic principles were used to provide them guidance information. These included: interpretation, continuity, advance notice, relatability, prominence and unusual maneuvers. Most of the signs that have been employed not only have fallen short of these criteria, but have incorporated negative characteristics into their design and placement.

As recently as 1969, less than 50 per cent of the signs on our nation's roadways complied with nationally adopted standards. On roads built without federal aid, less than 20 per cent of the signs met national standards (58). In a state-wide survey, the Tennessee Department of Highways (59) inventoried some 400,000 official signs. Of these, only 44,000, or 10 per cent, were judged to be even adequate in wording or location. Of the remaining 90 per cent, some were labeled as unnecessary, some were removed altogether, some were replaced and over half of them were replaced and repositioned.

Another study in Costa Mesa, California, involved a program of night inspection of the roadways for environmental hazards. It was reasoned that traffic signs which were readily visible during the day might not be so after dark. In the first year, this program uncovered 300 dangerous conditions. These included such hazards as signs obscured by overgrown and poorly placed shrubbery, reflectorized sign surfaces that no longer reflected the message adequately, sign posts and signs allowed to remain in damaged condition (60).

The problems with many existing signs include print too small to read at great distances or at high speed, too many words on one sign to be read at high speed, signs not lighted or reflectorized, signs too dirty to read, signs badly damaged or completely missing, some obscured by overgrown trees and other obstructions and many not clearly visible due to conflicting commercial signs and lighting.

Over the past few years, the United States has converted many of its road signs to the international system which employs a system of pictures which are, therefore, easier for motorists to perceive and involve no reading. These new signs have been used primarily on major highways, and most intersections have retained a cluster of unnecessary and confusing signs.

Safety engineers have found that people react differently to what they see at various speeds and under various conditions (61). Signs had to be designed for the particular environmental situation into which they were to be placed. Equally important as the type of sign is the placement of it, so as to be in the most readable position for the driver. The mounting position is dependent to an extent on the type of lighting available. Straub and Allen, as cited by Forbes (16), found that a mounting position 5 feet to the right and 8 feet above the pavement was the most effective, and that overhead mounting was the least effective.

Traffic engineers have even gone to such extremes as using candy-cane striped poles for stop signs in an effort to make them more visible to drivers. In one study, a "before and after" survey showed a marked decline in the number of drivers failing to stop at stop signs with these special poles. It was also reported that accidents at these intersections had declined (62).

Traffic signals have been used for many years as the primary means of controlling intersection traffic. For the most part, these signals have been installed when an intersection became congested due to a heavy traffic flow. Little thought was given to many other variables which affected the placement and function of traffic control signals.

Traffic signal systems have raised the traffic output of intersections, enhanced safety and facilitated an orderly traffic flow by establishing distinct time relationships and displaying clearly discernable signals (41). Properly installed traffic control signals involve four areas of operation:

a) provision for orderly movement of traffic and increase in the traffic-handling capacity of most intersections,

b) reduction of certain types of accidents - most notably the right angle collision,

c) provision for a substantial flow of vehicular traffic at a reasonable speed along a roadway when coordinated with each other and

d) provision for safe crossing of heavy traffic (18).

Few traffic signals have met these criteria. Much research has been devoted to developing appropriate signals and solving intersectional traffic flow problems.

The selection of the proper signal, its placement and phasing have had to be determined either on an intersection by intersection basis or on an intersection system basis. Too frequently, signals to control vehicular movements have been placed randomly with less than satisfactory results. In fact, little study has been undertaken to determine whether a traffic signal is even the best form of control for a particular intersection.

Intersection accidents have been classified into distinct categories, each having a common set of causative factors. Improvements in design or control have usually been directed toward a particular type of accident. A multiple approach is necessary to reduce all types of collisions. It is first important to know how many and what type of collisions have occurred. As may be seen in Table 10, which shows types of intersection accidents by frequency of occurrence, over half of the intersection accidents in Oklahoma City in 1970 have been angle collisions. Nearly 20 per cent were rear-end collisions involving two vehicles traveling in the same direction and over 10 per cent resulted when one vehicle was turning left and one going straight in the opposing direction (63).

In many studies, the key to traffic control at a particular intersection has been found to be the volume of traffic handled by the intersection. Vey's (64) studies showed that traffic control signals by no means resulted in fewer total accidents, although they did reduce certain

TABLE 10

TWO-VEHICLE INTERSECTION ACCIDENTS - OKLAHOMA 1970

Type	All Acc.	Fatal Acc.	Non-Fatal Injury Acc.	Property Dam. Accidents
1. Entering at angle	3809	23	897	2889
2. From same direction				
a. Both straight	443	0	35	408
b. 1 straight-1 turn	508	0	41	467
c. 1 stopped	1363	0	196	1167
d. All others	44	0	5	39
3. From opposite dir.				
a. Both straight	101	1	29	71
b. 1 straight-1 turn	926	0	202	724
c. All others	54	0	3	51
4. Not stated	0	0	0	0
Totals	7248	24	1408	5816

kinds of accidents. Generally, after signalization, right angle collisions and others involving vehicles on crossing approaches showed a drop, while rear-end and turning collisions between vehicles on the same street increased. Other studies have shown that many of these rear-end and turning collisions could be avoided by the installation of channelization and special turning intervals.

A study by Solomon (65) in Michigan, involving 39 intersections, showed that after signalization, total accidents actually increased. He noted however, that accidents decreased at complex intersections and at intersections with high traffic volumes. He also observed that there were fewer people killed or injured at these intersections.

Syrek (66) conducted a study comparing the effectiveness of four-way stop signs with traffic signals at high and low volume intersections. He found that four-way stop signs showed a lower accident rate when the traffic volume for the minor street was 7,000 vehicles per day and for the major street was 8,000 vehicles per day. At high volume intersections where the minor street volume remained the same, but the major street volume increased to 15,000 vehicles per day, the traffic signals proved to be considerably safer than four-way stops. The results of this study are presented in Table 11.

Since the invention of the traffic signal, there have been many adaptations and revisions in this traffic control device. There have been many features, besides the sequencing itself, that have led to smoother traffic flow and fewer accidents. The simple prohibition of left turns at an intersection all but eliminated left turn accidents, and drastically reduced rear-end collisions. Ray (67) found that the employment of right-

TABLE 11

ACCIDENT RATES PER MILLION VEHICLE MILES FOR

HIGH AND LOW VOLUME INTERSECTIONS

	Low Volume 8,000 major-7,000 minor		High Volume 15,000 major-7,000 minor	
	4-Way Stop	Signal	4-Way Stop	Signal
Right angle	.35	.30	.44	.30
Rear-end	.14	.19	.34	.19
Left turn	.07	.17	.07	.17
Totals	.56	.66	.85	.66

turn-on-red signs, in conjunction with traffic signals, reduced right turn accidents in comparison to right turn traffic volume.

Adjustments to the signals themselves have produced favorable results. By employing more signal faces at the intersection, and by increasing the size of each light, visual perception was improved. Larger flashing signals, measuring 1 foot in diameter, have been installed at crosswalks in Los Angeles. These flashers have also been provided with 2-foot wide back plates allowing the flashing light to become more visible (68).

Even the position of the signal has been important in reducing intersection collisions. The modernization of 25 Detroit intersections with mast-arm suspended signals and new pedestrian signal indications resulted in a 78 per cent reduction in angle collisions and a 33 per cent reduction in pedestrian accidents (69).

In the past, many angle collisions in particular have revolved around the length of the amber or yellow phase of the signal cycle. There are regions approaching the intersection from which the motorist has to either brake sharply, or enter the intersection at the risk of a collision with cross traffic (8). This has resulted primarily from the traffic engineer's rule of thumb for setting the amber phase to allow 1 second for every 10 miles of approach speed. Generally this has taken into consideration only stopping distance, not the width of the intersection nor the length of a vehicle and its acceleration and stopping characteristics coupled with driver reaction time (70). In short, many signals do not allow a sufficiently long amber phase for all traffic to come to a safe stop. The use of an all-red period of a few seconds has also been successful in reducing angle collisions. A study of 12 intersections over a 24-month period showed a 41 per cent reduction in injury accidents as a result of the installation of the all-red phase (8).

At complicated intersections, the installation of signals without conflicting indications has become increasingly difficult. Drivers approaching such intersections have become confused and slowed down, immediately creating a traffic hazard (71). A solution to this problem has been found, but has not yet been used extensively in many cities. A method has been developed to channel the signal's light to a specific roadway area, thereby reducing driver confusion. This optical device has been developed to allow clear visibility for all relevant lanes - even around curves - but appears dark to motorists in lanes not governed by this signal (72).

The promotion of smooth traffic flow and reduced accidents has often required more than a single signal at one intersection. It has become necessary to tie together series of intersections with coordinated signal phases, allowing a group of vehicles traveling near the speed limit to reach all of the lights while green, and thus provide a smoother traffic flow. Allsop (73) found that when neighboring intersections in a network of roads were controlled by traffic signals, delay to traffic in the network could be reduced by linking the signals so that as many as possible of the vehicles released by one signal reached the next during the green period. Furthermore, some of these systems have been tied into computer networks allowing the changing of the signal phases depending on traffic conditions. Some of these systems have even made use of closed circuit television to check traffic conditions from minute to minute and adjust the signal phases appropriately.

Los Angeles traffic safety engineers recently placed in operation the fourth in a series of interconnected traffic signal systems. This marked an important step forward in a vast master control supervision system that would, by 1974, tie together all principal signalized intersections within the city (74). San Jose, California researchers have also tested the effects of a digital control system, and evaluation studies have indicated that measurable improvements in the traffic flow through the system have resulted (75).

Charleston's traffic controllers have instituted a similar program of moment to moment signal variation, and also included a data bank to compile information on traffic patterns for use in long range planning. Their initial system included control over 90 intersections, and expected results included an estimated 25 to 35 per cent rise in rush hour traffic flow and increased car speeds of 10 to 20 miles per hour (76). New York traffic experts have also begun using a similar system dividing the city into 19 major traffic control areas, which receive their information from a number of control sensors placed throughout the system (77).

The proper use of traffic control signs and signals has been a very complicated one. Every intersection has had to be treated separately, depending on its particular environmental conditions; yet such intersections have had to be coordinated in series in order to provide the most efficient traffic flow and safety. Most cities have not modernized their traffic control system to cope with the increasing traffic volumes and accident rates.

Roadside Billboards

Even at many appropriately signalized intersections, accident rates have remained high due to the confusion created by the competition for the driver's attention. In commercial areas, where advertising signs and store window displays have been designed to attract the eye, this problem has become most acute. This has been particularly true on wide streets (two or more lane approach) where a signal post-mounted on the corner might be out of the driver's cone of sharp vision. If the signal had been made more competitive visually, accidents might have been reduced. Based on an accident history of 68 Los Angeles intersections at which signal visibility was improved, it was concluded that this type of improvement had a significant effect in reducing the most prominent types of accidents at urban signalized intersections and would, therefore, have a high payoff in relation to the relatively low cost of the improvements (78). A Vermont study showed that policies on off-premises outdoor advertising in its present form was distractive to the motorist (79).

The visual clutter provided by these roadside signs and other extraneous lighting undoubtedly interferes with the driver's view of traffic signals, as well as his perception of the roadway itself.

Visibility and Illumination

In order for a driver to maneuver his vehicle safely from one point to another, it is necessary for him to have a favorable environment which would allow him to operate his vehicle safely within the limits of his vehicle's turning and handling capabilities and his own motor response characteristics. For him to negotiate this roadway, it is necessary for him to be able to see the features of the roadway, as well as the roadside characteristics. When considering visibility, the separate factors of physical obstruction of view, inadequate illumination and interference all are part of this category (8).

Intersections have proven to be very complex problems in this respect. They require adequate visibility on all roadways, ramps and areas of speed change (80). Visibility obstructions include such common roadway features as guardrails, walls and fences, trees and shrubs and parked and moving vehicles. Many of these visibility obstructions have also been significant in increasing the severity of collisions. These include such roadside hazards as bridge abutments and piers and lighting and utility poles, in addition to those already mentioned.

Many roadside signs and poles have been placed within 3 feet of the roadway. Any vehicle straying from the roadway might have become involved in a collision with one of these fixed objects before the driver had time to recover control of his vehicle, and return it to the roadway.

Many of these hazards could have been removed, or at least set back further from the road. In cases where this was not possible, or where dangerous ditches and embankments were located, guardrails could have been installed, or the roadway could have been redesigned for safer travel.

The second aspect of visibility is illumination. Studies have shown that unlighted highways were far more dangerous and had higher accident rates than lighted ones. This has been particularly true with the over 40-year old driver. Middle aged and older motorists have been involved in three times as many accidents resulting in injuries, when driving unlighted roads (81).

A study by Rex cited in The State of the Art of Traffic Safety (8), showed that illumination of 31 miles of main thoroughfare in Detroit reduced the night-to-day fatality ratio from 7 to 1 to 1.25 to 1. Similar findings were reported in a 1948 study by Marsh, cited from the same source (8), for New Jersey and San Francisco.

In Chicago, a well lighted stretch of expressway had a death rate of only one-third the average for all American expressways. A study in Indianapolis showed that auto fatalities dropped 54 per cent after a new lighting system was installed. In Virginia, improved lighting at nine "high accident locations" cut accidents by 38 per cent and fatalities by 90 per cent (82). The need for good lighting was particularly critical at intersections due to the heavy traffic load and the conflicting situations found at these locations.

The third aspect of visibility, glare, has been the most difficult to control. Glare is produced by a number of factors, particularly weather conditions, bright sunlight, reflection from roadside lighting and the headlamps of oncoming vehicles. Tinted windshields have shown some merit in reducing this glare but there also are some highway design practices which could reduce much of the glare produced by artificial roadway lighting. The mounting of street lights higher above the roadway, often over 100 feet, reduces the angle of reflection which reduces glare and provides more even illumination of the roadway and roadside areas. Certain surfacing materials have been found to improve roadway visibility by reducing the glare from headlamps of oncoming vehicles.

Lane Widths

Lane width has played an important role in determining traffic flow and safety. Narrow lanes found in most urban areas were not built to accomodate the larger cars of today. On these older roads, there is a smaller margin of safety with regard to the amount of deviation allowed a vehicle before it collided with the vehicle in the adjoining lane. Current design standards permit lane widths of less than 12 feet but researchers have indicated 12 feet to be a desirable width for roadway lanes (8).

In many urban locations, this problem has become impossible to solve. The right-of-way on which most roads were originally constructed were not wide enough to allow improvement of the road width and the roadside area (12). This problem has become particularly critical at busy urban intersections where increased traffic volumes have necessitated wider and more complicated intersections.

Road Surface

The road surface has always been one of the most important segments of the transportation system. The vehicle has to travel on the road surface and its properties have affected the economy, comfort and safety of motor travel. The surface can be smooth, providing comfort, but having a low coefficient of friction or it could be rough and uncomfortable but provide good traction.

The primary role of the road surface in accident causation has been through skidding. Skidding occurs either before or after the application of the brakes, and quite often, both before and after the brakes are applied. Shelton (83) studied highway accidents in Virginia, and determined that 40 per cent of all accidents reported in 1 year involved skidding. In about one-third of those cases, skidding occurred before brake application. It was reasoned from this study that skidding was a contributing factor in accident causation.

A study of accidents in London revealed that about 70 per cent occurred at or within 20 yards of road junctions. It was also found that, due to the polish from the wheels of braking, turning or accelerating vehicles, the skid resistance at these sites fell off sharply as the junction was approached (84).

In Detroit, studies revealed that Michigan Avenue traffic was involved in an extraordinary number of accidents, of which about two-thirds were rear-end collisions, at the intersection with Clark Street. This portion of Michigan Avenue, which was paved with brick, was re-surfaced, and the number of accidents greatly reduced. The year before resurfacing, there were 57 accidents at this location, the year after, only 18. The number of accidents occurring while the surface was wet dropped from 32 to 8 (85).

The amount of skidding which occurs on a road surface is directly related to the road's coefficient of friction. Coefficients of 0.6 and greater have provided good resistance to skidding; 0.5 to 0.6 has been rated satisfactory, 0.4 to 0.5 considered generally satisfactory, except under difficult conditions, and below 0.4 designated as potentially slippery (86).

Wet pavement has always been a problem with regard to skidding. Pavements of all types are more slippery when wet. The skidding hazard has been greatest during the first few minutes of rainfall that followed a period of dry weather. Slickness decreases greatly after a continued downpour (87).

Of the 34,390 state-wide total of reported accidents on West Virginia State Highway Systems for 1969, 10,267, about 30 per cent of the total, were at intersections. It was also found that nearly 3,500 of these occurred on wet pavements, and that only about 1,500 of the 3,500 would have occurred in a like period of time on dry pavement (88).

Table 12 shows the minimum stopping sight distances for both wet and dry pavements. Comparison of these values indicates that much longer distances are required for stopping on wet pavement that dry. At 64 miles per hour on wet pavement, over 700 feet is required to stop from the first sign of danger (89). This has created serious problems at intersections where drivers have not been able to stop prior to reaching a vehicle already stopped, or not being able to stop without sliding out into the intersection if front of cross traffic. Improvements in road surfaces

TABLE 12

MINIMUM STOPPING SIGHT DISTANCES FOR WET AND DRY PAVEMENTS

Design Speed	Assumed Speed for Conditions	Perception & Brake Reaction Time	Perception & Brake Reaction Distance	Coefficient of Friction	Braking Distance on Level	Stopping Sight Distance
mph	mph	sec.	feet	f	feet	feet
			Wet Pavement			
30	28	2.5	103	.36	73	176
40	36	2.5	132	.33	131	263
50	44	2.5	161	.31	208	369
60	52	2.5	191	.30	300	491
65	55	2.5	202	.30	336	538
70	58	2.5	213	.29	387	600
75	61	2.5	224	.28	443	667
80	64	2.5	235	.27	506	741
			Dry Pavement			
30	30	2.5	110	.62	48	158
40	40	2.5	147	.60	89	236
50	50	2.5	183	.58	144	327
60	60	2.5	220	.56	214	434
65	65	2.5	238	.56	251	489
70	70	2.5	257	.55	297	554
75	75	2.5	275	.54	347	622
80	80	2.5	293	.53	403	696

in order to increase stopping ability under all conditions and shorten the stopping sight distances, particularly on wet pavement have been needed for many years.

Many substances have been tried experimentally in an effort to increase road surface friction. These procedures have included both resurfacing with a roughened asphalt or concrete, or application of a chemical treatment to the existing road surface.

A study conducted by Hatherly and Lamb (84) evaluated the effect of the application of a resin/bauxite compound to a total of 41 road intersection sites. "Before and after" fatality and injury accidents were compared and it was found that the application of this resin/bauxite material reduced all accidents by 31 per cent. It caused a decrease of 73 per cent in rear-end collisions, the most common type of intersection collision resulting from skidding. Accidents on wet roads decreased by almost 72 per cent and even accidents occurring on dry roads dropped by 7 per cent. The complete results of this study are contained in Table 13.

Another method of increasing friction which was tried experimentally was slotted roadways. This technique consisted of slots running in the same direction as the roadway cut about 2 inches apart into the road surface. The use of this procedure, particularly on sharp curves and high speed roadways has increased greatly in recent years. Little has been done through any of these means to improve the traction in the immediate vicinity of intersections where the danger of a skidding collision has been greatest.

TABLE 13

NUMBER OF ACCIDENTS BEFORE AND AFTER

RESIN/BAUXITE TREATMENT

	Before	After	Percentage Change
Total accidents	288	200	-31
Total casualties	337	258	-23
Accidents on wet roads	105	29	-72
Accidents on dry roads	183	171	- 7
Rear-end collisions	37	10	-73
Loss of control	23	7	-70
Crossing collisions	54	31	-43
Turning collisions	23	18	-22
Pedestrian accidents	76	65	-14
Other accidents	75	69	- 8

Rumble Strips

Rumble strips, which are raised and roughened stripes across the roadway, have been used primarily as a warning device in highway safety. Reductions in accident rates and changes in driver behavior have stemmed from the added visual, audible and tactile stimuli produced by such strips (90). These strips have been used to alert the driver to some particular hazard ahead, often over a hill or around a curve, which necessitated the vehicle stopping or slowing down. They have been quite effective since driver reaction times are generally faster in response to audible and tactile stimuli than they are to visual stimuli. Also, their cost has been low and installation relatively easy.

A study by Kermit (91) involved a T intersection between Third Avenue and Parr Boulevard in Richmond, California. In the 32 months prior to the installation of rumble strips, 15 accidents occurred at the intersection of which 13 were typically overrun in nature. During the 39 months following the installation of these rumble strips, the number of accidents was cut in half. During the next 18 months only two accidents occurred at that location and the common overrun type of accident had completely disappeared.

Improvement Programs

In an effort to make the nation's road system safer, the federal government instituted a set of Highway Safety Standards. As of June, 1972, not a single state had fully complied with all 16 federal standards for highway safety and, in many states, some standards have been ignored completely (92). In the same year, Pyle (93) reported that the state and community highway legislation, which was 6 years old, had only had 57.6 per cent of its specified authorizations actually appropriated.

Through many types of research, the high density accident locations have been identified, and, as a rule, have sharp turns, obstructed vision or hazardous intersections. Defects of this type could have been repaired and saved many lives. This type of roadway improvement has come to be referred to as spot repairs.

Jorgensen and Laughland (10) found that highway safety benefit cost ratios and accident reductions as high as 80 to 90 per cent were possible from spot improvements. As was expected, relatively low cost projects ($20,000 or less) yielded the greatest safety benefit per dollar expended.

Tanner (94) calculated the rate of return on capital investment by comparing the monetary cost of the accidents saved with the capital costs of improvements made at 22 test sites. His results, found in Table 14, also emphasized the value of a program of spot elimination of road hazards.

TABLE 14

RATE OF CAPITAL RETURN FOR ROADWAY IMPROVEMENTS

Type of Change	Percentage Reduction in Injury Accidents	Rate of Return on Capital-Percentage/Yr.
Realignment	80	15
Super elevation	60	70
Improved visibility	65	60

In addition to spot repairs, Baltimore County traffic control specialists have gone one step further. They have proposed a surveillance program to include high density accident areas, and other locations such as sections of roadways with numerous skid marks, where drivers appeared to encounter frequent problems (95). This program was designed as a preventive measure to locate and alleviate road hazards before they proved fatal to some unsuspecting driver.

The federal government has taken an active part in making spot repairs through the TOPICS project (Traffic Operations Program to Increase

Capacity and Safety), which has hoped to achieve its goals through such devices as improved signal systems, channelization, pavement marking, signing, turning lanes at intersections, installation of reversible lanes and control systems, upgrading of highway lighting, provision of bus turnouts and construction of pedestrian off highway grade separations at complex intersections (96).

The first completed TOPICS project in Dover, New Hampshire, reduced by 11 minutes what used to be a 15 minute trip for motorists through a heavily-traveled, 0.6-mile bottleneck. The project cost $103,400 and included such improvements as channelizing two key intersections, adding traffic signals at one, providing curb and gutter for driveway control, widening the bottleneck area from two to four lanes and painting pavement markings (97).

This project made some progress in eliminating environmental hazards, but a more concerted effort is necessary on the part of the state and local governments to attempt similar programs on their own. The environmental factors are one area where man could aid in reducing automobile accidents, injuries and deaths, but in most respects, the states have been very slow to adopt any constructive program in this area of traffic safety.

Human factors are difficult to work with in that many poor drivers can be removed from the roads by various measures, but even good drivers are involved in accidents. Many human factors are instantaneous variables, and not under the control of traffic safety specialists.

Great amounts of time and money have been invested in automobile safety devices which cannot prevent accidents, but only reduce injuries and fatalities. At the same time, these changes take 3 to 5 years to reach the production stage, and persons riding in older vehicles already on the road will never receive the benefit of these safety features.

Environmental research has been greatly limited and underfunded. This is extremely ironic, since improvements in environmental factors are relatively quickly realized in terms of accident prevention. This is in line with the basic principles of public health in promotion of health through preventive measures.

CHAPTER III

PURPOSE AND SCOPE

Automobile accidents are probably this country's most important public health problem and could certainly be considered to be an epidemic. Motor vehicle collisions involve a tremendous financial loss in addition to over 50,000 fatalities and more than 2,000,000 injuries annually.

Much has been learned about accident causation and injury production through research and experimentation. By the application of epidemiological techniques the three key factors in accident studies - the human, vehicle and environment - have been subjected to varying degrees of investigation.

Human factors have proven difficult to evaluate since they involved individual attitudes and behavior which vary with time, geographical region, and socio-economic class. Even good drivers have been involved in accidents, so removal of bad drivers from the roads would only provide a partial solution. The effect of alcohol on drivers has become an important consideration and has continued to increase in importance with regard to automobile collisions. Driver examination and licensing practices have been made more strict in an effort to improve the quality of drivers but human factors are difficult if not impossible for traffic safety researchers to control.

Vehicle factors have been found to play a minor role in accident causation. In only a small percentage of the cases has a component malfunction resulted in a collision. Most research in this area has been directed toward severity reduction through the incorporation of safety features into the vehicle design. This work has been only partially successful and has not brought about any measurable reduction in accident occurrence.

The third aspect of highway safety, the environment, has received little attention in comparison with the other two. However, this is the one area over which man has control. High density accident locations have been isolated and the hazardous components corrected or removed, bringing about a reduction in motor vehicle accidents.

It was the purpose of this research to investigate the environmental factors at high accident locations and to evaluate the role of such factors in accident causation. For this study the ten highest density accident locations in Oklahoma City for the year 1972 were determined. Police accident reports for each of these locations were examined and compared for similarities in human, vehicle and environmental causative factors. The accident records for each location were analyzed to determine similarity of occurrence and to develop theories concerning causative factors.

The second portion of this research involved detailed examination of the ten accident locations and analysis of all potential environmental causative factors. Next, these physical and environmental characteristics were related to the accident pattern at each particular location.

Through a cross comparison of these data, environmental factors which acted as contributory causes were identified and recommendations made concerning remedial action to improve environmental conditions at these and similar intersections in order to decrease accident occurrence. These recommendations would also be applicable on a national scale and if utilized could bring about a nationally significant reduction in the occurrence of automobile accidents. This research could further be employed to effect design changes in an effort to avoid creating a dangerous driving environment through future construction.

CHAPTER IV

METHODS AND PROCEDURES

In this study, motor vehicle accidents in the Oklahoma City area were examined through information gathered from the Oklahoma City Police Department, the Oklahoma City Department of Traffic Control and on-site examination of accident locations. Additional information was obtained from the University of Oklahoma, Center for Safety Research, Multidisciplinary Accident Investigation Team.

A list of the ten highest density accident locations for the year 1972 was obtained from the Oklahoma City Police Department's Record Bureau. These were, in order of decreasing accident occurrence:

a) Main and North Western,

b) Northwest Expressway and North Portland,

c) Southwest 74th and Pennsylvania,

d) Northwest 39th and May Avenue,

e) Northwest 36th and Meridian,

f) Northwest 23rd and Classen Boulevard,

g) Northwest Expressway and May Avenue,

h) West Expressway and Meridian,

i) Southeast 59th and High Street and

j) Reno and South Western (98).

Each of these locations had 29 or more collisions during 1972, and the Main and Western location accounted for the greatest number with 40 accidents. These locations were selected for this list according to the total number of accidents, rather than accident rate which is dependent on traffic volume.

The police accident reports for these locations, which totaled 323 individual reports, were then assembled and examined to abstract certain facets of the official report. These reports contain information concerning the driver's condition, the vehicle condition and environmental factors. The items which were evaluated were:

a) date of the collision,

b) day of the week when the collision occurred,

c) time of day when the collision took place,

d) number of motor vehicles involved,

e) total property damage,

f) number of injuries,

g) number of fatalities,

h) use of lap and shoulder belts,

i) completion of a driver training program,

j) vehicle condition,

k) type of traffic control at the accident location,

l) lighting conditions at the time of the accident,

m) weather conditions,

n) road surface conditions,

o) condition of the drivers,

p) official cause and

q) a brief description of how the collision occurred.

Information provided by the Oklahoma City Department of Traffic Control concerned signal sequencing at these ten locations, as well as signal sequencing at adjoining intersections included in the same traffic control network. The Department of Traffic Control also released the results of traffic flow and volume studies for these ten intersections.

A variety of data were collected through an in-depth examination of the intersections themselves. Those factors evaluated included:

a) road lane width,

b) signal sequencing,

c) type of road surface,

d) condition of road surface,

e) roadside development,

f) roadside hazards,

g) visual obstructions,

h) roadway lighting,

i) special turning lanes,

j) roadway markings and

k) traffic control signs.

Data obtained from the Center for Safety Research consisted primarily of in-depth accident reports involving collisions at intersections included in this study. These reports were available for three of the intersections being used in this study.

The information gathered from all sources was combined with regard to the individual accidents occurring at each intersection for the purpose of isolating both causative agents and those factors which increase injury severity. Intersection features which contributed to safety and injury severity reduction were also considered.

Based on these environmental hazards, recommendations were made concerning corrective measures. These recommendations were determined by practicality of implementation and cost benefit relationship.

Following the examination of each accident site in detail, similarities concerning type of accident at each intersection were studied. Data from all ten locations were examined to locate environmental factors which were common contributors to accidents at other intersections throughout the Oklahoma City urban area. The ultimate goal of this investigation was to ascertain certain environmental characteristics which were primary or contributing causes to large numbers of accidents occurring not only at the study locations, but also at similar locations which could be found in any urban area.

CHAPTER V

OBSERVATIONS AND DISCUSSION

Initial Observations

Analysis of the accumulated data involved all three major areas of concern; the driver, the vehicle and the environment. The use of records of past accident experience as a predictor of future accident occurrence, and therefore as an indicator of necessary remedial action, is an accepted approach in the highway safety area (99). A total of 323 Oklahoma City Police accident reports were examined for information concerning the official cause of the accident. A sample accident form appears in Appendix A. These data are summarized in Table 15.

The most common official cause of accidents was listed as "failure to yield," which implied a basic conflict between two vehicles. These collisions were attributed to driver error, when this intersectional conflict could have been resolved through redesign of environmental factors. The other most frequently used explanation was inattention, a vague and nondefinitive explanation which could have been more appropriately designated as distraction. The driver may not have been paying attention, but it was most likely due to a preoccupation with some facet of his driving environment. A more in-depth investigation should have been made to isolate the actual causative factors.

TABLE 15

OFFICIAL CAUSES - OKLAHOMA CITY TOP TEN ACCIDENT LOCATIONS BY PERCENTAGE - 1972

Intersection	Fail to Yield	Inat-tention	Follow Closely	Unknown	Change Lanes	Fail to Stop	Faulty Vehicle	Improper Turn	Other
Main & Western	53	8	10	10	10	5	3	3	0
NW Exp. & Portland	43	22	14	5	5	5	0	0	5
SW 74 & Penn.	50	17	11	6	3	3	3	3	6
NW 39 & May	48	15	15	3	3	3	6	6	0
NW 36 & Meridian	80	3	3	3	6	0	0	0	3
NW 23 & Classen	33	30	10	6	0	10	0	3	6
NW Exp. & May	3	73	20	0	0	0	0	3	0
W Exp. & Meridian	27	31	17	10	0	0	6	0	6
SE 59 & High	66	6	3	3	6	6	0	6	0
Reno & Western	45	12	6	9	17	0	3	3	0
Averages	45	21	11	6	5	3	2	2	2

Definite failure or incapacity with regard to the human variable was noted in only 24 out of 669 drivers. At most, this could have accounted for only 7.4 per cent of the accidents occurring at the study locations. Of these 24 drivers, 21 were listed as driving under the influence of alcohol, and one each as aged, tired or asleep. The remaining 645 drivers were reported by the investigating officer to be normal.

The official accident reports also indicated that only 32 per cent of the drivers involved in those collisions under study had completed an approved course in driver training. It was not possible to determine conclusively whether or not such a course would have prevented the occurrence of these existing accidents. Of the 669 drivers involved in these 323 collisions, there were 215 drivers who had participated in a driver training course. Of these 215 drivers, 94, or 44 per cent, were found to be at fault in causing the collision. This does not indicate that driver training was a significant factor in accident reduction. A more detailed description of these data is included in Table 16.

Vehicle malfunctions were reported to be present in only 12 vehicles, or 2 per cent of the 669 vehicles included in this study. From these results, it does not appear that vehicle malfunctions are responsible for more than a very small number of motor vehicle collisions.

Much of the effort in the field of motor vehicle safety has been devoted to automobile crash-worthiness and injury-reducing features, such as seat and shoulder belts. A survey of the police accident reports yielded some information in this area. Of the 556 vehicles equipped with seat belts, only 29 per cent of the drivers reported that they were wearing them at the time of the collision (Table 16). The use of shoulder

TABLE 16

HUMAN AND VEHICLE FACTORS

Intersection	Number of Vehicles Involved	Percentage Use		Percentage Drivers Completing Driver Training Course	Abnormal Vehicle Condition	Driving Under the Influence
		Lap Belts	Shoulder Belts			
Main & Western	81	35	9	28	1	5
NW Exp. & Portland	79	39	0	33	0	3
SW 74 & Penn.	76	26	0	28	3	3
NW 39 & May	70	19	4	47	3	1
NW 36 & Meridian	64	42	5	27	0	1
NW 23 & Classen	65	16	0	27	0	6
NW Exp. & May	60	46	0	35	0	0
W Exp. & Meridian	58	29	10	41	5	9
SE 59 & High	58	26	0	28	3	3
Reno & Western	58	25	7	29	3	0
Totals	669	29	3	32	2	3

belts was even more discouraging with only 3 per cent of the drivers whose vehicles were equipped with shoulder belts reporting that they were in use at the time of the collision. Despite this situation, the number of people injured was still relatively small, most likely as a result of low vehicle speeds at the time of the collision and not apparently due to the use of lap and shoulder belts.

With only 5 per cent of the collisions attributed to driver error and vehicle malfunction, the remaining 95 per cent had no apparent causative agent. As shown in Table 15, official causes, as reported on the police accident reports, were extremely vague. These included driving characteristics such as failure to yield, inattention, improper lane changing, following too closely or improper turning.

It is highly unlikely that any driver has ever gone through a stop sign or red light knowing that he was going to be involved in a collision. There must have been something that led him to believe he would not be involved in a collision. Therefore, his action of failing to yield was not a cause, but rather, it was a result of the information he perceived as he approached the intersection. It becomes important to determine what factors of the environment might have caused the driver to incorrectly perceive his surroundings.

It has been shown that freeways have fewer accidents than urban areas (100). This is due to the number of points of confusion and potential conflict commonly occurring at urban intersections.

An in-depth investigation of the ten intersections in this study showed numerous environmental defects at each location, which contributed in varying degrees to accident causation. All of these intersections were high-volume intersections, accommodating from 16,000 to over 45,000 vehicles per day. Although the defects at each location were respectively related to different environmental problems, all were correctable with the expected result of marked accident reduction.

Each intersection being unique, it was important to evaluate each one independently, and to recommend specific solutions for the problems identified at each location. Data concerning these locations are contained in Tables 17, 18, 19, 20 and 21.

Main and North Western

The intersection at Main and North Western (Figure 4) involved the major downtown artery in Oklahoma City and a heavily traveled north-south route which extended to both the northern and southern borders of the city. The streets were each four lanes wide, with the exception of the area east of the intersection. This segment of the roadway was six lanes in width, and it incorporated four westbound lanes leading out of the downtown area. There were special lanes on Main Street for making left turns, one from the west and two from the east, although, there was no left turn signal phase. The roadway surface was asphalt and generally in fair to poor condition with numerous cracks, patches and deep gutters on all four corners. Pavement markings were of paint and quite worn.

The roadside environment was of a commercial nature with business establishments on all four corners. There were no outstanding visibility obstructions, with the possible exception of a building on the southwest corner which was within 6 feet of the street. There were several telephone and light poles within 3 feet of the curb which could have been dangerous fixed objects to any vehicle leaving the roadway.

TABLE 17

SUMMARY COLLISION DATA - TOP TEN ACCIDENT LOCATIONS

Intersection	No. of Acc.	No. Inj.	Est. Prop. Dam./$	Ave. Prop. Dam./$	Types of Collisions					
					Rear-End	Right Angle	Left Turn	Side Swipe	Fixed Object	Other
Main & Western	40	8	21,905	548	8	19	10	3	0	0
NW Exp. & Portland	37	13	22,855	618	15	5	14	2	1	0
SW 74 & Penn.	36	10	18,765	521	9	12	15	0	0	0
NW 39 & May	33	3	19,715	597	11	9	12	1	0	0
NW 36 & Meridian	30	11	20,095	670	3	3	23	1	0	0
NW 23 & Classen	30	4	17,780	593	10	4	15	0	0	1
NW Exp. & May	30	1	9,160	305	28	1	0	0	0	1
W Exp. & Meridian	29	11	16,690	575	12	6	7	0	4	0
SE 59 & High	29	4	15,970	550	3	14	8	3	1	0
Reno & Western	29	2	13,035	450	6	14	3	6	0	0
Totals	323	67	175,970	545	105	87	107	16	6	2

TABLE 18

ACCIDENT OCCURRENCE BY DAY OF WEEK

Intersection	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.
Main & Western	3	7	4	6	7	8	5
NW Exp. & Portland	3	2	7	9	8	4	4
SW 74 & Penn.	1	2	7	3	10	5	8
NW 39 & May	5	2	5	3	7	7	4
NW 36 & Meridian	8	0	6	4	7	2	3
NW 23 & Classen	4	4	6	3	3	7	3
NW Exp. & May	4	5	7	1	7	3	3
W Exp. & Meridian	0	5	6	2	6	4	5
SE 59 & High	1	4	5	5	7	5	2
Reno & Western	6	5	3	5	5	2	3
Totals	35	36	56	41	67	47	41

TABLE 19

ACCIDENT OCCURRENCE BY TIME OF DAY

Intersection	11:01 1 AM	1:01 3 AM	3:01 5 AM	5:01 7 AM	7:01 9 AM	9:01 11 AM	11:01 1 PM	1:01 3 PM	3:01 5 PM	5:01 7 PM	7:01 9 PM	9:01 11 PM
Main & Western	3	1	0	1	4	6	6	6	6	3	2	2
NW Exp. & Portland	2	1	0	0	4	3	7	6	6	1	3	4
SW 74 & Penn.	3	1	0	1	0	5	6	3	8	5	3	1
NW 39 & May	2	0	0	0	3	3	5	4	3	5	4	4
NW 36 & Meridian	1	0	0	0	3	6	3	4	5	3	3	2
NW 23 & Classen	1	0	0	0	2	4	7	2	6	3	2	3
NW Exp. & May	0	0	0	0	3	2	6	6	7	3	1	2
W Exp. & Meridian	2	2	1	1	1	2	1	5	6	5	1	2
SE 59 & High	2	0	0	0	8	2	3	3	2	7	0	2
Reno & Western	0	0	0	1	2	0	9	4	6	5	1	1
Totals	16	5	1	4	30	33	53	44	55	40	20	23

TABLE 20

TOTAL DAILY TRAFFIC VOLUME BY INTERSECTION

Intersection		Daily Traffic Volume			Annual
		Total	Major St.	Minor St.	Volume
Main & Western		31,827	11,365	20,462	11,616,855
NW Exp. & Portland		33,040	20,358	12,682	12,059,600
Penn. & SW 74	(N)	18,937	14,063	4,874	6,912,005
	(S)	19,423	14,378	5,045	7,089,395
May & NW 39	(N)	29,512	24,621	4,891	10,771,880
	(S)	28,740	25,251	3,489	10,496,100
Meridian & NW 36		29,559	19,100	10,459	10,789,035
Classen & NW 23		45,733	30,296	15,437	16,692,545
May & NW Exp.*		43,186	20,158	23,028	15,762,890
W Exp. & Meridian		39,718	23,441	16,277	14,497,070
SE 59 & High		16,527	14,588	1,939	6,032,355
Western & Reno & Exchange		33,383	19,513	9,818 4,052	12,184,795

* Values approximated through use of data for adjoining intersections.

TABLE 21

ACCIDENT RATES PER 100,000 VEHICLES

Intersection	Accident Rate Per 100,000 Vehicles
SE 59 & High	0.483
Main & Western	0.345
NW Exp. & Portland	0.306
NW 36 & Meridian	0.278
SW 74 & Pennsylvania	0.257
NW Exp. & May*	0.242
Reno & Western	0.237
W Exp. & Meridian	0.200
NW 23 & Classen	0.179
NW 39 & May	0.157

* Value approximated through use of data for adjoining intersections.

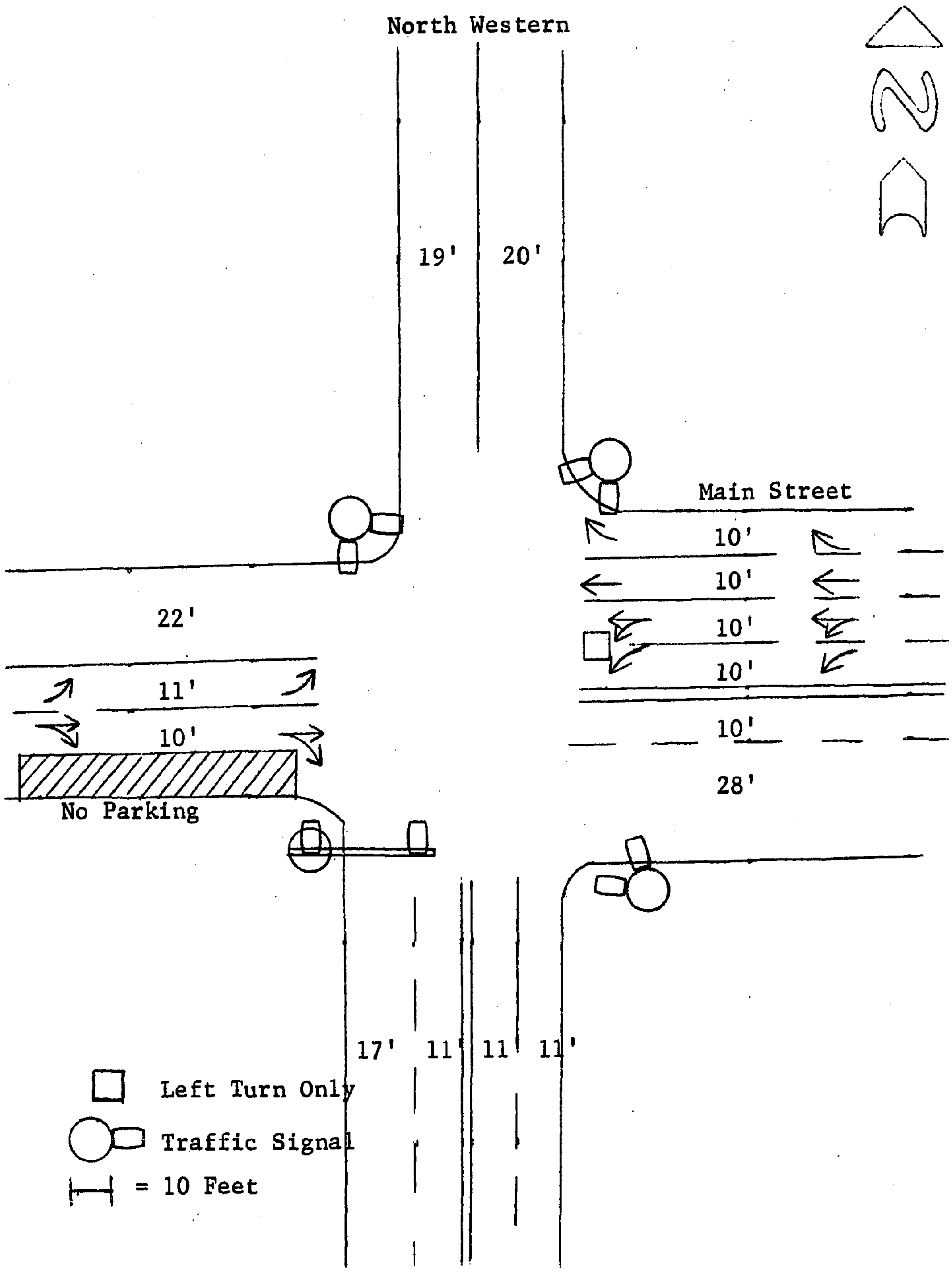

Figure 4. Main Street and North Western

The traffic signals operated on a normal red, green, yellow sequence with no turning or all red phases. They were located so as to be clearly visible, and they were not found to be malfunctioning at the time of any of the reported collisions. All directions received an equal 30-second green phase, 5-second yellow phase and 35-second red phase.

Main Street was the major street at this intersection and received priority through the traffic actuated signal system, but it had a traffic volume only slightly over half that of North Western which was classified as the minor street. Traffic volume studies showed that peak hours for this intersection occurred between 7:30 and 8:30 in the morning and 4:00 and 5:30 in the afternoon. A detailed breakdown of traffic flow at each intersection is contained in Appendix B.

The occurrence of collisions showed no clear relationship to these peak periods due to the consistently heavy flow of traffic resulting from the proximity of this intersection to the downtown area. The distribution of collisions according to the days of the week (Table 18) was relatively normal compared to all accidents in the Oklahoma City area (Figure 1).

This intersection was credited with the largest number of accidents in 1972, a total of 40, although, when compared with traffic volume, its accident rate (Table 21) was actually second highest among the ten intersections investigated. As shown in Table 17, the most prominent type of collision at this intersection was the right angle type, with rear-end and head-on from left turn collisions contributing about equal numbers.

There appeared to be no single feature at this location which led to the large number of collisions, but rather, there was a combination of features resulting from the confusion caused by poor design.

The most common type of collision was the right angle type, which normally are few in number at signalized intersections (64). Of 19 right angle collisions, 16 of them involved a northbound vehicle. There was the possibility of a visibility obstruction, but the cause was more likely a resultant of the signal phasing and the intersection size.

Right angle collisions normally occur at a change in the signal phases. With only a 5-second yellow light, it was likely that many vehicles entering the intersection during a yellow light phase would not be able to clear the intersection by the time the red light phase occurred. The possibility of this taking place was increased by the width of the intersection. Traveling at the speed limit on North Western, 30 miles per hour, it would take approximately 2 seconds for a vehicle just to cross the intersection. However, lengthening the yellow phase would not eliminate right angle collisions since the conflict of the changing signal phases would not have been resolved.

Seven of the ten left turning collisions also involved traffic on North Western. This was primarily a result of the lack of special left turn lanes and turning signal phases. On Main Street, where pavement arrows indicated turning lanes, the number of left turn accidents was significantly lower than on North Western.

Rear-end collisions are common at signalized intersections. The best preventive measure has been found to be a series of intersections with interconnected signals providing an even traffic flow. This type of system creates a situation where a platoon of vehicles reaches the intersection while the light is green. If stopping is reduced, so are rear-end collisions.

Another characteristic of this location which contributed to two collisions was the double left turn lane on Main Street. Two vehicles making a left turn, side by side, with no lane markings to guide them, have an increased opportunity for collision. This situation could have been easily rectified by providing lane markings or limiting the left turning movements to a single lane.

The following remedial measures were recommended in an effort to reduce the frequency of collisions at this intersection:

a) convert the north and southbound passing lanes to left turn lanes, and equip the entire intersection with left turn signal phasing,

b) connect this intersection to other intersections in a network to promote smoothness of flow and a reduction in rear-end collisions,

c) eliminate one of the left turn lanes on the westbound side of Main Street,

d) introduce a 5-second all red phase to reduce the number of vehicles caught in the intersection on a signal change, thus compensating for the short yellow phase and

e) install new pavement markings for better traffic separation.

Northwest Expressway and North Portland

Northwest Expressway and North Portland (Figure 5) were both major arteries for access to downtown Oklahoma City, although the intersection was actually located approximately 4 miles from the center of the downtown area. Each street was a four lane roadway, and the Expressway also had a median and a single left turning lane.

The speed limit on the Expressway was 50 miles per hour, and on

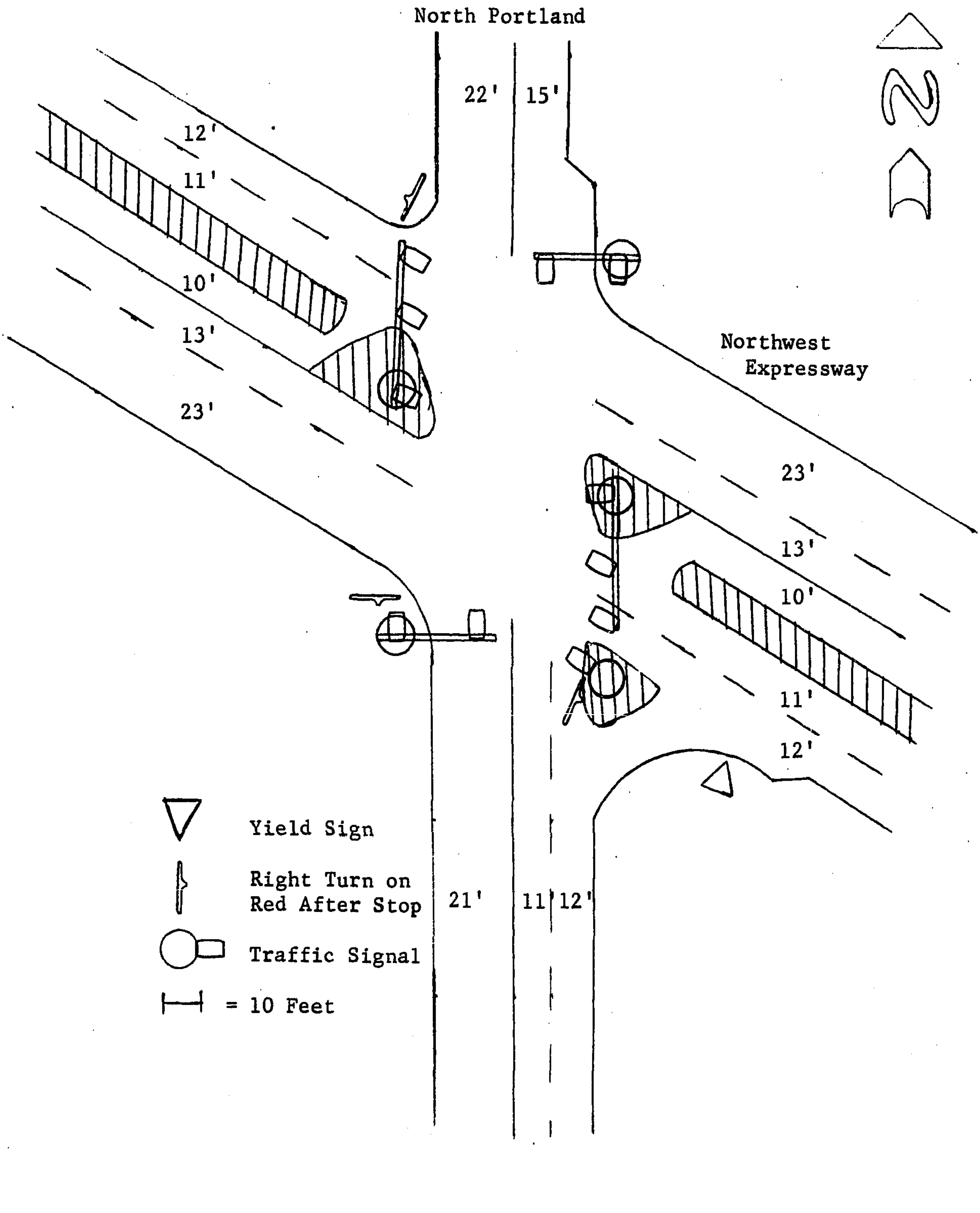

Figure 5. Northwest Expressway and North Portland

Portland it was 40 miles per hour. The road surface on both streets was asphalt and in relatively good condition. The pavement markings were quite visible, although the southbound lane on Portland had no markings to separate the two lanes.

The roadside area was fairly open, and it was a combination of commercial and residential development. There were no fixed visibility obstructions on either roadway; however, vehicles stopped on Portland, waiting to make a left turn, often obscurred the vision of oncoming drivers, particularly those who were also making a left turn. The traffic signals were actuated signals, allowing a longer green phase on the Expressway and use of the left turn phase only when needed. Traffic signs permitted all but northbound travel to make a right turn on a red light, and the northbound traffic could make a similar movement by the use of a cut-off coupled with a yield sign.

Traffic volume studies showed that the daily volume for this intersection was over 33,000 vehicles (Table 20), with the peak hours being 7:30 to 8:30 in the morning and 4:00 to 5:30 in the afternoon. The increase in traffic beginning at the noon hour was reflected in the increased occurrence of accidents during that time period. Accidents occurred throughout the week (Table 18) at this location according to the normal pattern for Oklahoma City (Figure 1). Based on the intersectional traffic volume, the accident rate per 100,000 vehicles was the third highest among those intersections examined.

The injury rate and property damage were relatively high due to the high speed limits on both roadways. The two prevalent types of collisions here were rear-end and head-on collisions from a left turn (Table 17) with smaller numbers of right angle and side swipe collisions. There was also one fixed object collision out of the 37 occurring at this location.

The most obvious problem at this intersection was the need for left turn lanes and signal phases on North Portland. All 14 left turn collisions at this site occurred on North Portland which has no left turn provisions. Not a single left turn accident occurred on the Expressway which was equipped with both left turn lanes and signal phasing. The cost in property damage alone of these 14 accidents was over $7000 in 1972, which would have paid for the installation of the proper left turn equipment. An alternative measure of changing the signal phasing to allow the northbound and southbound traffic to advance at separate times would remove the conflict for left turning vehicles and achieve the same results.

The rear-end collisions were distributed relatively evenly among the northbound, eastbound and westbound traffic with no rear-end collisions being attributed to the southbound traffic. This was accounted for by the high speeds of travel of all but the southbound vehicles. The southbound lanes led from a low speed residential area, and traffic was already moving at a slow rate as it approached the intersection. Synchronization of this intersection with adjoining ones would significantly reduce rear-end collisions.

An additional environmental factor involved at this intersection was a slight hill sloping upward for the eastbound traffic, just west of the intersection. The crest of this hill has been shown to obstruct the eastbound driver's view of brake lights at the intersection only a few hundred feet ahead. Since this traffic was of a high speed nature, this distance was sufficient to create a stopping problem.

There were no right turn related accidents, although all four directions were permitted right turns on a red light. This indicated the safety of this maneuver and its advantages to increasing traffic flow.

Recommendations for this location were:

a) the installation of a left turn system on North Portland, or adaptation of the signal sequence to allow north and southbound traffic to advance at alternate times,

b) the interconnection of this locality with other intersections to provide a more even traffic flow, particularly during the rush hour, and reduce rear-end collisions,

c) the use of a 5-second all red signal phase to reduce right angle collisions and

d) the installation of a warning device or rumble strip for eastbound traffic to alert drivers of a stop at the crest of the hill.

Southwest 74th and South Pennsylvania

This intersection involved the problems of two separate intersections. Southwest 74th was an access road in the form of a two lane, two-way roadway located on both sides of a divided highway. The four lane divided highway was constructed on an overpass over South Pennsylvania. South Pennsylvania was a four lane, two-way undivided roadway constructed perpendicularly to Southwest 74th Street. This location included two intersections, one on the north and one on the south side of the highway, connected by an underpass. As shown in Figure 6, the north side of the intersection consisted of two lanes in the east-west direction, four lanes in the north-south direction plus a left turn lane for northbound vehicular movement. Almost all of the lanes exceeded the 12-foot recommended width.

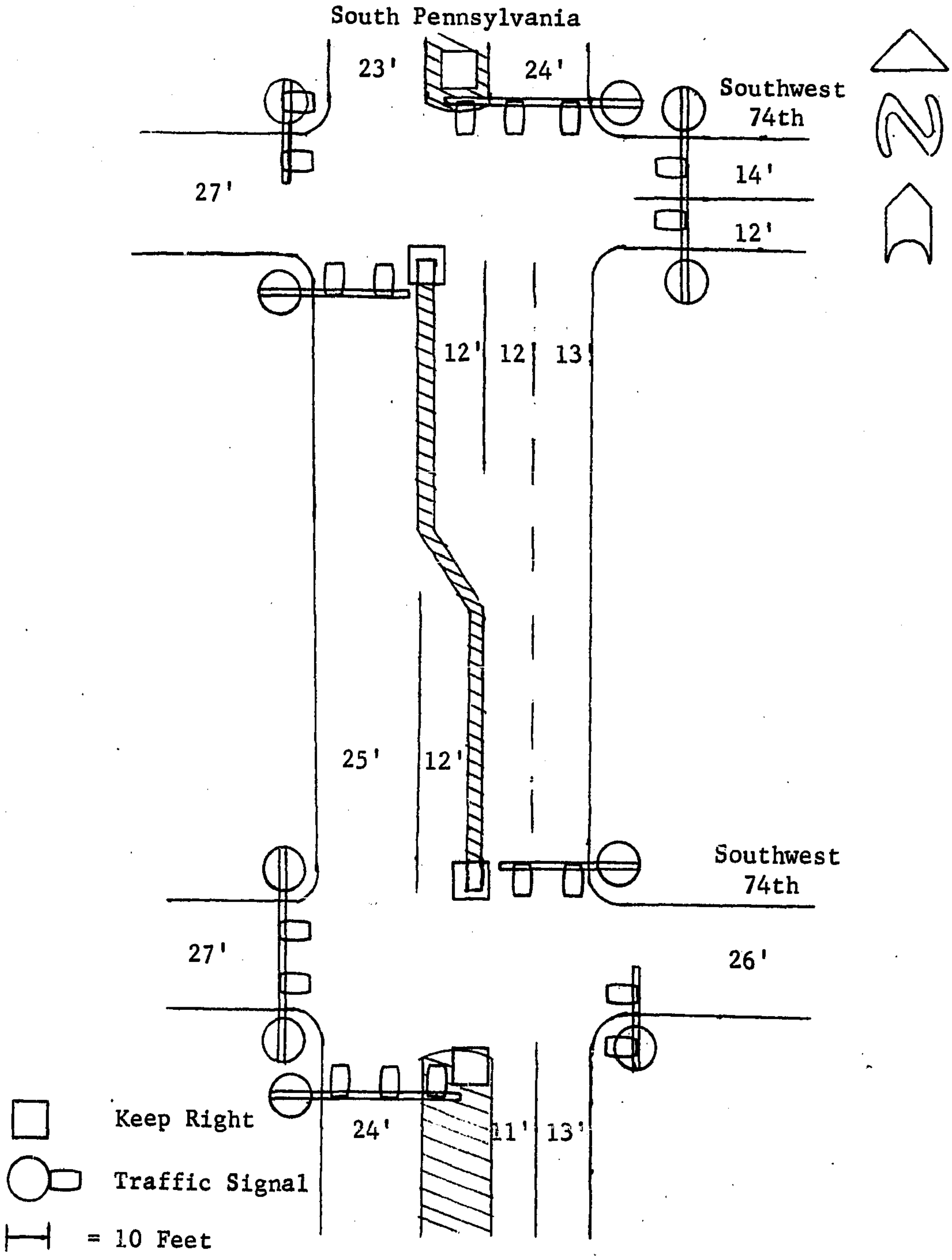

Figure 6. Southwest 74th Street and South Pennsylvania

The south side was of similar design and construction having a left turn lane for southbound traffic. Pavement markings were in fair to good condition, although the southbound area between the north and south sides had no lane divisions.

Both sides of the crossing were signal controlled, but did not utilize either a left turn phase or an all red phase. The two intersections were interconnected to allow traffic to clear both segments of the intersection on the same signal phase and avoid creating a bottleneck. As an added safety measure, a traffic island was constructed to separate the north and southbound traffic throughout this area.

The roadway surface was concrete in some areas and asphalt in others. The entire intersection was surrounded by a 6-inch curb, which was the only protection from the several poles and concrete bridge abutments, all within 4 feet of the roadway. The roadside area was commercial in nature with several gasoline stations and shopping areas.

Turning motor vehicles at this intersection created an exceptional hazard. In addition to Southwest 74th Street being a through street, it also served as an access route to the highway which greatly increased the left turning volume at this location.

Being further removed from the downtown area, the peak hours for traffic flow were earlier in the morning, 7:00 to 8:00, and later in the evening, 5:00 to 6:00. The majority of the collisions occurred during the afternoon, both before and during the rush period (Table 19). Friday was the day of the week when the largest number of accidents took place, which was consistent with other study locations. This intersection accounted for the fifth highest accident rate based on traffic volume

(Table 21).

The most common collision configuration was, once again, the head-on from a left turn (Table 17), which was expected due to the large volume of left turning traffic. The second most frequent type of collision was the right angle impact, normally a rarity at signalized intersections (64). This indicated a basic design flaw in the intersection construction.

No more than one left turning collision happened at each possible point of conflict, with the exception of one. This remaining point of conflict was responsible for nine left turn collisions and was the least likely of all for this poor record. These nine collisions all involved the north side of the intersection where a left turn lane was provided for northbound traffic to aid in channelization. This site appeared an even greater problem, since 25 per cent of the 36 collisions occurred there, while only 2.7 per cent of the total traffic at this intersection was involved in making a left turn at that point.

This pattern became explicable when the high accident rate was correlated with the time of occurrence of these nine collisions. All but one took place between 3:00 and 7:00 in the afternoon, when left turn traffic would have had to cross a heavy southbound flow away from the city. The simplest solution to this situation would be to initiate a separate left turn signal phase to allow these vehicles to cross in safety. This action would have a similar beneficial effect on other areas of this intersection with regard to left turn collisions.

Analysis of the right angle collisions introduced a new environmental hazard. Three of these right angle collisions involved vehicles entering busy South Pennsylvania from gasoline stations and shopping areas. One method of reducing such accidents would have been to place entrances and exits for these commercial facilities as far away from the intersection as possible. This would have given the drivers of these entering and exiting vehicles a better view of the traffic flow and simplified their driving maneuvers. The remainder of the right angle collisions could have been eliminated through the use of an all red signal phase. An all red signal phase would compensate for the poor intersection design and be far less expensive than a reconstruction program.

Approximately 44 per cent of the rear-end collisions occurred on the access road, Southwest 74th Street. There was no particular time relationship or other common factor except for speed. Although only a two lane road, Southwest 74th Street was straight and level and no speed limit signs were present for over a mile both east and west of South Pennsylvania. Excessive speed on this road would have made it difficult to stop suddenly on approaching the intersection. The number of rear-end impacts could have been greatly reduced by synchronized intersection signals, which would have reduced the need for sudden stopping. It is accepted that signalized intersections will have more rear-end accidents than non-signalized ones, but traffic control engineers could still do much to reduce the number of such occurrences (64).

Recommendations for accident reduction at this intersection were:

a) initiation of a left turn signal phase for traffic traveling both north and south on Pennsylvania,

b) limiting and redirecting turning movements into and out of commercial establishments, particularly with regard to relocating these turning areas to points as far away from the intersection as possible,

c) placement of speed limit signs, as well as "stop ahead" signs, on Southwest 74th Street both east and west of the intersection,

d) synchronization of the intersection with adjoining ones to speed vehicular flow,

e) initiation of a 5-second all red phase to reduce angle collisions and

f) application of lane markings in the southbound lane of Pennsylvania and on the three sections of Southwest 74th Street which are presently unmarked.

Northwest 39th Street and May Avenue

The Northwest 39th Street and May Avenue intersection (Figure 7) had many similarities to Southwest 74th Street and Pennsylvania. It was a double intersection with signal lights at both the north and south sides. The east-west street also served as an access road to a divided highway. The location was subject to a very heavy flow of vehicles, of which over 75 per cent was on May Avenue (Table 20). May Avenue crossed a concrete bridge with concrete side walls located between the two sides of the intersection. This bridge formed an overpass over a four lane divided highway.

The most outstanding problem at this intersection was confusion. Not only was the intersection itself complicated, but the roadside environment was not conducive to safe vehicular operation. The area was highly commercialized for several blocks both north and south of the intersection. These establishments included four automobile dealerships, four gasoline stations and three restaurants, all of which involved heavy

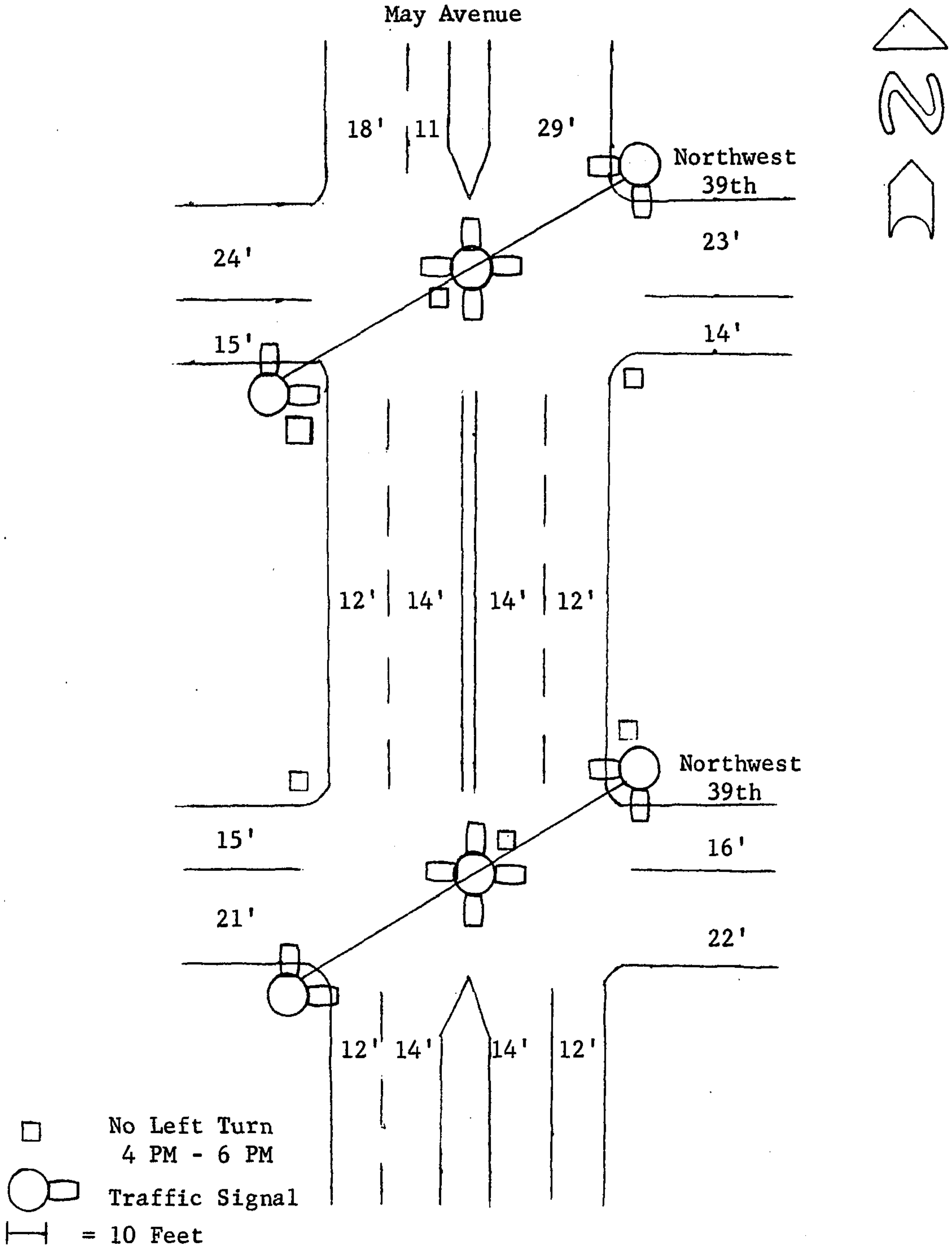

Figure 7. Northwest 39th Street and May Avenue

traffic flow and complex traffic patterns. A multitude of painted and neon signs added to the visibility problem.

The roadway was surfaced with asphalt, which was in fair condition, while the painted roadway markings were badly worn. The speed limit on May Avenue was 40 miles per hour, and on Northwest 39th Street, it was 30 miles per hour. There were no special left or right turn lanes on either road.

Traffic was controlled at both the north and south sides of the intersection by traffic signals of the standard type. They were synchronized to allow traffic entering one side of the intersection on May Avenue to clear the other side during the same signal phase. There was no left turn signal sequence on either side of the intersection. Signs prohibited northbound vehicles from making left turns at the north side of the intersection, while similar signs were in force for the southbound traffic at the south side of the intersection. These left turn prohibitions were in effect from 4:00 to 6:00 in the evening. Despite this restriction, left turn collisions were the most common type at this location.

Vehicle flow studies have indicated a daily traffic volume of over 58,000 vehicles between both sides of this intersection. Based on this extremely heavy vehicular flow, the accident rate per 100,000 vehicles was 0.157, or the lowest of those intersections examined. Most probably there were other intersections in the city with higher accident rates although their total number of collisions was smaller.

Accident incidence with regard to day of the week was similar to the experience for Oklahoma City as a whole (Table 18) (Figure 1). Collisions at this intersection occurred evenly throughout most of the day as would have been anticipated due to the extremely heavy vehicle flow through this entire area.

In 33 accidents at this intersection, only 3 injuries were recorded, which indicated that the speed of the vehicles at the time of the impact was comparatively low. The nature of collisions arising most frequently were equally distributed among rear-end, right angle and left turn configurations.

Rear-end collisions at this locale would have been difficult to eradicate, because of the complexity of the entire system, but signal synchronization with other intersections, both north and south of 39th Street, would most likely have a beneficial effect on their frequency of occurrence.

Of the nine right angle collisions, eight took place on the south side of the intersection involving a southbound vehicle and an eastbound vehicle. Of the eight southbound vehicles, six were traveling in the right lane. The importance of this configuration was that both drivers were well screened from each other by the concrete bridge sidings. These right angle collisions involved signal changes, and removal of the concrete wall to improve vision would be very difficult and expensive. A solution might be to make use of an all red signal phase of several seconds duration to permit the vehicles that had entered one side of the intersection to clear the other side before the cross traffic was released.

The most numerous type of collision, once again, involved left turning vehicles. Of ten left turn accidents involving May Avenue, only one involved a southbound vehicle at the south side of the intersection, while nine involved northbound vehicles at the north side of the intersection. Daily, left turn traffic volumes from either side of the intersection were nearly equal, so another factor must have been responsible for this large difference.

North of the intersection was a hill sloping up to the intersection. Vehicles ascending that slope would not have been visible for more than a short distance prior to reaching the intersection. A driver making a left turn at this point might have had a difficult time estimating the approach speed of such a vehicle. This situation was further complicated by an intervening lane of southbound traffic. In all nine instances, the vehicle striking the left turning one was in the extreme right, southbound lane. Between the hill and the traffic in the second, southbound lane creating visibility problems, a very dangerous situation was created. Once again, a left turn signal phase would have permitted vehicles to complete their left turn movement in safety.

Recommendations for this intersection were very similar to those for each of the preceeding locations. They were:

a) the prohibition of all left turning movements, or the initiation of a left turn lane and signal phase,

b) the utilization of an all red phase of several seconds duration, due to the width of the intersection,

c) the use of signal synchronization to improve traffic flow characteristics,

d) the limitation of turning movements with reference to commercial establishments and

e) the removal of some of the clutter of surplus route signs and other roadside accessories, as well as those commercial advertising signs which have proven distracting or confusing to motorists.

Northwest 36th and North Meridian

This intersection (Figure 8) was comprised of two streets intersecting at right angles. Each roadway consisted of four lanes, all of which met the recommended 12-foot width. The road surface was asphalt on both streets and in relatively good condition, although, the pavement markings, which were of paint, were badly worn in some places and moderately worn throughout the remainder of the area.

The surroundings were predominantly residential, with private dwellings situated on three corners, and a vacant lot on the fourth corner. With the exception of the northwest corner, visibility obstructions, in the form of large trees, were in evidence.

The speed limit on both roadways was 40 miles per hour, and traffic, particularly northbound on Meridian, regularly exceeded this limit. Meridian was one of the major access routes to downtown Oklahoma City, and there were no traffic signals within a mile to the south of this intersection. This situation allowed northbound vehicles to attain high speeds prior to arriving at the Northwest 36th and Meridian intersection.

The intersection was controlled by traffic signals with two signal faces for each approach, one pole mounted on the right side of the roadway and the other suspended from a mast-arm over the center of the two lanes which it controlled. The signal phasing was normal with no left or right turn phases. It was a traffic actuated system, and allowed twice as much green time to the traffic on Meridian. Pole mounted signs on the right side of the road allowed the northbound, southbound and

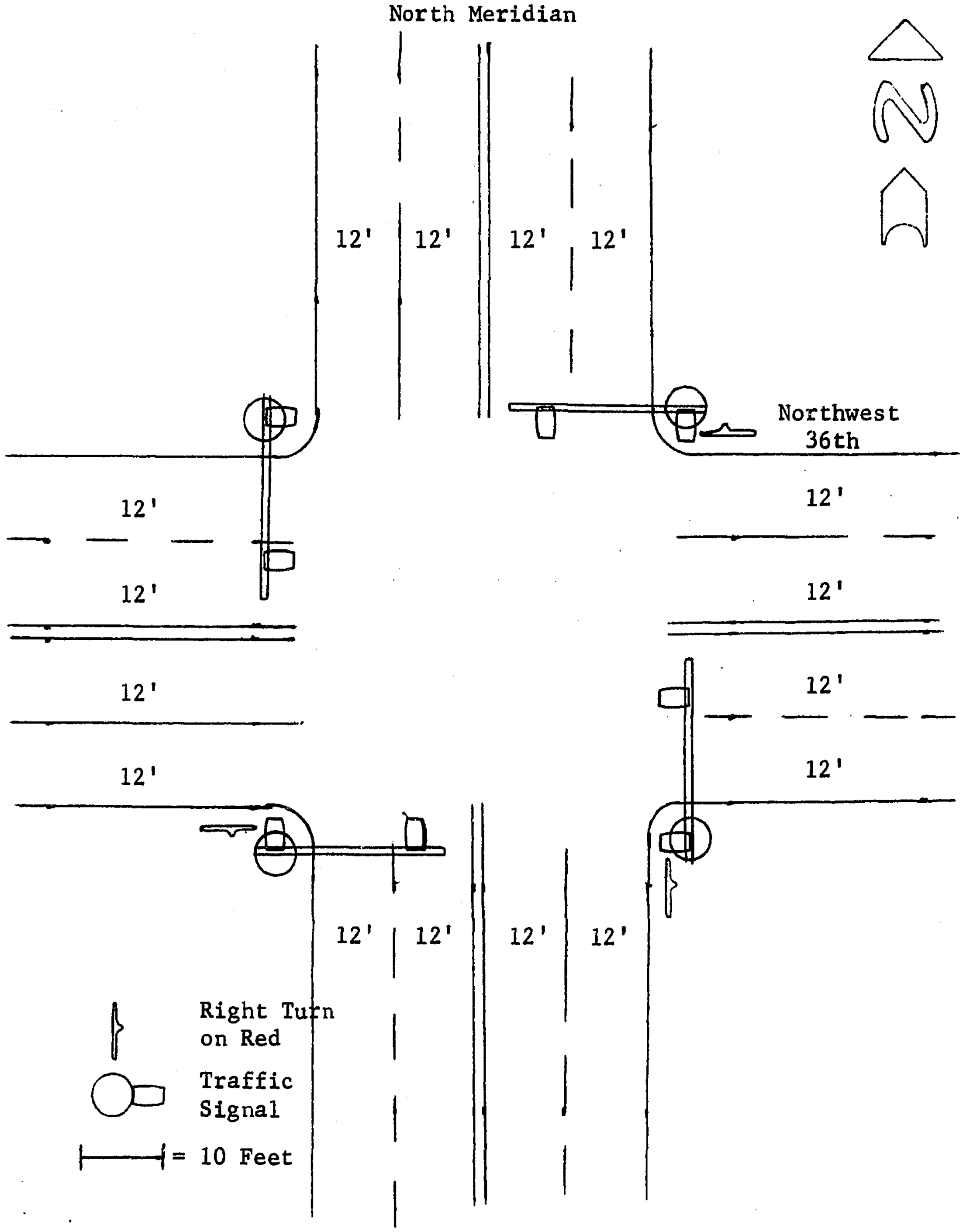

Figure 8. Northwest 36th Street and North Meridian

eastbound vehicles to make a right turn on a red light after stopping.

The daily traffic volume for this location was just under 30,000 vehicles (Table 20), of which more than 70 per cent was on Meridian. The traffic flow was particularly heavy between 3:00 and 6:00 in the afternoon when over 45 per cent of the daily vehicular flow occurred. The accident rate per 100,000 vehicles was 0.278, or fourth highest of those intersections studied.

In 30 collisions at this intersection, there were 11 injuries, second highest among the 10 locations surveyed. The average property damage per collision was the highest of these 10 locations at $670 (Table 17). These two factors appeared to be the result of the relatively high vehicular speeds on Meridian.

One type of collision was so dominant at this site as to make the others almost insignificant. Of the 30 reported accidents, 23 of them were of the head-on from a left turn variety.

Of these 23 left turn accidents, only 3 took place on Northwest 36th Street, and the remaining 20 occurred on Meridian. Sixteen of the 20 accidents on Meridian involved a southbound vehicle making a left turn and being struck by a northbound vehicle. On all but two of these occasions the northbound vehicle was traveling in the right lane, which made it more difficult for the turning operator to perceive.

The major problem at this location appeared to be twofold. Left turns have always been hazardous, but coupled with high speed oncoming traffic and a visibility obstruction in the form of the second lane of northbound traffic, the increasing frequency of this manner of collision was inevitable. Based on the volume of left turning vehicles, the accident rate was 8.1 per 100,000 southbound, left turning vehicles, or more than 29 times as great as the rate for the intersection as a whole (0.278).

The northbound traffic making a left turn was comparable, but only four collisions occurred involving these vehicles. This further supported the importance of speed as a contributing factor at this location.

The three right angle collisions all involved the corners of the intersection where a visibility obstruction was present. Although this was not the primary cause, it was most likely a contributing factor.

Recommendations for reducing the number of accidents at this intersection were:

a) the installation of "no left turn" signs for traffic on Meridian, or the establishment of signal phasing to allow the northbound and southbound traffic to move at different times (a cost benefit analysis of this type of improvement would produce highly favorable results),

b) the use of an all red signal phase to minimize right angle collisions,

c) the reduction or strict enforcement of the speed limit on Meridian,

d) use of thermoplastic or other plastic lane markings to provide better channelization and

e) the removal of the trees which provided a visibility obstruction was not recommended, since these right angle collisions could be alleviated in another manner without affecting the aesthetic value of the trees to the roadside environment.

Northwest 23rd Street and Classen Boulevard

Northwest 23rd and Classen Boulevard (Figure 9) was characterized as being a heavily traveled locality. Classen Boulevard was a main access route to the downtown area, and Northwest 23rd Street was a principal east-west commercial route.

Classen Boulevard was a six lane roadway, with an additional lane in both directions specifically for left turns. North and southbound traffic were separated by a median. Northwest 23rd Street consisted of four lanes, two in each direction. Both roadways were asphalt surfaced with some cracks and patches, but the intersection as a whole was in relatively good condition. The lane markings were moderately faded, and the lane widths were quite irregular, contributing to the traffic flow problems.

Traffic control devices included pole mounted signals for all traffic with separate signal faces on the north-south median indicating a green arrow for left turns. The signals on Classen were part of a system on that roadway, and traffic in the north-south direction also received a longer green phase than east-west moving vehicles. Motorists on Classen also had the opportunity to make a right turn on a red light after stopping. Left turns by east-west traffic were prohibited at all times through the employment of "no left turn" signs. The speed limit on Classen was 35 miles per hour and on Northwest 23rd, 30 miles per hour.

The surrounding environment was almost totally commercial with many driveways and distractions. This was just one more factor contributing to the confusion surrounding vehicle movement through this area.

This intersection had the second highest total daily traffic volume

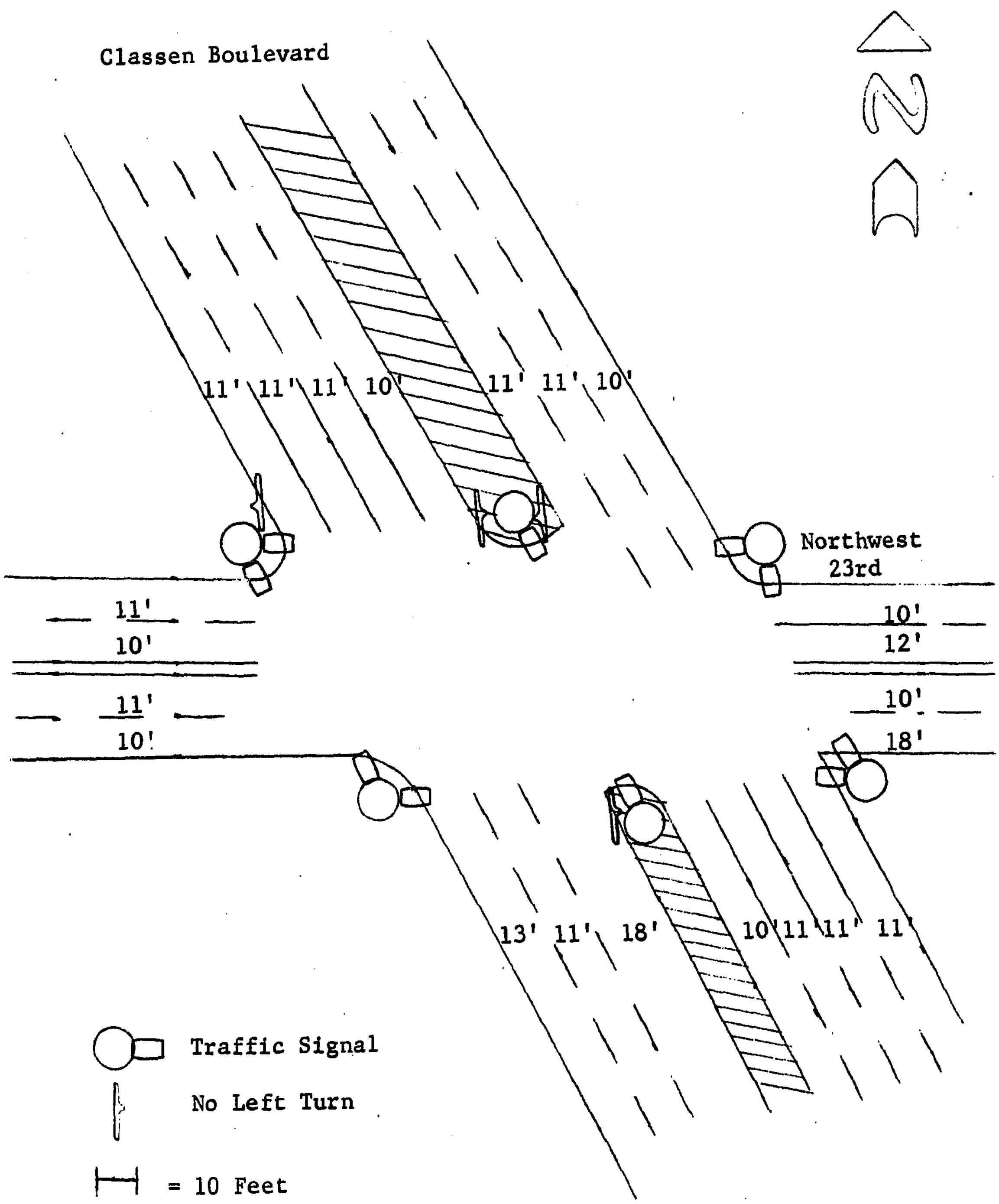

Figure 9. Northwest 23rd Street and Classen Boulevard

of all those studied, and correspondingly, the second lowest accident rate (Table 21). The peak hours for vehicular flow were 7:30 to 8:30 in the morning, and 5:00 to 6:00 in the evening rush hour. Accidents at this location occurred predominantly during the noon hour and in the late afternoon, and generally, earlier in the week than the distribution for Oklahoma City as a whole.

Of the 30 accidents reported by investigating officers, left turn and rear-end accidents were the most common. Due to the fairly low speeds of the vehicles, the number of injuries was minimal (Table 17).

The large number of left turn collisions on Classen seemed unusual, since Classen had both a left turn lane and signal phase. The times at which these collisions took place were dispersed throughout the day, and were not solely a product of rush hour traffic.

The common factor seemed to be the length of the left turn phase which was only 10 seconds in length. No more than two or three vehicles could cross the intersection on a single phase and after a lengthy wait in the left turn lane, many vehicles attempted a left turn even after the signal had turned red, creating a conflict with the oncoming traffic. Because of the heavy traffic volume, it would be very impractical to eliminate left turns completely. Although regulation of north-south movement at different times through the use of alternating signal phases would have created some delay, the signal phasing could have been adjusted to allow the heavier flow a longer green light, and thereby expedite traffic flow at peak periods. A reduction in left turn collisions could also have been achieved through lengthening the left turn signal phase. A study by Gurnett (45) showed that most drivers would have been willing to accept an extra delay to reduce the possibility of a collision and its associated expenses and possible injury.

Rear-end collisions here were related to two specific sets of conditions. Those on Northwest 23rd were the result of no signal synchronization, with the signal to the east only 150 yards away. This created a constant stop and go situation where rear-end collisions were inevitable.

An equal number of rear-end collisions occurred on Classen, which had a synchronized signal system. One explanation was that the synchronization could have been out of phase, creating a hazardous situation. Most likely, the problem was created by the large number of accesses to Classen between the signalized intersections. The advantage of platooning through signal synchronization is lost if large numbers of vehicles enter the roadway between intersections.

Considering the general confusion surrounding this location, those changes that would bring the greatest accident reduction per dollar spent were:

a) permitting north and southbound traffic on Classen to proceed at alternate times or increasing the length of the left turn signal phase,

b) synchronizing both the north-south and east-west traffic flow,

c) installing larger, more prominent, and more numerous signal faces, particularly for the left turning traffic on Classen and

d) using new lane markings with particular emphasis on making all the lane widths relatively equal.

Northwest Expressway and May Avenue

This intersection (Figure 10) was unique in its construction and configuration. Unlike the other intersections, this one was a cloverleaf shaped rotary. Both May and the Northwest Expressway were four lane, divided roadways, each with an asphalt surface. May Avenue crossed over the Northwest Expressway by means of an overpass.

There were no traffic signals or other control devices, except for "yield" signs at the ends of each of the ramps. Painted lane markings were in fair to good condition on both roads; there were none on the ramps. The lanes on both roadways were at least 12 feet in width, and the ramps, which were only a single lane wide, were all at least 16 feet wide.

The surrounding area was primarily commercial, although, there were no establishments in a close proximity to the accident sites themselves. The roadways and ramps were both well lighted, and there were no apparent visibility problems. Speed limits on the roads were 40 miles per hour on May Avenue, and 50 miles per hour on the Northwest Expressway. There were no speed limit signs on any of the ramps.

No traffic volume studies were available for this rotary, however, an approximation of travel on the two major roadways was arrived at through the use of vehicular flow data for adjoining intersections on both the major arteries. These figures gave an approximate vehicular flow of 44,000 vehicles per day on the two major roads, but no estimates were obtainable for the entrance and exit ramps.

The accidents at this location occurred earlier in the week than would have been expected, probably as a result of commuter traffic, and just under two-thirds of them took place between the hours of 11:00 in

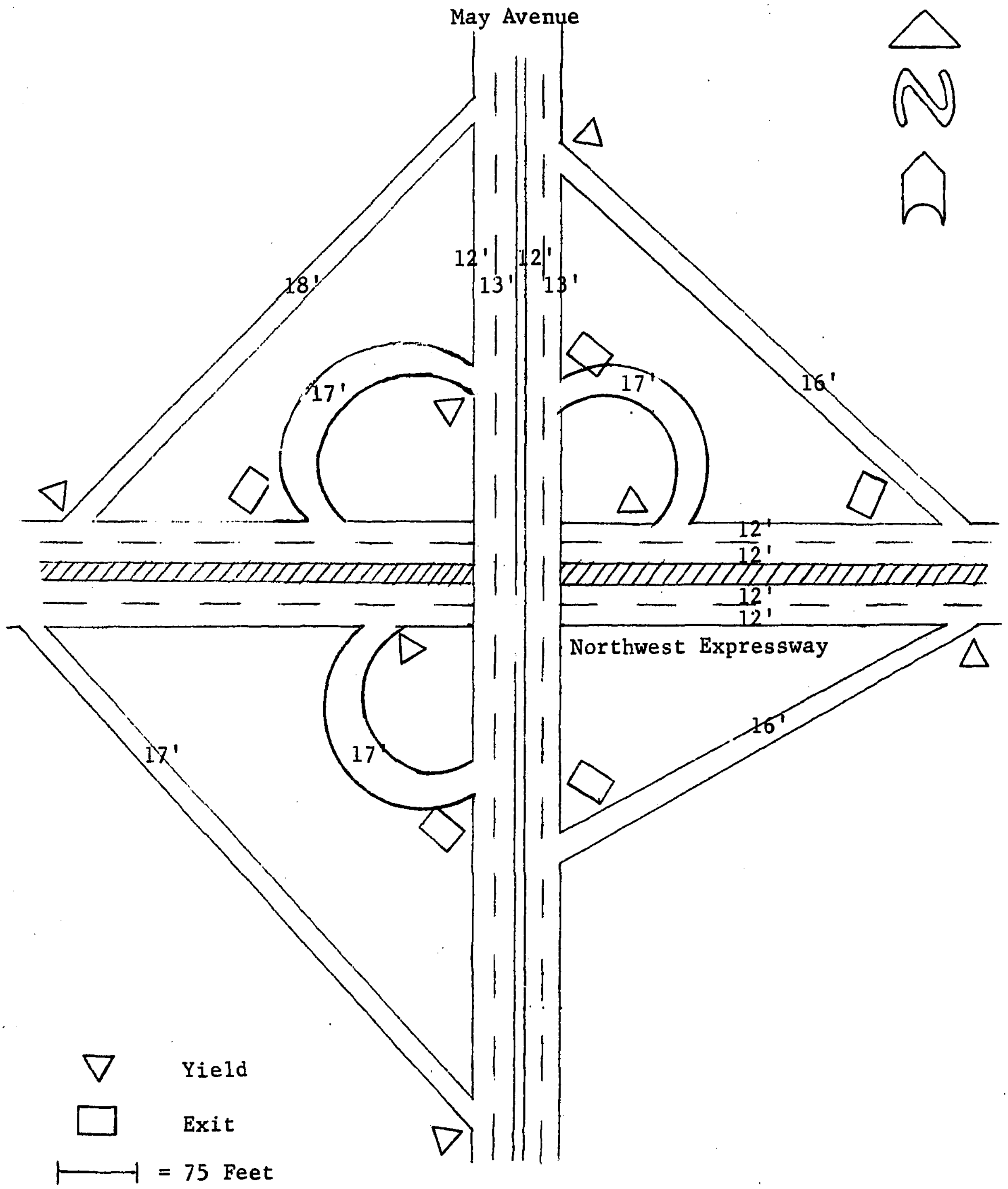

Figure 10. Northwest Expressway and May Avenue

the morning and 5:00 in the afternoon. This was most likely related to the increased noon hour and afternoon rush hour traffic flow.

The most common type of collision at this site was the rear-end type, by an overwhelmingly large margin of 28 out of 30. As a result of this, there was only 1 injury and only $305 average property damage, the least of the 10 locations surveyed.

The primary environmental causative factor in all of these accidents was the lack of entering or exiting lanes from either of the major roadways. Vehicles were impelled to leave a lane of high speed travel, 40 or 50 miles per hour, and immediately slow down to less than 25 miles per hour in order to negotiate the tightly curved ramps. This problem was reversed when leaving the ramp and entering the high speed traffic. With no entering or exiting lanes, smoothness of traffic flow could not be maintained, thus creating a very choppy, stop and go, traffic movement. The addition of these special turning lanes would be expensive in lieu of the minor property damage collisions which were occurring; however, the costs would be offset in only a few years, and traffic flow and accident occurrence would be greatly reduced.

There were two other environmental hazards, whose role in accident causation was not clearly identifiable, but which should still have been remedied. There were no signs on any of the exit ramps stating the safe speed. This was even more important in that the ramps were sharply curved, and would require slow speeds to be negotiated safely. The second problem also concerned signs. The ramps were not clearly marked resulting in drivers missing the ramp entirely or having to jam on their brakes in order to execute the turn. For those ramps that were marked, only three out of seven, the exit signs were located at the junction just beyond the exit instead of before it.

Recommendations for improvement of the driving environment at this location were:

a) the construction of entrance and exit lanes on all ramps,

b) the placement of speed limit signs on all ramps and

c) the relocation of existing exit signs and placement of new ones at unmarked ramps to facilitate better traffic flow and provide the driver with more information upon which to base his driving decisions.

West Expressway and North Meridian

Both North Meridian and the West Expressway (Figure 11) were major access roadways. North Meridian consisted of four lanes plus one lane for left turns only. The West Expressway contained six lanes plus one specifically for left turns. It also had a wide grass median nearly 50 feet across. Both roads were of asphalt and utilized both painted and thermoplastic lane markings. Generally, the thermoplastic strips remained more intact and visible than the painted markings.

The entire intersection was controlled by a traffic actuated signal system, giving more green time to the east-west flow and providing special phasing for left turns. Signal faces were both pole mounted and mast-arm mounted. All four directions were allowed to make a right turn on a red light after stopping. The speed limit on Meridian was 40 miles per hour and on the West Expressway 50 miles per hour.

The roadside area was highly commercialized with gasoline stations on all four corners, each of which had driveways entering both of the

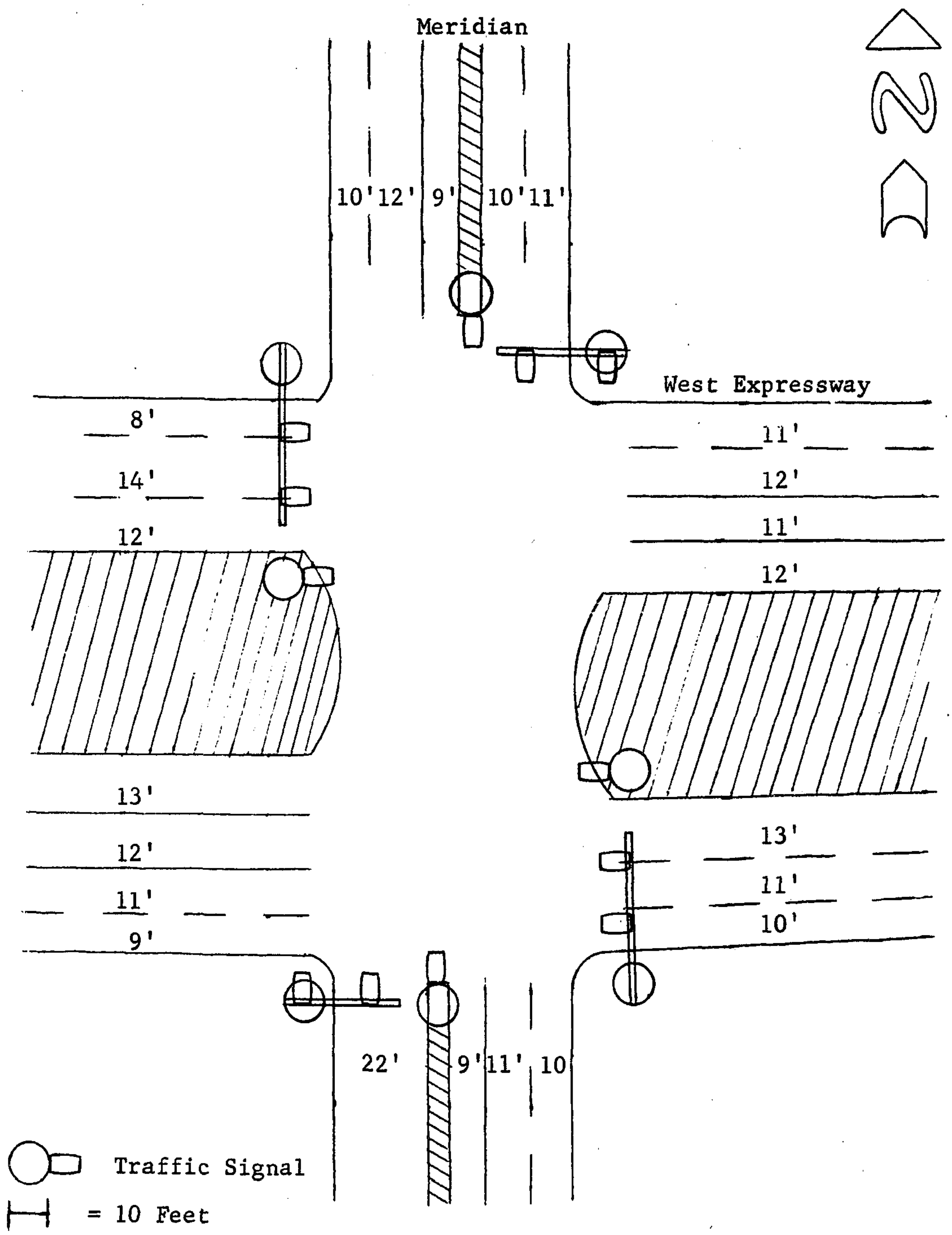

Figure 11. West Expressway and Meridian

major streets. Numerous painted and neon signs provided a poor background for driver visibility, and added one more problem to an already complicated intersection.

Due to the heavy flow of traffic, nearly 40,000 vehicles per day, the accident rate was relatively low, only 0.200 per 100,000 vehicles. This heavy vehicular movement itself was an indirect factor in accident causation.

Collisions here were apportioned throughout the week with the majority occurring toward the latter part (Table 18). Their distribution by the time of day (Table 19) was fairly even with one large peak in the afternoon from 2:00 to 6:00.

Rear-end collisions were the most common type with about half as many left turn and right angle impacts. There were also four fixed object collisions.

The approach to decreasing the accident occurrence at this intersection was one of a systems approach, rather than an analysis of independent factors. To arrive at the causes of these accidents, the entire intersection, as well as the roadside environment, had to be considered.

The left turn collisions all fell into the same category. Vehicles attempting to make a left turn after the green arrow had changed to yellow were struck by oncoming vehicles in the first lane of travel, beyond two lanes of visibility obstructing traffic. These collisions could have been virtually eliminated by allowing a 2- or 3-second red phase following the green arrow to permit turning vehicles to complete their movement safely before the oncoming traffic was allowed to proceed.

The other collisions were of many varied configurations, following no clearly definable pattern. The best explanation for these collisions was that they were simply a result of the overall confusion, heavy traffic volume and numerous distractions present at this location. Both roads were high speed arteries, yet this intersection required many complicated maneuvers including slowing down, turning and changing lanes.

A basic premise of traffic control is separation of vehicles and limitation of their movements as a means of improving traffic flow and decreasing collisions. This was a necessary remedial action at this intersection. A combination of changes including better roadway markings such as arrows to indicate proper movements and all red signal phases to limit access to the intersection to only one group of vehicles at a time were important remedial measures. Synchronization of adjoining intersections would have been an improvement leading to a smoother traffic flow with no sudden stops or turning maneivers.

This intersection has all the necessary lanes and signals, but better utilization of them would have reduced accidents and eliminated much of the confusion. Some of these recommendations were:

a) all red phases between each phase of the signals,

b) extensive, but clear, pavement markings to indicate movement of various lanes and provide better separation of traffic performing different maneuvers,

c) limiting of commercial advertising in the vicinity and placing of business accesses as far away from the intersection as possible and

d) synchronization of this intersection and other adjoining ones to increase smoothness of traffic flow.

Southeast 59th Street and High Street

Southeast 59th Street (Figure 12) was a four lane, two-way road, and High Street was a two lane, two-way road. Both roadways were surfaced with asphalt which was in fair condition on Southeast 59th Street and in very poor condition on High Street with many cracks and holes. In addition to being a side street, High Street, south of this intersection, served as an access road to an interstate highway. The intersection was further complicated by an exit ramp from the highway which emptied onto Southeast 59th Street in a westbound direction.

The roadside area was entirely commercial with two gasoline stations on the northwest and southwest corners of the intersection. There was a large amount of loose sand and gravel throughout the intersection which had a definite adverse effect on vehicle traction, particularly when braking. A large number of trucks used this intersection primarily for entering and exiting the highway, and many had some difficulty maneuvering through the small intersection, particularly in turning procedures.

The only method of traffic control at this intersection was the use of stop signs on High Street. Southeast 59th Street had no method of traffic control. The speed limit on Southeast 59th Street was 40 miles per hour, and there were no speed limit signs within a mile of the intersection on High Street.

This intersection had the lowest traffic volume of the ten locations examined (Table 20) with nearly 90 per cent of the traffic entering the intersection on Southeast 59th Street. Because of this low volume, this location had the highest accident rate at 0.483 (Table 21). The collision pattern with regard to day of week was relatively normal compared with

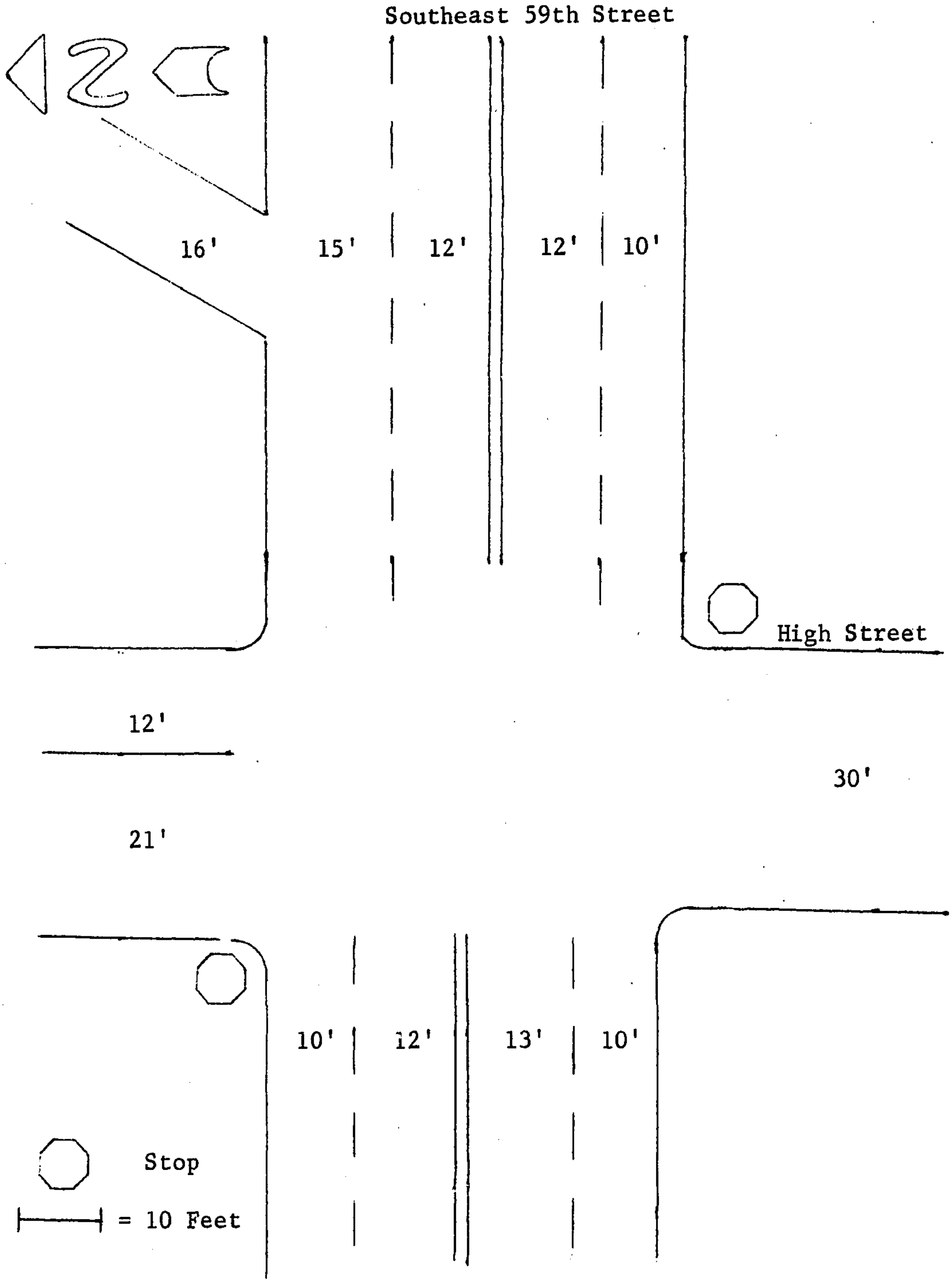

Figure 12. Southeast 59th Street and High Street

that of Oklahoma City as a whole. Large numbers of accidents occurred during both the morning and evening rush period.

Nearly half of the accidents at this site were right angle collisions, which was the expected pattern for non-signalized locations. For the same reason, rear-end collisions, which were more prevalent at signalized intersections, were few in number. There were several left turn accidents, mostly involving vehicles turning south onto High Street to enter the highway.

The basic problem at this intersection was the necessity for the installation of a signal system. The system would be traffic actuated, so as to allow a green phase on High Street only when vehicles were approaching. There was enough room for expansion of Southeast 59th Street to include a left turn lane with s special left turn signal, which would also be utilized only when vehicles were waiting to make a left turn. The remainder of the time, the light would be continuously green for traffic on Southeast 59th Street.

The recommendations concerning this locale were logical ones:

a) the installation of a traffic signal system including left turn phasing to better structure traffic movement through this intersection,

b) the improvement of the performance of some highway maintenance, cleaning the roadway of loose sand and gravel and the repair of the road surface and

c) the construction of a left turn lane on Southeast 59th Street.

<u>Reno and South Western</u>

This intersection actually included three streets (Figure 13). In

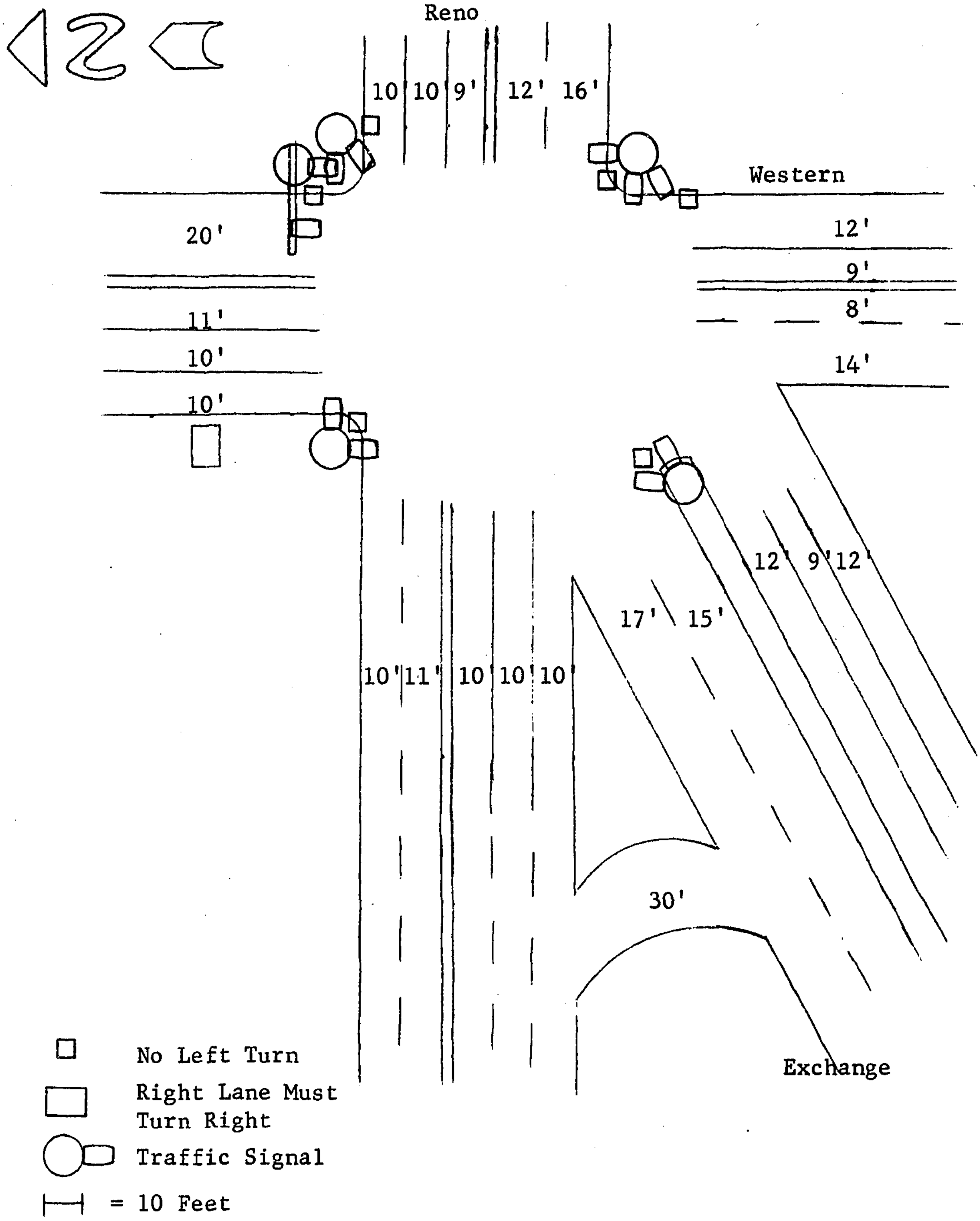

Figure 13. Reno and South Western

addition to Reno and South Western, Exchange Street entered the intersection from the southwest corner. This served to complicate the vehicle movements and increased the hazard of collisions.

All three roadways were asphalt and in relatively poor condition, and there were numerous ruts, cracks and holes. Some of the pavement markings were clear, but most were moderately faded. There were no painted arrows on the roadway. Lane widths were quite erratic, including many lanes of less than 10 feet in width which increased the opportunity for side swipe and lane changing collisions.

Traffic control signs north of the intersection on the southbound side of Western directed traffic in the right hand lane to make a right turn only. Vehicles approaching from the north, south and west were not permitted to make left turns during the morning and afternoon rush periods.

This entire intersection was controlled by traffic signals, all but one of which were pole mounted. North, south, east and westbound vehicles all received the same amount of green time, with the northeastbound traffic receiving slightly less time. The southbound traffic was allowed to make a right turn when the northeastbound traffic had the green light.

The total daily traffic volume at this intersection was over 33,000 vehicles, with an accident rate of 0.237 per 100,000 vehicles, which was seventh highest among the 10 locations included in this study. The accidents at this intersection were related to commuter traffic, in that they occurred evenly throughout the Monday to Friday period (Table 18). All but five of the accidents occurred between the noon hour and the end of the afternoon rush hour (Table 19). Only two people were injured in collisions here, and the average property damage was $450, the second lowest of those locations observed (Table 17). This indicated that the collisions were minor in nature, often the result of a confused driver making a wrong move in a crowded intersection.

Normally, at a signalized intersection, right angle collisions are rare. At Reno and Western, it was the most common type. There were equal numbers of rear-end and side swipe accidents and only three left turn collisions.

With no left turn lanes or arrows, a larger number of left turn collisions would have been expected. There were three alternative factors which limited this type of collision. The volume of traffic making a left turn was only 6 per cent of the total volume handled by this intersection. Left turns were prohibited for eastbound, northbound and southbound traffic during rush hours. To a lesser extent, the vehicle speeds were moderately low here, and drivers were able to stop before striking a turning vehicle.

The rear-end collisions were distributed on all roadways leading to the intersection, indicating a simple lack of smooth flow. This intersection was not synchronized with any others, accounting for this situation.

The large number of right angle impacts indicated that the signal lights were not effectively stopping one lane of traffic before allowing another to proceed. Most likely, an all red phase would have reduced the number of these collisions markedly.

The last type of collision, side swipes, illustrated an interesting characteristic of intersections of the Reno and Western type. The reduction of conflicting movements is primarily a matter of reducing large open areas, such as this one. These open areas multiply the number of conflicts, create lane changing problems through the lack of channelization, they are difficult to signalize, and they are likely to create traffic jams (9).

Eastbound and westbound traffic were forced to change lanes as they traversed the intersection, due to the uneven alignment of Reno. Traffic on Exchange Street found it necessary to make a left turn side by side through an unchannelized intersection into a large open space two lanes wide. These built-in hazards only increase the confusion and burden placed on the driver in making certain decisions while negotiating the intersection.

Recommendations for this intersection could have been generally characterized as simplifying operations. These were:

a) the resurfacing of the entire area and new, clearly discernable lane markings applied,

b) the alignment of the roads improved to eliminate side swipe collisions,

c) the use of an all red signal phase to restrict traffic movements and limit right angle collisions,

d) the increasing of the number and size of signal faces, preferably on mast-arms where they would be more visible and

e) the prohibition of all left turns or the installation of left turn lanes and signal phasing.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Traffic safety is one form of safety which is considered part of the field of public health. With over 50,000 fatalities and 2,000,000 injuries annually it is among the most important public health problems. Neither traffic safety researchers nor public health specialists have yet advanced any effective solution to this problem.

Traffic safety researchers have, for the most part, assumed the theory of driver negligence and therefore, have devoted much of their efforts to the investigation of human variables and to a lesser extent, vehicle factors. Despite their efforts, the number of accidents and injuries have increased annually. Recently, some concern has been expressed over the role of the environment in automobile accident causation. This area of research is most important, since it is the one over which safety researchers have the most direct and immediate control.

The remodeling of antiquated and dangerous intersections has also been shown to be an effective measure in facilitating traffic flow. The frequency of collisions is directly related to traffic density itself.

In this research, the 10 highest accident density intersections in Oklahoma City for 1972 were studied in detail to relate environmental factors to accident occurrence. There were between 29 and 40 collisions at each location. Each of the intersections examined in this study was found to contain certain environmental features which contributed to accident causation. Elimination of these hazards would result in accident reduction.

Equally as important as remodeling dangerous intersections is the design of future intersections with safety features built in. Many of the environmental factors isolated through research should have been corrected in the planning stage before new intersections were constructed. This approach to accident reduction is of a preventive nature, and is compatible with the basic principles of public health.

Through this research, many measures have been discussed to reduce intersection accidents. As a result of this discussion the following conclusions and recommendations were made.

1. Nearly all of the ten intersections studied had one predominant type of collision which was more easily related to environmental factors rather than to driver negligence. At Northwest 36th and Meridian, where no left turn lanes or phases were in operation, 23 collisions of the left turn type occurred during the past year. The same problem exists at the Northwest Expressway and Portland intersection, and at the Southwest 74th and Pennsylvania location. Virtually all of the collisions at the Northwest Expressway and May Avenue rotary were of the rear-end type. This was due to the lack of special turning lanes and not to driver error. As a result of the overwhelming evidence contained in this research the obvious conclusion is that environmental factors do, in fact, play a major role in accident causation.

2. These environmental hazards can be easily identified through investigation of high density accident locations. Common types of collisions can be related to individual environmental components of the particular intersection. It is recommended that a program of continuous evaluation be established to identify hazards and to recommend modifications of these intersections. This program would also include continuous incorporation of these revisions into design and planning for future intersection construction. Similar investigative programs should be established in other major cities to bring about a nationally significant reduction in automobile collisions. Several aspects of each intersection to be considered in this survey include:
   a) organization of intersections into a system to promote better traffic flow,
   b) placement and utilization of traffic control signs and signals,
   c) special lanes for special purposes,
   d) road surface, roadway markings and lane channelization,
   e) signal phases, including left turn, all red and longer yellow phases and
   f) removal of roadside hazards, including visibility obstructions and commercial advertising which interfere with signs or signals.
3. Environmental hazards, once identified, can be easily remedied, usually by minor design changes or addition of special turning lanes and signal phasing. These changes prove extremely worthwhile when evaluated by means of a cost benefit analysis. In most cases,

environmental defects can be remedied for $10,000 or less and thus reduce the annual property damage through collisions by more than $20,000 annually. Even redesign projects costing $50,000 or more would be paid for in only 2 or 3 years through reduced accidents alone, without even considering the reduction in personal injury and medical expenses.

4. There is an obvious need for an improved accident report system to identify the real causative factors in accident occurrence whether human, vehicle or environmental in nature. The present system relatinf virtually all accidents to driver error is a hindrance to automobile accident reduction.

5. Research is still needed in this area and could be accomplished through in-depth investigation of hazardous intersections where large numbers of collisions occur. Some areas of further research include:

    a) designing signal systems and traffic patterns for entire cities to evaluate the effect of improved traffic flow on accident reduction,

    b) investigating the effect of roadside advertisements, such as neon signs and billboards, on driver distraction and inattention,

    c) examining the skid resistent properties of intersection approaches and relating this information to rear-end collisions,

    d) studying the relationship between the dawn and dusk periods and visibility problems as they relate to accident occurrence and

e) evaluating the effect of mass transportation systems on both traffic flow and accident occurrence.

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APPENDIX A

OKLAHOMA CITY POLICE ACCIDENT REPORT

Sheet ___ of ___ Sheets **FATALITY = yes** [ ]

OKLAHOMA

OFFICIAL POLICE TRAFFIC COLLISION REPORT

Reporting Agency : ______

Do not write in this space

No. ______

Date : ______ Day of Week : ______ Hour : ______ AM ______ PM County : ______

—Type or Print—

Distance From ______ Miles N [ ] S [ ] — Nearest City Limits ______ Miles E [ ] W [ ]

Name of Nearest City (If outside city limits)

STATE HIGHWAY CODE

Control No. Int. No. Location

County Number

County Section Line Grid — East — North

City Code

LOCATION

IN ______ city or town

ON ______ name or number of street or highway

AT ______ name of intersecting road or landmark

NOT AT INTERSECTION

______ ft. North [ ] South [ ] OF ______ show nearest intersecting street or highway

______ ft. East [ ] West [ ]

OF: Control Location .... [ ]

Total Number Motor Veh. Involved: ______

No. Injured: ______ No. Killed: ______

Time Notified: Date : ______ Hour : ______ AM ______ PM

Arrived At Scene: Date : ______ Hour : ______ AM ______ PM

Unit 1

AFP [ ]

Driver: ______ last first middle phone no.

Address: ______ street or RFD city and state zip code

License: ______ exp. yr. state number [ ] Operator [ ] Chauffeur [ ] ______ other

Race: ______ Age: ______ Sex: ______ Date of Birth : ______ Mo. Day Year

Highschool Driver Training [ ] Yes [ ] No

Veh. ID No.- ______

Vehicle ______ year make model style ( ) size = { ______ towed vehicle

	Equipped	In Use
Lap belt	Yes No	Yes No
Shoulder belt	Yes No	Yes No
Crash helmet		Yes No
Ejected?		Yes No

License Plate ______ year state number

Owner's Name ______ last first middle phone no.

Address ______

Is Veh. Operable? Yes [ ] No [ ]

estimated speed: ______ MPH legal speed ______ MPH before contact ______ MPH at contact Burned? No Yes $ ______ estimated damage

Veh. removed to: ______ by: ______

Unit 2

Driver [ ] Pedestrian [ ] Animal [ ] Train, etc. [ ]

AFP [ ]

: ______ last first middle phone no.

Address: ______ street or RFD city and state zip code

License: ______ exp. yr. state number [ ] Operator [ ] Chauffeur [ ] ______ other

Race: ______ Age: ______ Sex: ______ Date of Birth : ______ Mo. Day Year

Highschool Driver Training [ ] Yes [ ] No

Veh. ID No.- ______

Vehicle ______ year make model style ( ) size = { ______ towed vehicle

	Equipped	In Use
Lap belt	Yes No	Yes No
Shoulder belt	Yes No	Yes No
Crash helmet		Yes No
Ejected?		Yes No

License Plate ______ year state number

Owner's Name ______ last first middle phone no.

Address ______

Is Veh. Operable? Yes [ ] No [ ]

estimated speed: ______ MPH legal speed ______ MPH before contact ______ MPH at contact Burned? No Yes $ ______ estimated damage

Veh. removed to: ______ by: ______

INJURED or WITNESS or INJ.

#										
1	Injured– [ ] Witness– [ ]	last	first	middle	address	Phone No.	age	sex	race	veh.#	Position in vehicle 1 2 3 / 4 5 6
	Injury Type: A K B C	Head [ ]	Trunk-External [ ]	Trunk-Internal [ ]	Arm Leg [ ]	Crash Helmet: No Yes	Ejected? No Yes	Shoulder Belt: Equipped Yes No; In Use Yes No	Lap Belt: Equipped Yes No; In Use Yes No	ped.
2	Injured– [ ] Witness– [ ]	last	first	middle	address	Phone No.	age	sex	race	veh.#	Position in vehicle 1 2 3 / 4 5 6
	Injury Type: A K B C	Head [ ]	Trunk-External [ ]	Trunk-Internal [ ]	Arm Leg [ ]	Crash Helmet: No Yes	Ejected? No Yes	Shoulder Belt: Equipped Yes No; In Use Yes No	Lap Belt: Equipped Yes No; In Use Yes No	ped.
3	Injured– [ ] Witness– [ ]	last	first	middle	address	Phone No.	age	sex	race	veh.#	Position in vehicle 1 2 3 / 4 5 6
	Injury Type: A K B C	Head [ ]	Trunk-External [ ]	Trunk-Internal [ ]	Arm Leg [ ]	Crash Helmet: No Yes	Ejected? No Yes	Shoulder Belt: Equipped Yes No; In Use Yes No	Lap Belt: Equipped Yes No; In Use Yes No	ped.
4	Injured– [ ] Witness– [ ]	last	first	middle	address	Phone No.	age	sex	race	veh.#	Position in vehicle 1 2 3 / 4 5 6
	Injury Type: A K B C	Head [ ]	Trunk-External [ ]	Trunk-Internal [ ]	Arm Leg [ ]	Crash Helmet: No Yes	Ejected? No Yes	Shoulder Belt: Equipped Yes No; In Use Yes No	Lap Belt: Equipped Yes No; In Use Yes No	ped.

PEDESTRIAN

Injured Taken To :

1. ______ By: ______ Time left scene : ______ Time arrived hospital : ______
2. ______ By: ______ Time left scene : ______ Time arrived hospital : ______
3. ______ By: ______ Time left scene : ______ Time arrived hospital : ______

Damage to property other than vehicles: ______ $ ______ Owner– ______ Address– ______

Investigation made at scene? Yes [ ] No [ ]

Investigation completed? Yes [ ] No [ ]

Operator's report given to driver – Veh. 1 Yes No; Veh. 2 Yes No

Photos taken? Yes [ ] No [ ]

CHEMICAL TEST									HIT & RUN	
Driver #1			Driver #2			Pedestrian				
Yes	No	%	Yes	No	%	Yes	No	%	Yes	No

Name: last first middle — Citation: ______ Citation No. ______

1. ______

last first middle — Citation: ______ Citation No. ______

2. ______

SIGN HERE– ______ (officer's rank & name)	Badge No.	District ≠ Division	Reviewed by: (Initials & Badge No.)	Date of report:

DPS 67 1 Revised Dec. 1970

Unit 1	Unit 2	WHAT VEHICLES WERE GOING TO DO
		1 Go ahead
		2 Turn left
		3 Turn right
		4. Make 'U' turn
		5 Stop
		6 Slow for cause
		7 Start from park
		8 Change lanes
		9. Overtake or pass
		10 Back
		11 Start in traffic lane
		12 Remain stopped / parked
		other

Unit 1	Unit 2	WHAT VEHICLES DID
		1 Went ahead
		2. Turned left
		3 Turned right
		4 Entered 'U' turn
		5 Stopped
		6 Slowed
		7 Started from park
		8 Entered other lane
		9 Overtaking
		10 Backed
		11 Started forward
		12 Remained stopped / parked
		other

Unit 1	Unit 2	TYPE OF ROAD
		1 Oneway road
		2 Alley
		3 Two lanes
		4 Three lanes
		5. Four or more divided
		6 Four or more not divided
		7 Driveway
		8. Turn bay
		9 On ramp
		10 Off ramp
		other

Unit 1	Unit 2	TRAFFIC CONTROL
		1 Stop sign
		2 Traffic signal
		3. Flashing signal
		4. Yield sign
		5 Warning sign
		6. RR gates, signals
		7. No-passing zone
		8 Officer
		9. No control
		other
		10 Abnormal control

Unit 1	Unit 2	ROAD CHARACTER
		1 Straight-level
		2 Straight-upgrade
		3. Straight-downgrade
		4. Straight-hillcrest
		5. Curve-level
		6. Curve-upgrade
		7. Curve-downgrade
		8. Curve-hillcrest
		9. Sharp curve (add to above if applicable)
		other

Unit 1	Unit 2	Ped.	CONDITION OF DRIVERS AND PEDESTRIANS
			1. Apparently normal
			2. Drinking ability impaired
			3. Odor of alcoholic beverage
			4. Very tired
			5. Sleepy
			6. Sick
			7. Condition not known
			Body defects ____ (arm, leg, eyes, etc.)
			other

Unit 1	Unit 2	POINT OF FIRST CONTACT ON VEHICLES	Unit 1	Unit 2	
		1 Front-center			7. Rightside-center
		2. Front-right			8. Rightside-forward
		3 Front-left			9. Rightside-aft
		4. Rear-center			10. Leftside-center
		5. Rear-right			11. Leftside-forward
		6. Rear-left			12. Leftside-aft

	LIGHT		WEATHER
	1. Daylight		1. Clear
	2. Darkness		2. Partly cloudy
	3. Lighted		3. Overcast
	4. Dawn		4. Raining
	5. Dusk		5. Snowing
	other		other

	WHAT PEDESTRIAN WAS DOING
	1. Crossing-at intersection
	2. Crossing-not at intersection
	3. Crossing-at other crosswalk
	4. Getting on/off vehicle
	5. Walking with traffic
	6. Walking against traffic
	7. Push/work on vehicle
	8. Playing
	9. Other working
	other

Unit 1	Unit 2	OBJECT STRUCK BY VEHICLE OR LOAD ON FIRST CONTACT	Unit 1	Unit 2	
		1. Street light pole			10. Traffic control sign
		2. Other utility pole			11 Ditch
		3. Guard rail			12. Embankment
		4. Guard post			13. Tree
		5. Culvert			14. Dividing Strip
		6. Traffic signal			15. Retaining wall
		7. Barrier			Bridge ____ (pier, abutment, etc.)
		8. Curb			Other highway struct.
		9. Island			other

Unit 1	Unit 2	ROAD CONDITION
		1. Dry
		2. Wet
		3. Ice/Snow
		4. Muddy
		other

Unit 1	Unit 2	ROAD SURFACE
		1. Concrete
		2. Asphalt
		3. Gravel
		4. Dirt
		other

	LOCALITY
	1. Residential
	2. Business
	3. Industrial
	4. School
	5. Not built-up
	other

Unit 1	Unit 2	VEHICLE CONDITION	TIRE CHECK U 1	U 2
		1. Apparently normal		
		2. Brakes (Abnormal Condition)	RF	RF
		3. Steering (Abnormal Condition)	LF	LF
		4. Headlights (Abnormal Condition)	RR	RR
		5. Rearlights (Abnormal Condition)	LR	LR
		6. Tires (Abnormal Condition)		
		other		

Indicate North by Arrow

DIRECTION OF TRAVEL

Veh. 1 N ☐ S ☐ E ☐ W ☐

Veh. 2 N ☐ S ☐ E ☐ W ☐

COLLISION DIAGRAM

____ visibility obscured by

Did Location of FIRST Damage or Injury Producing Event Occur on Travel Portion of Trafficway?

Yes ☐ No ☐

____ Defect in Road

REMARKS: (COMMENTS THAT WILL CLARIFY REPORT)
(Refer to vehicles by number)

UNSAFE, UNLAWFUL, OR OTHER ACTION (this section – primarily for general statistics and administrative purposes)

Unit 1	Unit 2	Describe	Unit 1	Unit 2	Describe
		1. Failed to Yield			10. Improper Overtaking
		2. Followed too Closely			11. Improper Parking
		3. Unsafe Speed			12. Inattention
		4. Made Improper Turn			13. Wrong way on –
		5. Changed Lanes Unsafely			14. Improper Start from –
		6. Stopped in Traffic Lane			15. Other Improper Act or Movement
		7. Failed to Stop			16. Not Known – or – No Improper Action
		8. Unsafe Vehicle			17. Other Action – not directly related to collision
		9. Left of Center			18. Pedestrian Action

APPENDIX B

TRAFFIC VOLUME DATA

TABLE 22

TRAFFIC VOLUME DATA

Intersection		7:00 8 AM	8:00 9 AM	9:00 10 AM	10:00 11 AM	2:00 3 PM	3:00 4 PM	4:00 5 PM	5:00 6 PM	Total
Main & Western		2,303	2,068	1,909	1,926	2,299	2,234	3,044	2,374	18,187
NW Exp. & Portland		2,512	2,335	1,651	1,680	2,036	2,624	3,042	3,000	18,880
SW 74 & Penn.	(N)	1,266	934	1,006	1,170	1,346	1,422	1,666	2,010	10,821
	(S)	1,404	994	1,020	1,135	1,398	1,387	1,699	2,062	11,099
NW 39 & May	(N)	1,809	1,921	1,697	1,764	2,163	2,267	2,578	2,665	16,864
	(S)	1,717	1,820	1,536	1,769	2,218	2,312	2,344	2,707	16,423
NW 36 & Meridian		2,410	1,933	1,562	1,381	1,847	2,327	2,767	2,664	16,891
NW 23 & Classen		3,344	3,121	2,638	2,670	3,197	3,134	4,085	3,944	26,133
W Exp & Meridian		3,241	2,352	1,985	1,871	2,734	3,069	3,575	3,869	22,696
SE 59 & High		1,409	1,024	813	735	986	1,312	1,646	1,479	9,444
Reno & Western		2,616	2,179	1,995	1,874	2,262	2,440	3,081	2,629	19,076

NW Exp. & May was not included since no traffic volume study was made at that location.