DISTANCE AND SPATIAL INTERACTION DYSFUNCTION ELEMENTS: THE EXAMPLE OF FATAL TRAFFIC CRASHES IN OKLAHOMA, 1976

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DISTANCE AND SPATIAL INTERACTION DYSFUNCTION ELEMENTS: THE EXAMPLE OF FATAL TRAFFIC CRASHES IN OKLAHOMA, 1976

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PREFACE

This thesis was concerned with the relationship between the residence to crash site distances of traffic fatality victims in Oklahoma and "system stresses" in the road and travel environment. The objectives were twofold. First, to calculate and examine residence to crash site distances for auto-drivers and motorcyclists killed in traffic fatalities in Oklahoma in 1976. Second, to examine, along an urban-rural continuum, the relationship between residence to crash site distance and levels of system stress. Several models were hypothesized which attempted to define the relationship between stress and distance traveled.

Many individuals made this thesis topic viable. The author wishes to express his appreciation to his major adviser, Dr. Keith Harries, for his expertise, wit and wisdom. Appreciation is also extended to other committee members. Dr. James H. Stine and Dr. Steve Tweedie. A note of thanks is given to George Moore, Accident and Records Division, Oklahoma Department of Public Safety, for data availability. A special tribute is due to the former Commissioner of Public Safety, Roger Webb, for his assistance and encouragement. Thanks are also extended to Linda Allred for typing the manuscript.

Finally, I extend many thanks to the faculty and graduate students who have made my graduate residency a most memorable experience.

Although so far away, the final word goes to my parents, brother and sister, for their unending sacrifice, constant encouragement and love.

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CHAPTER I

INTRODUCTION

Background

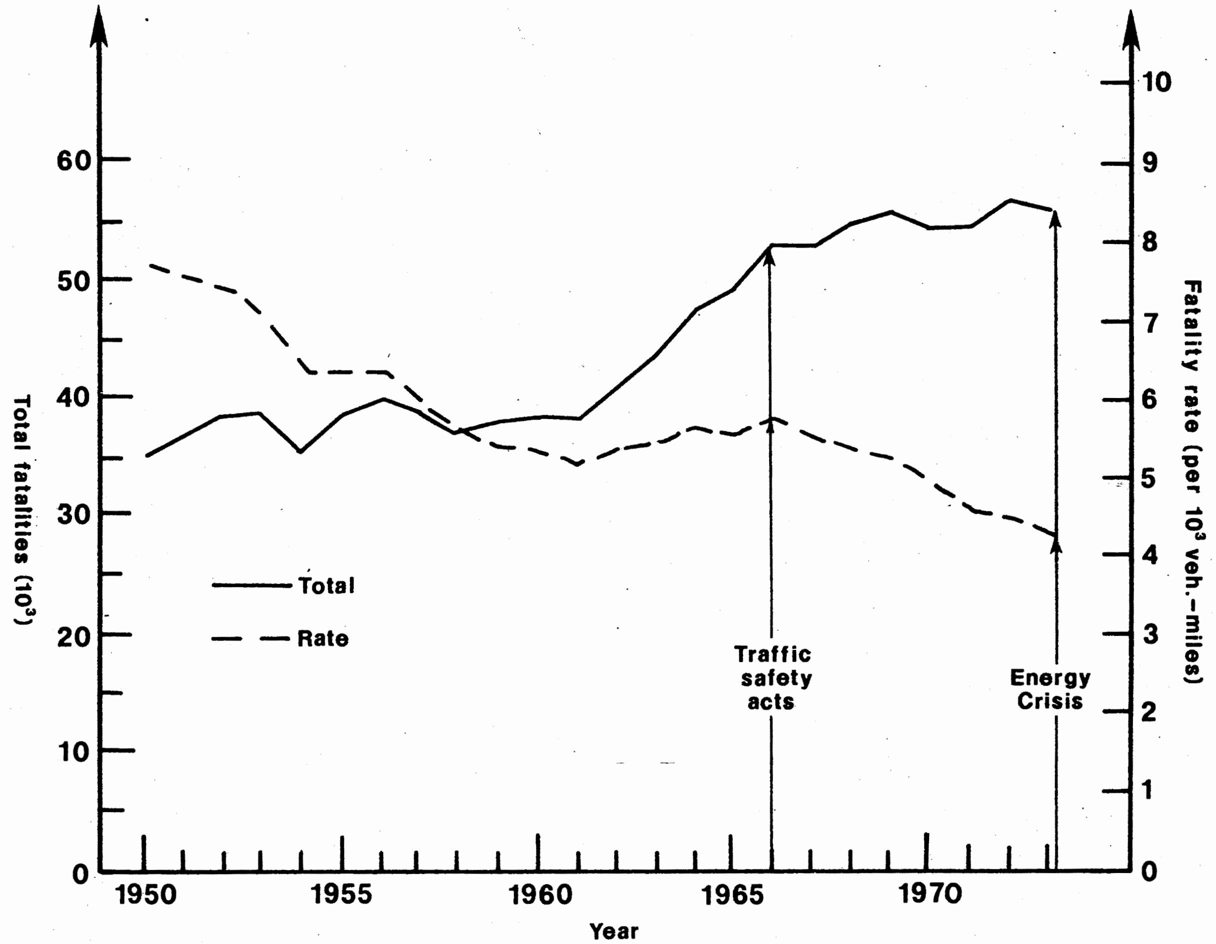
The fatal traffic accident phenomenon continues to be a problem of major proportions in the USA. Since the occurrence of the first automobile fatality in New York City in 1899, more than two million Americans have been killed in traffic fatalities. This figure is three times the number of American armed forces casualties during the past 200 years. In 1976, over 46,000 persons were killed in auto accidents throughout the United States: under today's conditions it is more dangerous to be a motorist than to be a soldier. Not only is loss of life high, but fatal accidents also contribute to more than 10,000 injuries each day, and involve approximately 20 billion dollars in economic losses each year. Furthermore, we have arrived at a situation where fatal traffic accidents rank third behind cardio-vascular diseases and cancer as killers in our society.

It is because of the persistence of such statistics that this research was undertaken. Of interest is the multidimensional framework that encompasses both distance and space. The concern of the author is not so much with the temporal aspects, but rather the analysis of fatal traffic accidents in their spatial context via geographic theory. This research is based on humanitarian motivation. Far too many people are being killed on our roads and highways. It is difficult to set a minimum "acceptable" figure, yet that figure can never be zero; abolition of the auto is an unrealistic solution. In addition to humanitarian principles, intellectual interest and social relevance were motives for the choice of research topic.

Trends in National and State Fatal Traffic Accident Statistics

The statistical picture for traffic fatalities during the 1960's and early 1970's was characterized by continued upward trends. Recently, there has been a significant decline in traffic accident fatalities throughout the USA, as shown in Figure 1. In 1965, the number of traffic accident fatalities was 49,000. By 1968, the figure had increased to 55,000 fatalities, a 12.2 percent increase.[1] Population growth, increased travel mileage, and higher rates of automobile ownership have contributed to this trend. In addition, total travel exposure measured in vehicle miles has grown at an even faster pace. Thus, while the risk of accidents has increased, the actual rate has fallen. In 1950, 7.6 persons were dying for every 100 million vehicle miles, but by 1973 this rate had dropped 40 percent, to 4.4 for every 100 million vehicle miles.[2] (See Figure 1.)

For certain groups of involvees, the risk of an accident has declined, while for others it has increased. Risk, as it relates to the highway system, is defined as the likelihood of a fatal accident for each mile of travel. In 1933, for each individual, the odds against a 100 mile trip ending in a fatality were 70,000:1.[3] As mentioned earlier, the risk of a fatal auto accident has increased. Between the



Source: D. P. Tihanski, "Impact of the Energy Crisis on Traffic Accidents", Transportation Research, Vol. 8, nos. 4-5 (1974), p. 482.

Figure 1. Motor Vehicle Accident Deaths in the United States, 1950-73.

period 1943 and 1969 the odds had deteriorated from 5,550:1 to 3,480:1.[4] On the other hand, reduced pedestrian fatalities indicated lower risk for this group of involvees. In 1937, there were 15,500 pedestrians killed, while in 1968 the chances against being a pedestrian fatality improved from 8,400:1 to 21,000:1.[5]

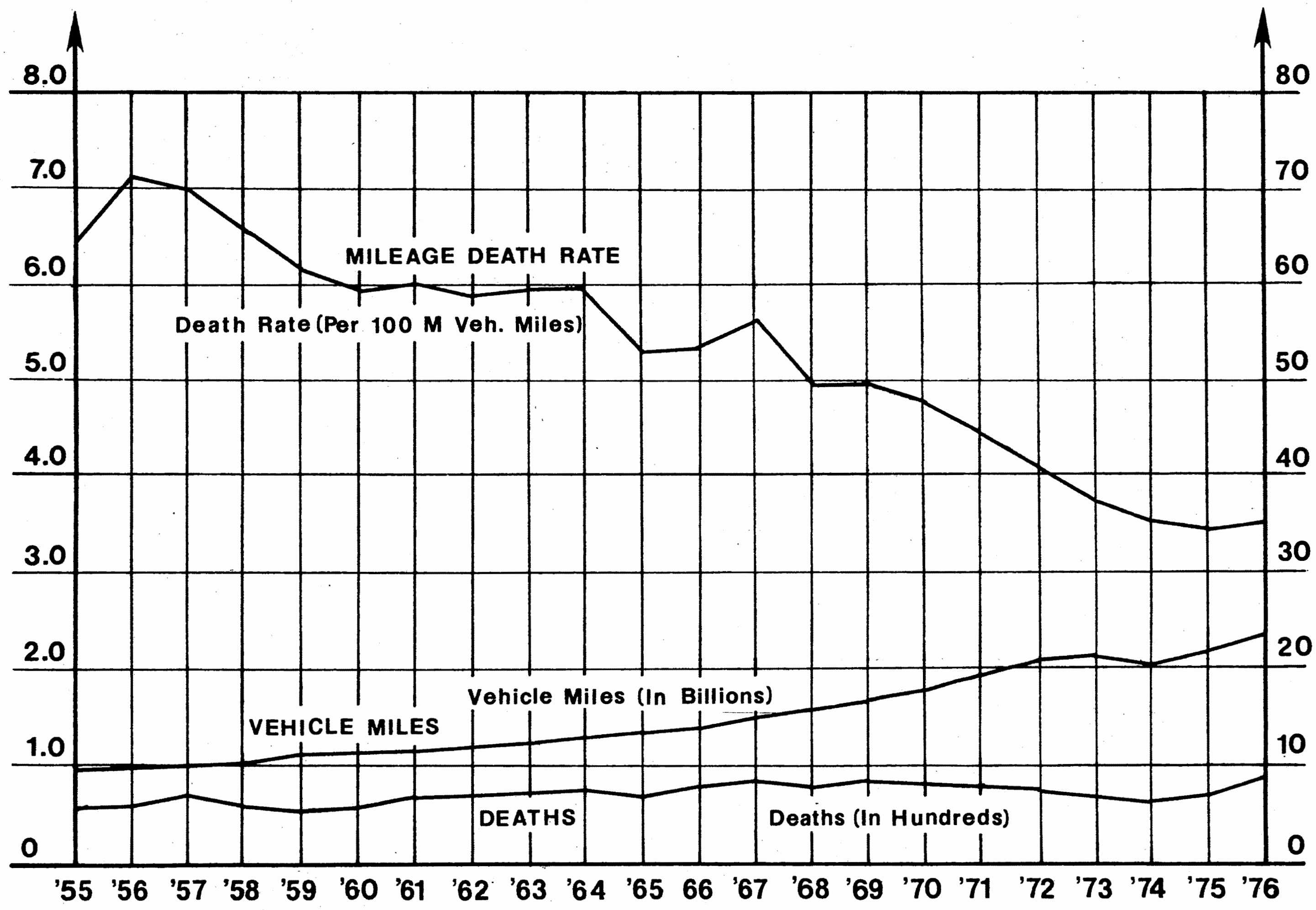
Despite the continued slaughter, the nation's highways have become safer over the years. Engineering improvements in automobiles, improved highway design and maintenance, and highway safety programs have contributed to safer conditions. In the mid 1960's, the Federal Highway Safety and Motor Vehicle Acts were passed with the expressed purpose of lowering the accident toll. This government initiative had no apparent effect upon total traffic accident fatalities. It was only with the recent energy crisis and implementation of the national 55 m.p.h. speed limit that fatal accidents declined. The energy crisis not only accelerated the already falling fatality rate, but the annual death toll was lowered by 0.5 percent relative to 1972 figures. With the passage of the Emergency Highway Energy Conservation Act in January, 1974, thereby establishing an upper speed limit of 55 m.p.h., most states experienced an average 21.0 percent reduction in fatalities by the end of the year.[6] The national benefits of energy-related safety factors were estimated to be in the range $0.7 billion to $2.0 billion over the six month period beginning November 3, 1973.

Fatal traffic accidents are of concern to the states as well. The State of Oklahoma has mirrored the national auto fatality trends over the past decades. In 1976, in Oklahoma, 693 fatal traffic accidents claimed the lives of 838 persons, a 10 percent increase over 1975.[7] Not only was the accident toll high, but property damage figures were estimated at $73 million. The mileage death rate in 1976 was 3.5 deaths per 100 million vehicle miles (MVM); it was the first increase in eight years. Declining death rates in Oklahoma have prevailed since 1956, when a rate of 7.1 per 100 MVM existed.[8] (See Figure 2.) On the other hand, vehicle miles traveled have been increasing steadily since 1957, as shown by Figure 2. In 1973, more than two billion vehicle miles were traveled in Oklahoma. The energy crisis and the 55 m.p.h. speed limit has had little effect on the auto death toll for Oklahoma.

Between 1972 and 1974, the death rate per MVM declined from 4.1 to 3.5 (see Figure 2). In terms of total death toll the figures were 846 and 751 respectively. By 1975, the fatality figures had increased to 763, while MVM traveled increased to 2.5 billion and the mileage death rate decreased to 3.5 per MVM.[9] The energy crisis appears to have had little impact in Oklahoma. What impact there was, was short lived. Yet for the nation as a whole it was very significant. Indeed, the benefits which the energy crisis bestowed upon annual fatality figures were regional in nature. Notwithstanding, the savings in lives has forced the accident problem up out of out national subconsciousness. Bureaucrats and laymen alike are now aware of the benefits of lower speed limits, reduced travel and higher gasoline prices.

A Perspective on Traffic Accident Research

Research into the traffic accident problem is not a new field. Since the turn of the century, research by government agencies and independent bodies has sought to find the causal factors associated with traffic accidents. The direct benefits of research have been manifested in safer automobiles, improved highway design and more



Source: Oklahoma Traffic Accident Facts (Department of Public Safety)

Figure 2. Oklahoma Traffic Trends, 1955-76

intensive law enforcement. Although research is voluminous in every aspect of the field, the impact of the research has not been as great as it could have been; one is led to wonder why the fatality numbers have not been reduced even more. While direct research benefits prevented traffic fatalities and reduced the severity of injuries, it was the energy crisis alone which had caused a large but short term decrease in fatal traffic accidents.

The much discussed and calibrated epidemiological approach provided the focus for traffic accident research after WWII.[10] In its simplest form, this approach treats accidents as diseases, it suggests that accidents result from a multiplicity of causes. This conceptualization of the origin of accident generating circumstances is useful in seeking measures to control accidents, since both the prior existence and the quality of causal factors imply that preventive measures are possible.[11] Gordon grouped the causal factors into three categories, (1) host, (2) agent, and (3) environment. The host is the person involved in the accident occurrence, the agent is the instrument or factor causing the injury, and the environment is a group of both localized and large scale factors (social and physical) that are associated with the accident. As applied to traffic accidents the host is the involvee, the vehicle the agent, while the environment is the larger set surrounding the accidents.

Within this influential approach, two lines of thought have been concentrated upon. First, the driver has been continuously blamed for fatalities; his failure is either physical or mental. With physical failure accidents can be reduced by improved driver safety education. On the other hand, the effectiveness of driver education programs, as presently constituted, has not been scientifically established.[12] In the latter type of failure, psychologists attempt to show, that some drivers, are less capable than others in evaluating road hazards. Lefeve[13] has used the word "accident prone" to describe this mental failure; the popular conception is of the "nut behind the wheel". The problem with this notion has been its endorsement by behavioral scientists, manufacturers of motor vehicles, safety educators and officials who regard enforcement as the key to traffic fatality prevention. While this view is relevant to some problems in the field, it is a narrow point of view. It has been stated that, ". . . Even when the magnitude of the human element in a certain kind of accident can be accurately assessed, it is important to note that its sheer magnitude does not inevitably make it the most appropriate target for preventive measures."[14]

In an innovative piece of research, Moellering[15] divided traffic accident research into four areas, vehicle characteristics, human physical factors, roadway factors and the behavioral approach. Vehicle characteristics research has dealt with every aspect of vehicle design, handling, safety and performance. Efforts are focused primarily upon impact collision between vehicles and other vehicles, and vehicles and fixed objects. Many private and governmental agencies carry out this type of research; for example, the Hit-Lab reports. Human physical fac-factors research is concerned with the interior of the vehicle. Investigations in this area examine what is known as the second[16] and third[17] collision.

Roadway features and their relationship to traffic accidents has been a big area of study by engineers. The most worthwhile studies have continued along the line of hypotheses testing. Smeed showed that the volume of traffic flow is related to accident frequency.[18] Others, such as Lundy, demonstrate a relationship between number of lanes and traffic accidents.[19] Much attention has been focused upon type of road surface, and gradient of highway. Research on number of accidents and traffic volume was used to demonstrate the urgency of improved highway conditions at locations in the road network which have a high volume of traffic. Locations affected were predominantly intersections.[20]

The final area of research, the behavioral approach, focuses upon a broad socio-economic analysis which attempts to link driving behavior with other aspects of the drivers social milieu.[21] Concentration of research has been in the area of alcohol related traffic deaths,[22] but studies now focus upon biographical and medical aspects of the driver involved (age, sex, occupation, family background, education, etc.). Psychopathology has focused upon social stress and acute disturbance among fatality victims.[23] At present, research in this sector can be divided into two classes (1) research concerned with the prediction of future driving performance, and (2) research concerned with the development and modification of driving habits. This research may be useful to administrators and law enforcement officials in identifying the problem driver.

The philosophy behind these areas of research has been based upon the notion of epidemiology, whereby the host-agent-environment concept has been applied to fatal traffic accident research. Most epidemiologically based studies maintained the following format: (1) identification of causal factors (2) development of preventive measures directed toward the causes (3) periodic evaluation of <u>accomplishments from the program instituted</u>. It has been recognized that the extension of this medical cause and effect analysis to highway safety introduced a problem related to the delineation of causes, i.e. which are the direct and indirect causes? Various technical disciplines develop preventive measures based upon the causal factors. Since there is no general agreement as to what constitutes cause, then the preventive measures have not been absolutely preventive. Instead, prevention has meant reducing the severity of accidents. In contradiction to this approach stand the systems theoreticians.

Much of the above research involved micro-studies. It was not until the systems approach became fashionable that a holistic view was taken. Studies by Recht[24] and Allegier and Yaksich[25] considered the total environment in identifying independent variables. Systems theory leads to viewing accidents as random events; accidents are a chance event which could occur to anybody. This school contends, in effect, that any driver-vehicle-highway combination is both safe and unsafe.[26] Accidents supposedly occur when the control system is inadequate at the wrong time. Cause is thus explained by difference in number of exposures and probability theory. The systems engineering exponents conclude that preventing accidents through improving the transport system is a more fruitful approach.[27] In summary, the greatest differences between the systems and epidemiological approach is their point of departure for analysis and the size of system under study.

In each of the above mentioned areas the spatial approach has been lacking, i.e. the utilization of geographic theory to analyze fatal traffic accidents has been negligible. Studies related to the location of occurrence of traffic fatalities has been considered to some extent, but not by geographers. The notion of location of occurrence was first used in 1949.[28] Since then, studies by Nuller[29] and Becheler and Marchal[30] have developed location of occurrence as a delimiting factor in traffic accident research, and it has been used both as a method of classifying accidents and in determining future accident locations.

This approach presents many possibilities for geographers, who could focus on the relationship of fatal traffic accident locations and land-use. The location and distribution of accident prone drivers in a large metropolitan area is another research topic which may prove valuable to traffic safety officials. More importantly, geographic concepts such as spatial interaction, areal association and distance, can be applied to this field thereby injecting new ideas and contributing to a deeper understanding of the problem.

Aims, Expectations and Organization of the Thesis

This thesis focuses upon the notion of distance as it relates to fatal traffic accidents in Oklahoma. It is primarily concerned with the anatomy and the characteristics of residence to crash site distances. The distance parameter was first used by Moellering,[31] where the aim was to determine the factors and characteristics behind residence to crash site distance for various categories of involvees. Trips undertaken by traffic fatality victims involved the process of movement over space, and hence, distance between two or more points.

Given the presence and persistence of <u>Spatial Interaction Dysfunction Elements</u> (SIDE) in the road and highway system, the distance traveled between residence and crash site can be seen as a reflection of their presence. "Stress" is another word synonomous with SIDE, and it is expected that distance traveled will vary with the level of stress in the system. Hence, the end point of the distance traveled, the fatal traffic accident site, is the location where stress is maximized.

In concluding his analysis of roadway and traffic accident data, Versace stated that

> . . . there are more accidents at those places where the situation places great demand on the momentary-perceptual-decision motor capacities of the driver. The driver's basic psychological capacities are heavily exercised when he must deal with a situation around him that is changing rapidly. This occurs when the traffic situation or conflict is greater, that is, where one encounters more cars . . . Accident frequency is proportional to the rate or load of demand placed on the driver's basic ability to perceive and cope with the situation.[32]

In this study, residence to crash site distance within the state of Oklahoma is expected to vary with the level of traffic friction or conflict.

The type of traffic situation and traffic conflict that Versace mentions is composed primarily of SIDE. What emerges, eventually, is a cumulative stress surface that displays geographic variations over a state (Oklahoma in this case), region or urban area. As the traffic situation or conflict varies over space, so the "momentary-perceptual-decision motor capacities" of the driver will vary as well. This type of stress needs to be distinguished from a second, that which the driver faces and undergoes the greater the distance traveled. An inverted distance-decay relationship exists, such that mental stress and fatigue on the driver increases with the length of the road journey. Both types of stress can be simultaneously present on a driver within an area, yet it is also conceivable that one can be present without the other. For example, long journeys in rural areas place mental stress upon the driver, yet the SIDE are likely to be at a minimum within this locational setting.

Traffic situations or stresses on the road system are composed of several elements. Average daily traffic, as measured for the State's road system, is one such element which varies with distance, especially from a rural to urban continuum. The short residence to crash site distances which are expected to prevail in metropolitan areas (Oklahoma City or Tulsa) are associated with high levels of traffic friction or stress, such as average daily traffic, in the system. Such a relationship ought to display a distance-decay effect. Conversely, where the average daily traffic is comparatively low, for example, in rural areas of the state, residence to crash site distances are expected to be relatively longer. Accident frequency, as measured at the county level or by distance increments, can be regarded as another element of stress displaying geographic variation. One would expect an association between high accident frequency areas and short residence to crash site distances, and vice versa.

As a consequence, residence to crash site distance is expected to vary over space; i.e. in Oklahoma there is expected to be a difference between the urban and rural counties of the state. In the rural counties, the low density population distribution and spacing of central places entails greater traveling distances as compared to the eastern part. In the urbanized counties, the presence of large urban centers means that distances separating central places will be shorter. Relatively higher density population distributions between these closer central places entails shorter distances and more fatalities.

General Hypotheses

Several hypotheses are to be tested in this research, some of which have already been alluded to. The fundamental hypotheses of this research are that:

1. The dysfunction elements (stresses) are reflected in the residence to crash site distances. Hence, the distance traveled will vary with the level of stress in the system.

2. There are expected to be differences between the urban and rural counties of the State of Oklahoma as regards the residence to crash site distance for groups of involvees.

3. Fatal traffic accidents will tend to cluster in space, especially where the SIDE are at a peak. Hence, a clustered pattern of crash sites is expected, as opposed to a random or uniform one.

While these hypotheses are general, they do indicate the questions which this thesis will attempt to answer.

The relationship between distance and SIDE is not viewed as being totally dependent. SIDE such as congestion, traffic volume, and road density, etc. may be present prior to the fatality and are causal factors in fatalities. For example, variations in average daily traffic flow will affect not only the distances traveled but the fatality frequency as well. If "stresses" had no effect upon the distances traveled by involvees, their trips would have been successful; origin and destination points, and vice-versa, would have been reached thereby completing a movement circuit within the road system, and the spatial interaction process as well.

To this extent, it is proposed to analyze, using several methodologies, the influence of several dysfunction elements on the residence to crash site distance. Residence to crash site distance is seen as the dependent variable. It is also valid to have distance as an independent variable so that it becomes part of the SIDE. In this case the dependent variable would be accident frequency or total fatalities. Independent variables are made up of the SIDE and driver characteristics. To this end, they comprise several of the variables used by Moellering in his distance study. These variables include traffic volume, population density, type of land use, age of involvee, weather condition, time of day, and road density, etc.

The above variables are not complete nor defined, that will take place in Chapter II, but it is imperative to note that several bear no relationship to distance as the dependent variable. Most of them would be viewed as causal agents of fatalities. Yet it can be argued that their presence has affected the residence to crash site distance. This analysis will cover fatality information for the year 1976. It is assumed that the fatal traffic accident situation for 1976 has been the cumulative result of past increases in levels of spatial interaction and dysfunctional elements.

While the main focus of research is on residence to crash site distance, it is necessary to consider the locations of fatalities and residences. If, as the engineers say, traffic accidents are random events, in a statistical sense, then it is expected that the locations of the fatalities should be random as well.[33] The theoretical expectation differs from the author's intuitive expectation. Most fatalities are expected to cluster at several locations where stress is maximum, i.e. at single and multiple locations within an area of Oklahoma. In addition, it is expected that residence to crash distance will be relatively short. Conventional wisdom has it that most fatal accidents occur within 25 miles of the involvees residence. If this is the case, then it raises questions as to the type of trips that were undertaken. Furthermore, if one considers the entire fatal accident set, then the question of variations in SIDE is brought into focus.

Significance of the Study

Research objectives and expectations, as outlined above, may be useful to state traffic authorities and public safety officials. Simple measures of residence to crash site distance, in combination with locations of fatality occurrences and residences, may lead to better manpower allocation and traffic code enforcement than at present. The presence of additional policemen at high frequency accident locations, or within a high driver stress area, may prove effective in preventing fatalities.[34] Where longer residence to crash site distances prevail, an effort should be made to examine the locations of occurrence in relation to location of hospital and ambulance services. Of interest here would be time savings between ambulance service notification of an auto accident and arrival at the accident scene, and time savings between departure from the accident scene to hospital location.

If the findings of this research belie the expectations, then the research has not been a futile attempt at model building, or in reiterating what is already known. The research would still have been of intellectual interest for it would have provided an opportunity to apply a geographic concept in an area which lacks such a perspective, and which is troubled by a lack of interdisciplinary research.

In Chapter II of this research, attention is placed upon a deeper discussion of the distance literature and the development of a distance and spatial interaction dysfunction model. Chapter III is a discussion of data, data sources and methodology. Following this, data is presented on the fatality situation in Oklahoma. Chapter IV also analyzes the results and presents a graphic and tabular evidence of residence to crash site distance, the characteristics of this distance and its geographic variation. Chapter V discusses the results of the model. The final chapter is a summary of the results, with a discussion of the implications of the study for Highway Safety and Transportation bodies.

FOOTNOTES

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[28]Smeed, op. cit., pp. 9-13.

[29]Norman A. Miller, *Rural Intersection Accidents* National Research Council, Bulletin 91, No. 334 (1968).

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CHAPTER II

DISTANCE AND FATAL TRAFFIC ACCIDENTS: A CONCEPTUAL MODEL

Models of Fatal Traffic Accidents and Highway Safety

Introduction

A multivariate apparoach to the persistent and escalating traffic accident problem became popular in the mid 1960's. Accident causality was defined operationally, and the basis of this approach was that any accident had multiple causes. Enmeshed in the multiple-causality doctrine were the factors: "vehicle-man" and "highway-system". These interdependent and random variables were utilized in multiple regression equations which attempted to, " . . . optimize that solution which comes closest to predicting the most accidents."[1] Unfortunately, many such models concentrated too heavily on the interaction of the vehicle-highway system; little attention was given to the human factors in highway safety.

System Models

Literature cited in Chapter I bears testimony to the proliferation of the systems approach. In addition, studies by Snyder,[2] Agent,[3] Goeller,[4] and Cirillo[5] have focused on specific problems and new relationships. Most studies have been oriented toward problem solving efforts, with the ultimate aim being the improvement of the vehicle-highway system and the prevention of fatalities. For example, the study by Cirillo was specifically concerned with modeling the relationships between accidents and the geometric and traffic characteristics of the interstate system. Nineteen models were developed and calibrated for relationships of accidents to acceleration lanes, loops, ramps of a diamond and underpass units, etc. The general findings indicated that changes in the standards for geometrics of the inter-state system would not appreciably alter the accident experience of the system.[6] Basically, the study was practical and aimed at highway planners, designers and engineers.

Other studies, by Head[7] or Schoppert,[8] have also utilized the multivariate approach. Schoppert, for example, developed multiple regression equations which were used to predict accidents on rural two-lane highways from roadway elements. His findings were, in essence, practical solutions: accidents increase, (1) when vehicle volumes increase, (2) access points increase in number, (3) sight distance is impaired, and (4) the cross section is reduced. Hence, eliminating such features on rural two-lane highways would reduce accident frequency. In addition, his analysis of data confirmed the theory that accidents are essentially chance occurrences resulting from errors in judgement.[9] On the other hand, Head's study modeled the relationship between traffic accidents and roadway elements on urban extensions of state highways. Again, his findings were practical solutions. The number of commercial units adjacent to urban highway sections, the number of traffic signals, and the number of traffic lanes and traffic volume were the major predictors of traffic accidents on urban extensions of state highways.[10]

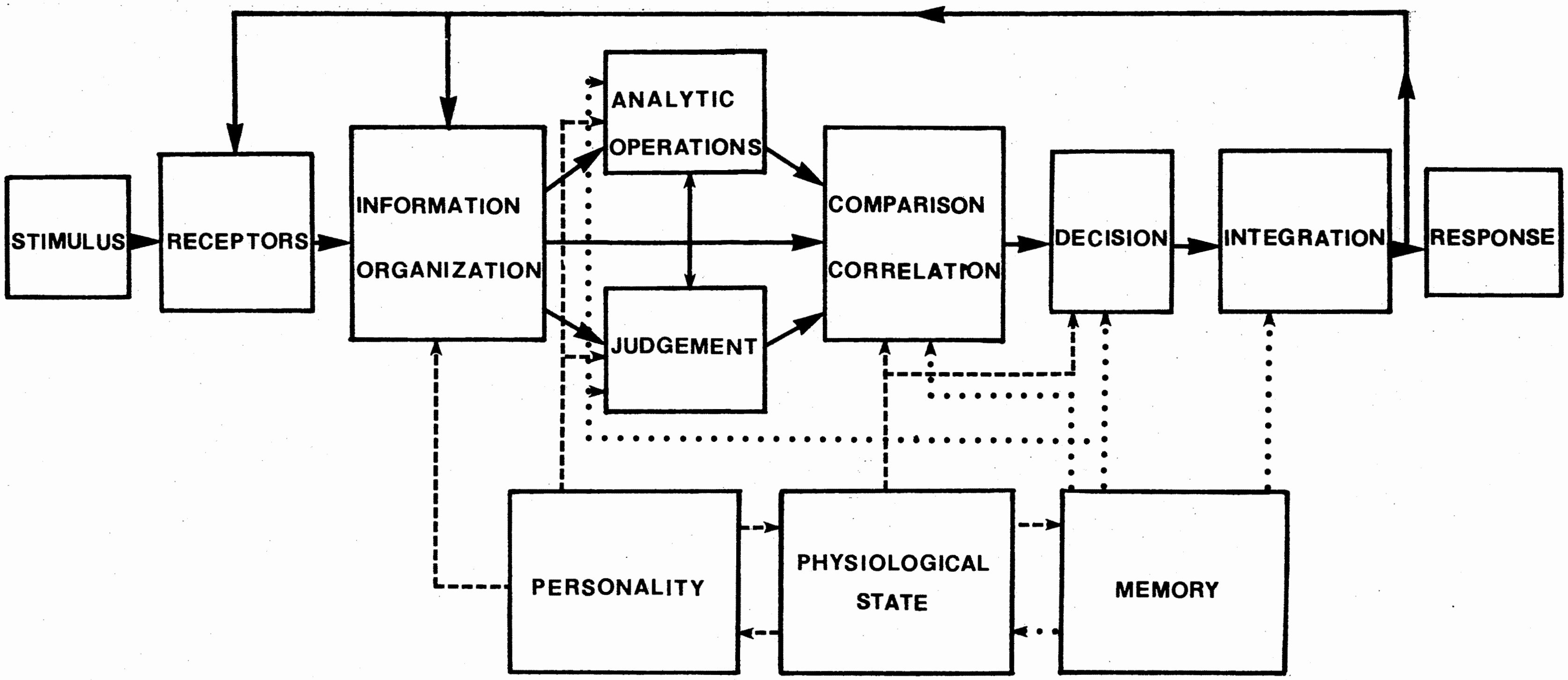
Such modeling efforts have been of unquestionable value to man because practical solutions have been found to some simple problems, yet the thorniest problem of all is still with us. Dependent and independent variables are clear cut in these modeling efforts. Not surprisingly, the human factors have been omitted or briefly mentioned in passing. Residence to crash site distance is another obvious omission. Most variables used are inanimate and, hence, easily quantifiable, while the human variables are not. More importantly, the consideration of human factors such as perception, psychological stress or socio-economic characteristics are, (1) difficult to model because of micro and individual levels of concern, and (2) difficult to place in a linear theoretic framework. Yet researchers have begun to consider human factors and significant progress has been made, for example, in identifying "accident prone" drivers, and linking the findings to improved driver safety programs.[11]

Human Factor Models

Two studies which have developed human factor models are worthy of note. Michaels departed radically with the systems theoreticians for his focus was upon driver errors in the highway system.[12] Thus, in order to minimize driver errors, the objective of highway safety is to increase the reliability of the driving system rather than the study of accidents. Given that all drivers have varying capacities required by the driving task, Michaels develops a model of the demands which the driving task places upon the driver. Figure 3 shows the complexity of human behavior required by the driving task. As Michaels states, " . . . it is the ways in which the demands of the task are adopted to the characteristics of the human being that will determine the safety or reliability of the highway transport system."[13]

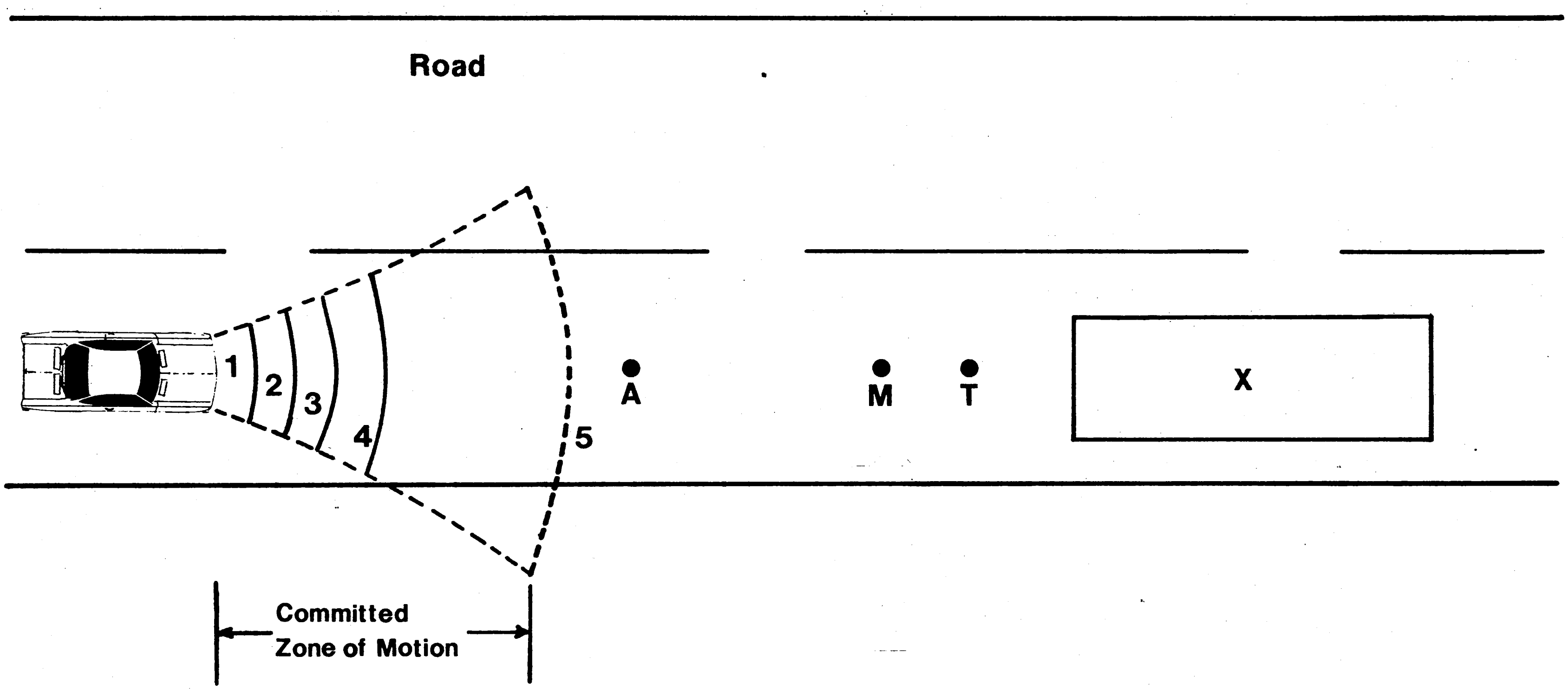
Thus, viewing the input and output side of the model many factors will determine the response. "In essence, driving requires man to function as a guidance system . . . the accuracy with which man can solve the guidance equations will, in part, determine how reliable the system functions."[14] Incorrect responses cause driving errors and, hence, accidents. This model captures human information processing in a spatial setting, although the author does not appear to be conscious of this. The stimulus-response mechanism occurs in a spatial environment, an environment represented by "spatial interaction dysfunction elements" and a road system. While sharp or frequent curves, fast changes in speed, or rapid changes in location require processing and response, the SIDE and distance traveled are also stimuli that affect response and probability of error.

A second model is that developed by Vanstrum and Caples.[15] It is a perception model that relates, "driver perception and action to hazards on the road." Perception can be classified as a human precrash factor and since it is difficult to quantify, the authors attempt to model it. Figure 4 demonstrates the perception model where a vehicle moves along a roadway with a committed zone of motion (bands 1-4). Area 5 represents minimum vehicle stopping distance based on vehicle weight, speed and braking efficiency, etc. This zone could be larger or smaller depending on the driver's perception. Box X indicates a



Source: R. M. Michaels, "Human Factors in Highway Safety," <u>Traffic Quarterly</u>, 15 (1961), pp. 586-99.

Figure 3. A Simplified Representation of Human Information Processing



Source: R. C. Vanstrum and G. B. Caples, "Perception Model for Describing and Dealing with Accident Involvement in Highway Accidents," Highway Research Record, No. 365 (1971), pp. 17-24.

Figure 4. A Driver Perception Model

hazard up ahead (on-coming vehicle, pedestrian, curve, etc.) Point T is the true point, the last point at which action can be initiated to avoid the hazard. Point M is the mental point or the driver's perception of the true point T. Point A is the action point, where the driver decides he will take action. These points and committed zones of motion are changing every second.

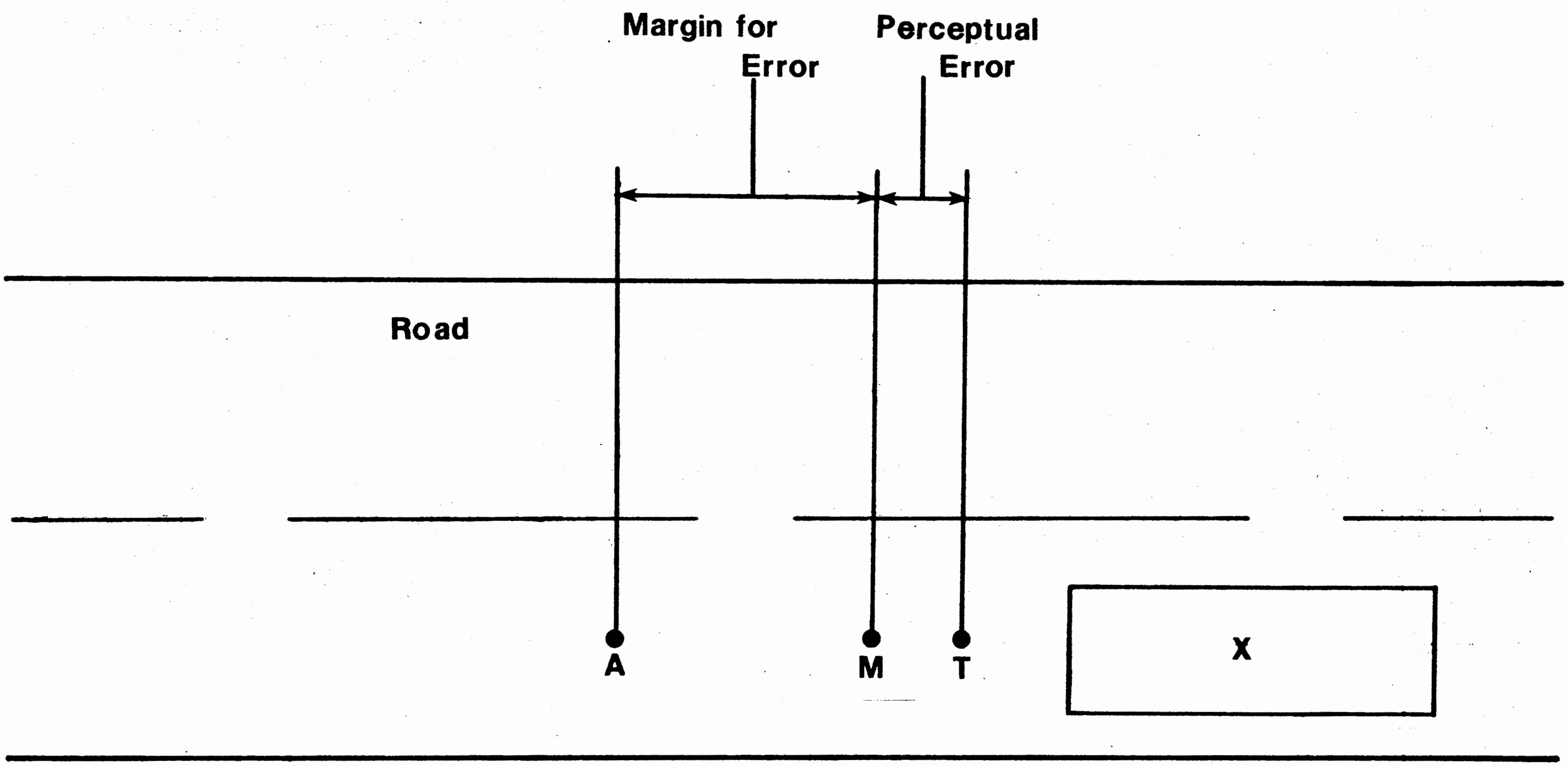
That the process is perceptual is shown by Figure 5. The distance between points T and M is the perceptual error, while the distance between points M and A is the driver's margin for error. According to the authors,

> the mental point M can be ahead or behind the true point T and, if no perceptual error is involved, it coincides with point T and the distance between points T and M is zero . . . generally. This distance is a plus or minus quantity . . . For most drivers, the distance (between M and A) is positive . . . He allows some margin for error.[16]

Hence, the interaction between points T and M, perceptual error, and points M and A, margin for error, determines whether an accident results. Two benefits are seen from this perceptual modeling procedure, (1) perceptual error is the proximate cause for most preventable accidents, it is the factor common to most accidents out of a myriad of factors possible in the chain of cause and effect, (2) the perception model indicates that accidents can be prevented by increasing the margin for error, making the perceptual error always positive, and by making it as small as possible. These are practical solutions, which through driver safety programs can develop larger margins for error.

Spatial Models of Traffic Accidents

Preoccupation with the modeling approach has been extensive in



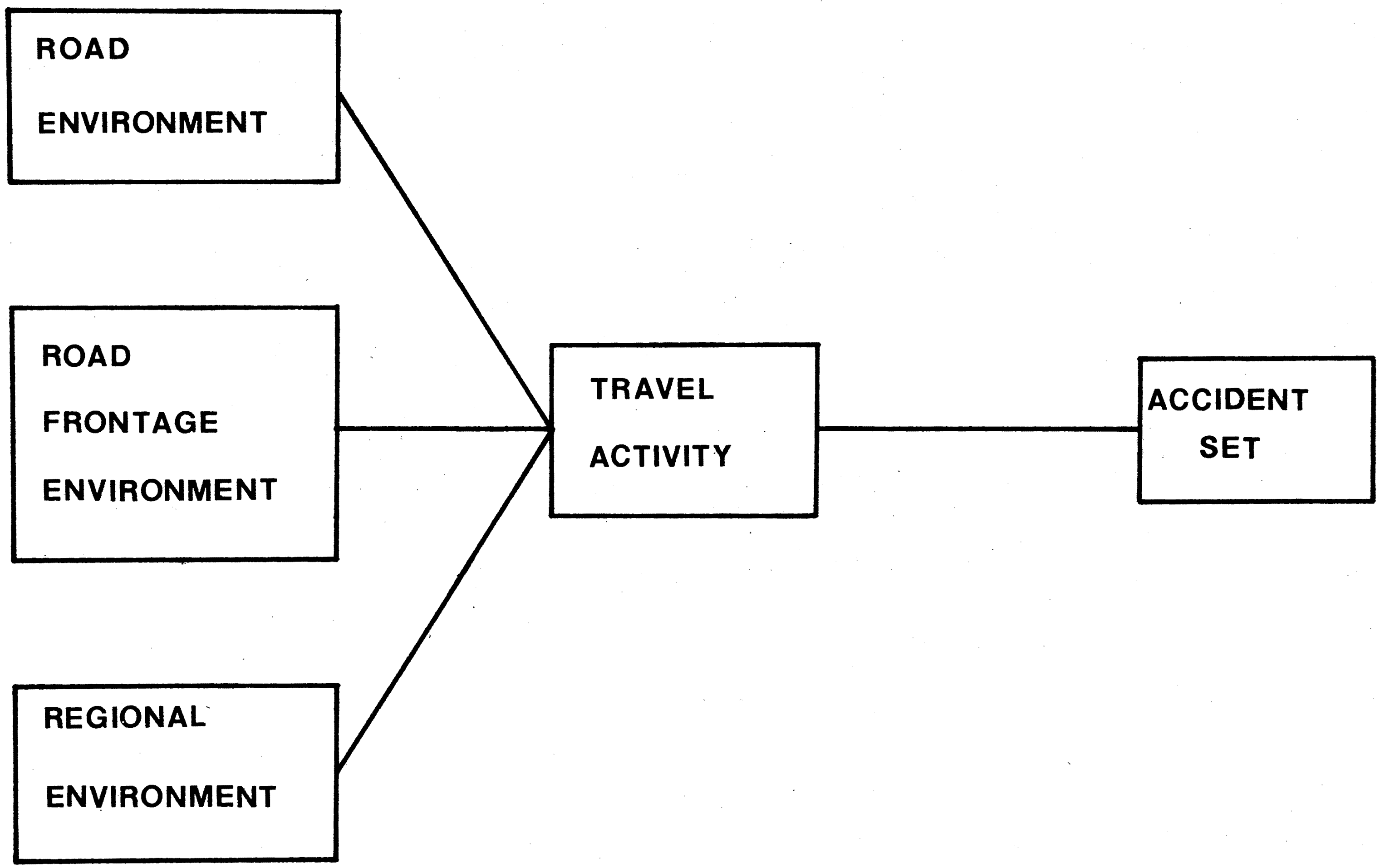
Source: R. C. Vanstrum and G. B. Caples, "Perception Model for Describing and Dealing with Accident Involvement in Highway Accidents," Highway Research Record, No. 365 (1971), pp. 17-24.

Figure 5. Driver Margins for Error and Conceptual Errors

geographic research, yet the modeling of traffic systems or of traffic accidents has been negligible. Only three research efforts exist in geography which deal with fatal traffic accidents: all three attempts will be discussed below. Movement theory and the modeling of traffic accidents would appear to be complementary, for the traffic accident is the end result of a movement process upon some linear surface, a process that involves both distance and spatial interaction. Even traffic accident research does not focus upon movement and distance, or movement and fatalities.

Early Studies. The study by Woods[17] was a primitive attempt at a spatial analysis of traffic accidents. Being mainly a location study, it concentrated upon the location of fatalities and the causes of fatalities. It did not attempt to answer the question of why fatalities occurred where they did, but only why they are caused. Woods set up his model whereby "accident-rate" was the dependent variable. Independent variables ranged from total number of motor vehicle accidents, square mile area of the counties and number of miles of hard surfaced roads, to per capita income and percent non-white. A low r-square value showed lack of causality among the choice of variables. More information was gained from the cartographic analysis than from the model building exercise. Wood's model was simple, with no proper relationship of dependent to independent variables.

A more improved and comprehensive approach was taken by Snyder when he considered the regional road and road frontage environment as a determinant of traffic accidents.[18] A total of 21 independent variables were considered. Figure 6 shows the conceptual model. The road,



Source: J. C. Snyder, "Environmental Determinates of Traffic Accidents," (Unpub. Ph.D. dissertation, University of Michigan, Ann Arbor, 1971).

Figure 6. A Conceptual Model of the Environmental Determinants of Traffic Accidents

road frontage and the region are elements of an environment in which travel activity takes place. Travel activity has certain characteristics (drivers, vehicles, origins and destinations) and a mixture of other parameters (speed, vehicle density and traffic volume). This complex set of interacting factors produces some set of accidents. Automotive Interaction Detection (AID) procedures were used to extract dependencies amongst the dependent and independent variables. Again, only specific variables yielded any significant results (time of day, type of land-use, traffic volume and population density). Automatic Interaction Detector Analysis is analagous to a stepwise analysis of variance. The technique examines categories of variables in order to make optimal binary splits to the data. The algorithm selects the strongest variables first for splitting while the weaker variables show up later.

A Recent Example. The most recent and significant research effort was that of Moellering.[19] Here, a twofold analysis was attempted. First, an attempt was made to relate the residence to crash site distance to a host of spatial, demographic and socio-economic variables for auto-drivers, pedestrians and motorcyclists. Through AID analysis the author was able to discern that the spatial variables were important in influencing the residence to crash site distance for the various groups of involvees. The significant spatial variables were, (1) Michigan State Police District, (2) highway class, (3) population of area of crash and, (4) population of area of residence. This was the first study of its kind to consider residence to crash site distance.

Rationale for the consideration of residence to crash site distance was based on the notion of "trips as spatial movement."[20]

Residence to crash site distance was expected to display certain characteristics and features, for example, a distance-decay effect, an approximation of home based trips taken in reality and patterns of movement in space, etc. Little attempt was made to tie this important distance notion into the wider concept of movement geography, but an attempt was made to link fatal movements in space with the interaction concept. The second stage of Moellering's analysis involved using the geographical model of population potential in an effort to predict movement in space and calculate a spatial population at risk. By aggregating crashes by county of occurrence, Moellering examined differences between observed crash frequencies and expected values derived from the Warntz population potential model. Basically, the interaction potential model did very well at predicting involvement.

A Critique of the Spatial Models. While each of the above mentioned studies were to some extent useful, they could be criticized on methodological and theoretical grounds. Methodologically speaking, substituting AID analysis for previous emphasis on multiple regression analysis was an attempt to overcome low and insignificant r-square values. As a result, some of the significant variables bear no direct relationship to residence to crash site distance. They do not appear to be "characteristics" or "factors" associated with the fatal trips. On the other hand, Snyder's analysis was more convincing in this sense; witness the significant independent variables mentioned earlier. Wood's study suffered from a lack of explanatory power.

Several reasons exist for the unproductiveness of the multivariate approach. Michaels mentioned several such reasons. First, most studies of highways indicate that in only about five percent of accidents do observable characteristics of the highway play a significant role. Secondly, the statistical characteristics of the variables and their time-varying nature. Finally, the incompleteness of a linear theory of accidents.[21] If traffic accidents are a consequence of random errors in the operation of the system, then any prediction using multi-variate methods would be negligible; for a multivariate analysis assumes single factors whose interaction causes accidents.[22] Furthermore, these studies can be criticized for their lack of conceptual and theoretical background within the realm of geographic inquiry. Moellering is somewhat of an exception to this, for his focus was upon the concepts of distance and spatial interaction.

The Relationship of Fatal Traffic Accidents to Distance and Spatial Interaction Dysfunction Elements

Some Theoretical Considerations

What follows is not a perfect abstraction or rationalization of the fatal traffic accident problem. Rather, it is an attempt to model the relationship between residence to crash site distance and SIDE, or "stresses" in the system. As such, it builds and extends upon earlier work, but its uniqueness is in the theoretical geographic base upon which it extends. The discussion is sometimes focused upon a model or the conceptual framework for a model.

The model presented here consists of five conditions: trip generation, directional movement, road surface, dysfunctional elements and accident site. Figure 7 shows the relations between the conditions and

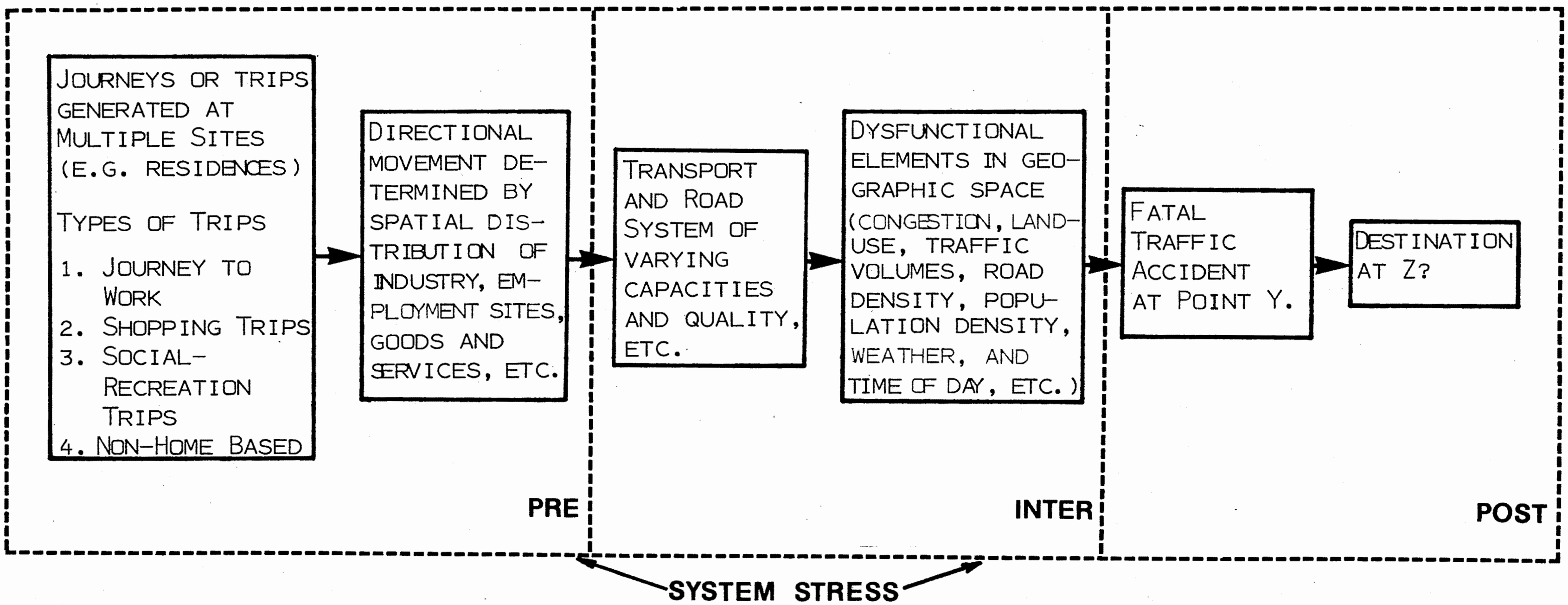


Figure 7. A Conceptual Model of the Dysfunction Process in Spatial Movement

the influence of "stresses" on the driver while traveling from point A to B. In this system model it can be seen that fatal traffic accidents are intimately tied to the movement of drivers on a road surface. More importantly, the movement process which results in a fatality has a distance property which needs to be explored. Residence to crash site distance is that very property. Since the "stresses" operate continually but at varying intensities, it was hypothesized that the residence to crash site distances will indicate the presence of SIDE and their spatial variations across the road and travel environment.

Each of the five conditions represents a model in itself. Some existing modeling efforts have focused solely on each condition. This model, for the purposes of both analysis and discussion, can be divided into three stages; the pre-accident stage, the intermediate stage, and the post-accident stage. The work of Goeller has provided valuable insights into each stage by modeling each stage separately and applying the results.[23] Each stage is interlinked, it is a causal chain that begins with an origin (usually the residence) and terminates at the fatal traffic accident site (the destination).

Rationale of the Model

The rationale of the model is as follows: Travel activity is composed of different types of journeys, with journeys being generated at multiple sites. Each journey taker has a particular set of socio-economic characteristics. Directional movement is determined by the layout of the road and street system, but it is also based upon the spatial distribution of goods, services, employment and industry, etc. Not only is movement affected by such distributions, but the distributions determine (in part) the location of trips. A characteristic of driver movement on a road system is the dysfunctional elements surrounding the man-vehicle-highway system.

Dysfunctional elements pertain to the road environment, land-use along the driver's route, population density and traffic volume, etc., but also to a larger set of factors which influence the perceptual and decision making capacity of the driver. A combination of these elements results in a fatal traffic accident. Here, the term Spatial Interaction Dysfunction was defined as a breakdown or negation of the functional role of movement in the interaction between people and places. Thus, the post stage accident segment of the model is where death, permanent disabilities and property damage occur. This process occurs in a system of stress. From the moment the driver leaves his point of origin (at various times of the day) up unto the fatality site he is subjected to system stresses, environmental stress and human psychological stress. In this research, the concern was not with the latter because the data base which was utilized did not document such information.

The Concept of Distance and Stress

Research pertaining to this area is absent, therefore, intuition served as the thrust for a conceptual framework. It was imperative to have several variables operating over distance, so that interaction could be evaluated. The concepts of distance and stress, as they relate to auto-drivers or motorcylists, work as a response to many factors, above all, the level of stress and the distance traveled. As used in this research, distance was the residence to crash site distance. It was considered to be an important geographic property of the event; the fatal traffic accident. Stress, on the other hand, is composed of the SIDE and can be termed system stress or environmental stress.

Human Stress. Two types of driver stress needed to be defined. Firstly, there was human physical stress that arises with longer distances traveled. Generally speaking, as human stress increases so does the probability of an accident occurrence; where stress is highest that is the time for a fatality. Stress in this sense is driver fatigue and tiredness, where margins for error decrease and decision making time slows down. This type of stress may also be related to time of day and type of journey. For example, there are high stress peaks during the journey to work and return journey home. For remaining hours of the day, the curve will be quite stable.[3] (See Figure 8.)

It was difficult to accurately portray the "average" stress-distance curve yet some generalizations were made. Figure 9 attempts the average stress distance curve. At the commencement of the journey/trip stress or anxiety may be high. Declining stress occurs as "one, gets with it." At longer distances stress and mounting anxiety contributed to "accident proneness" and fatalism on the road. Although stress varies with distance traveled, the driver vehicle combination itself becomes a hazard the lower the level of human stress. Figure 10 shows the theoretical variation of stress (inability to cope) and the driver as a hazard. Within the zone of safety, the driver vehicle system poses little hazard because minimum levels of stress are present to keep him alert. As stress declined, the driver-vehicle system becomes a hazard because of a declining attention, perception and alertness span for the driver. Within the fatality probability zone, it is at the widest point between the two curves that traffic fatality probabilities are very high.

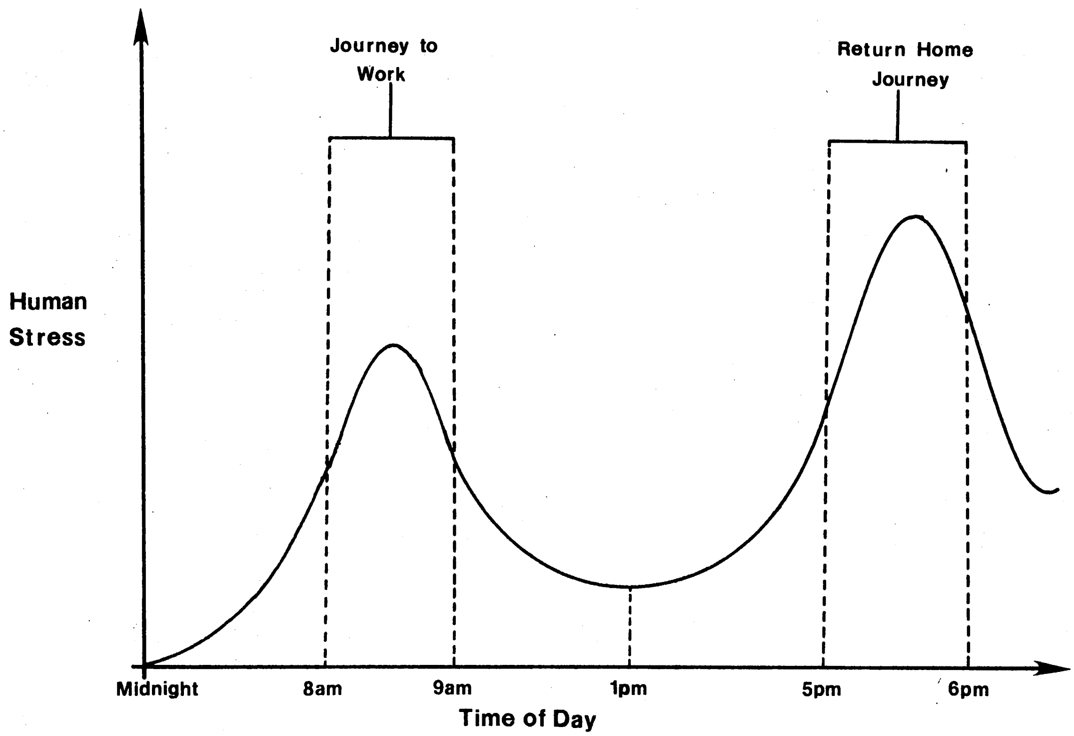


Figure 8. Variations in Stress with Time of Day

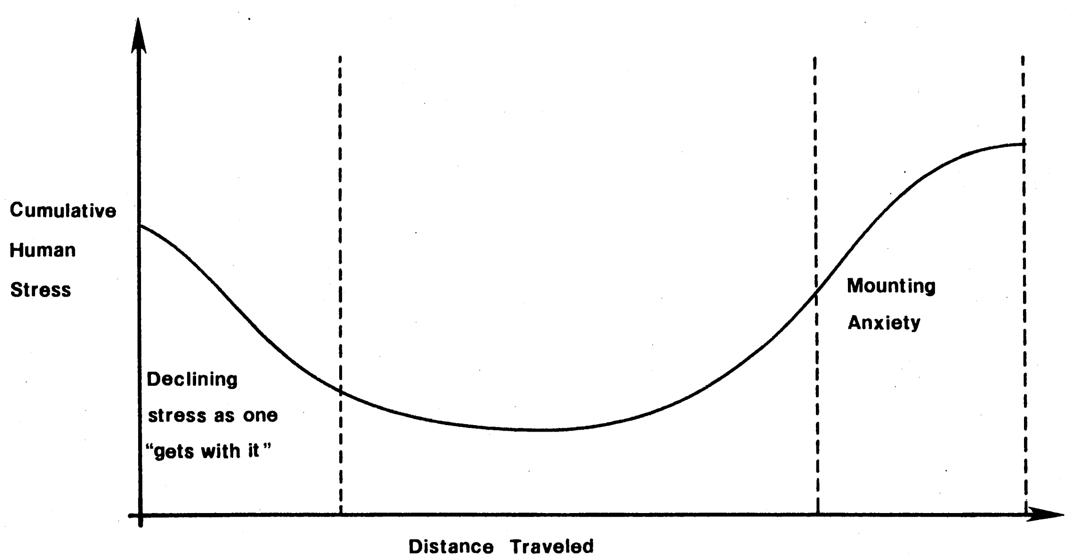


Figure 9. The Average Stress Distance Curve

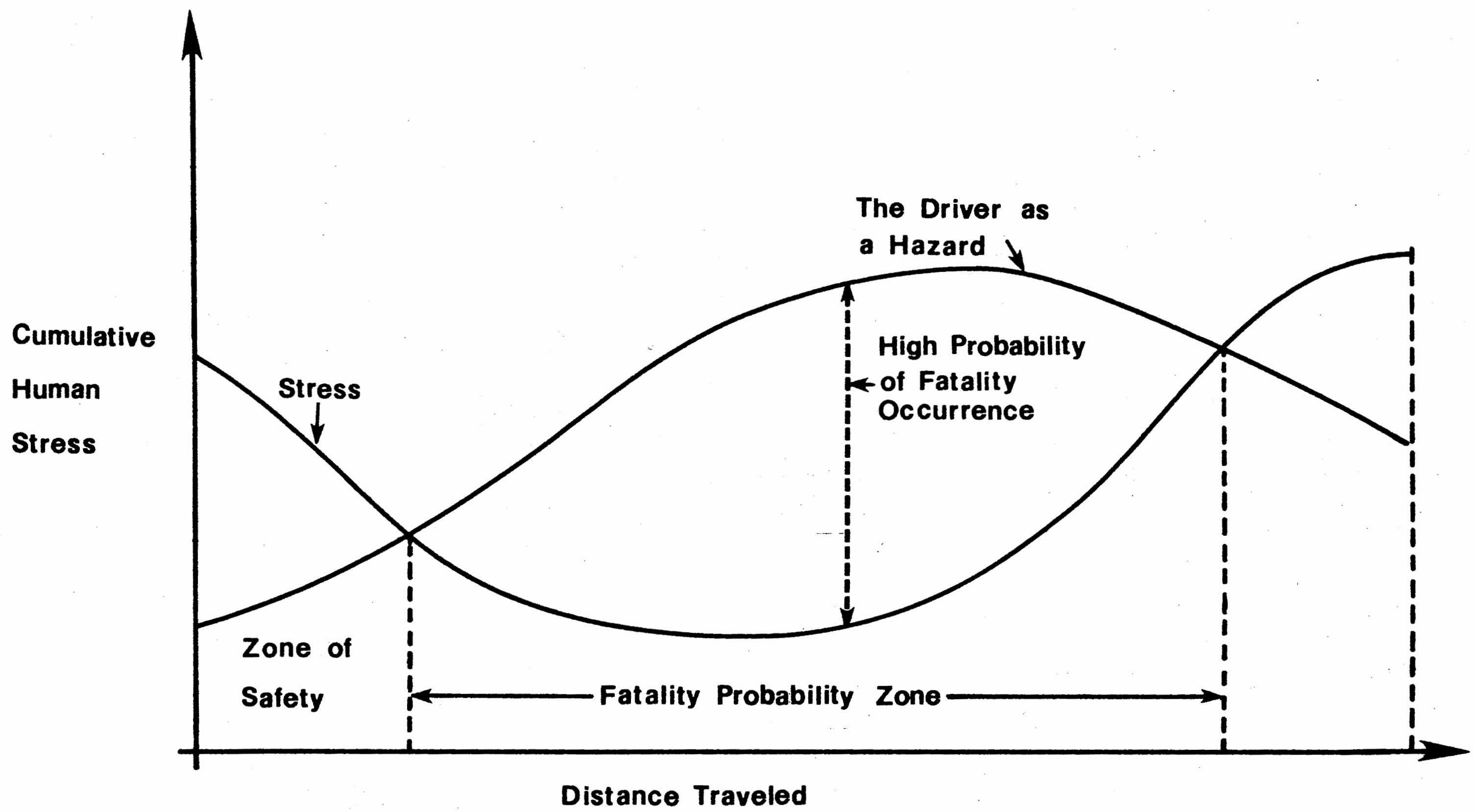


Figure 10. Human Stress, Distance Traveled, and the Driver as a Hazard

There exist yet other hazards on the road system besides the individual driver-vehicle; for example, other cars and people, distractions, dramatic changes in land-use type along the driver's route, confusing road directions, or a fork in the road system which is badly engineered thereby creating confusion as to which direction to follow. While the human stress curve still operates as in Figure 10, the actual real hazards (Figure 11) may appear when driver stress is low. The peaks at a, b, and c represent situations where hazards have confronted a driver at a point in which he could least cope. It is here where many fatalities would occur on the road system. Being a generalized subcurve, the hazard curve would differ by road type and land-use, etc. Yet it does represent a possible conceptualization of the traffic fatality phenomenon.

System Stress. The second type of stress which prevails is that composed of the SIDE, and it can be termed system or environmental stress. As mentioned in Chapter I, system stress culminates at the fatal traffic accident site; the point of maximum stress. The spatial variation of the cumulative stress surface will determine the location of fatal auto accidents and the residence to crash site distances as well. If one examines the movement of the potential victim in a homogeneous stress field, then the relationship is depicted as Figure 12. System or environmental stress is constant with distance traveled, yet driver accident proneness increases with distance traveled, yet driver accident proneness increases with distance from the origin (residence or other). In an areally differentiated stress field, the relationship would appear as Figure 13.[24]

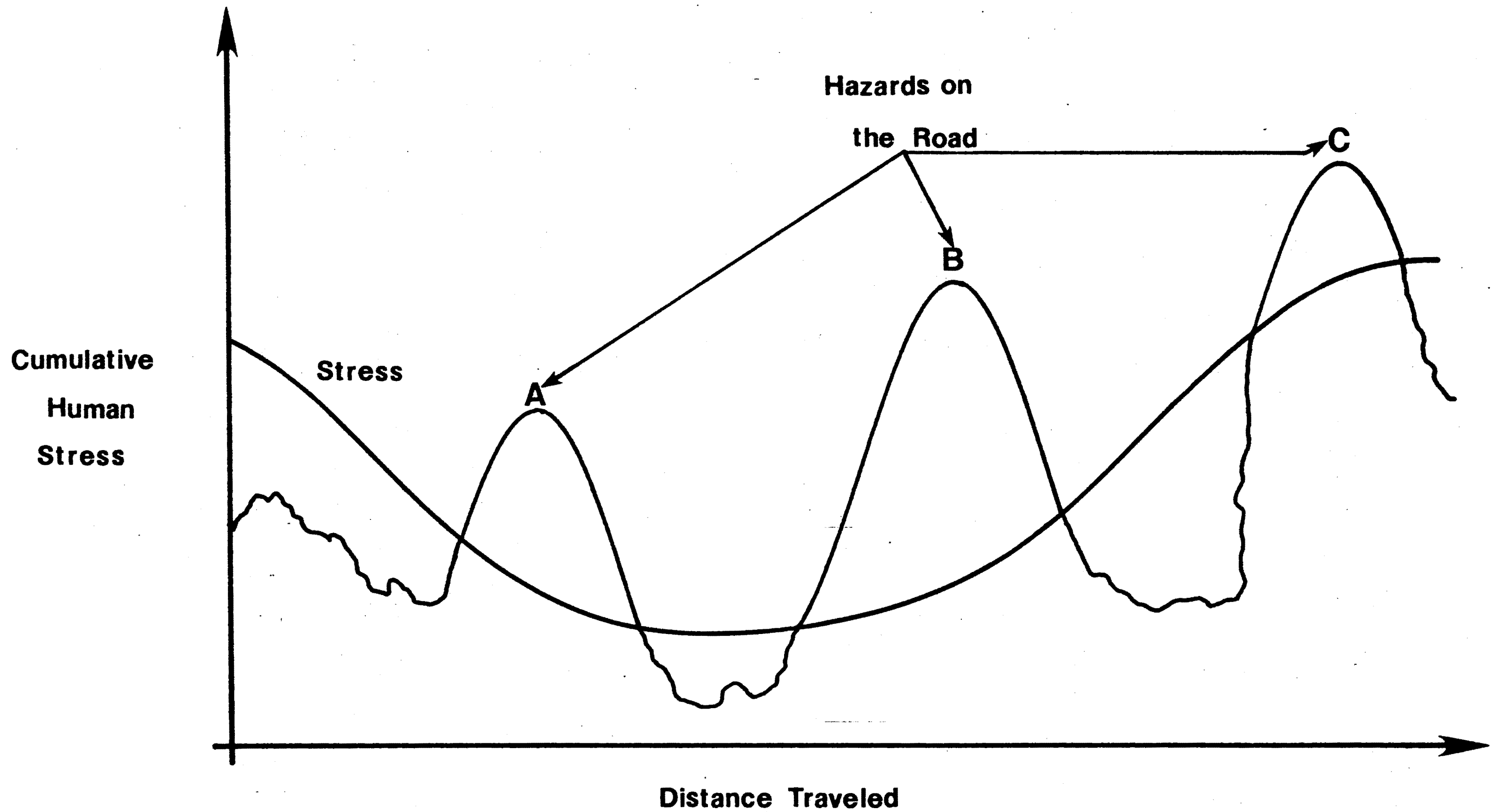


Figure 11. Driver Stress and Actual Hazards on the Road System

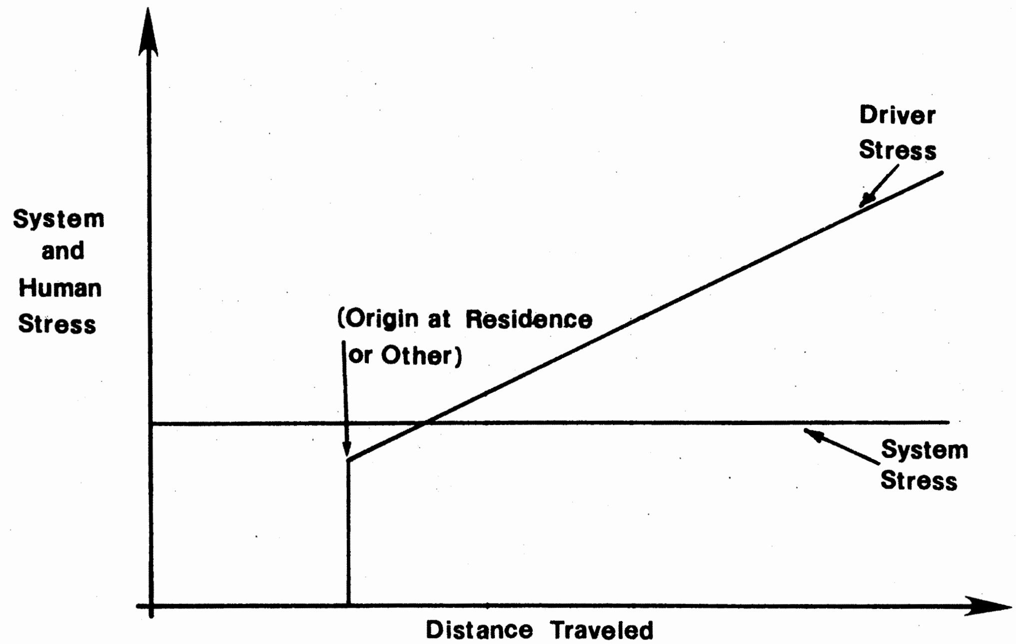


Figure 12. The Driver-Vehicle System in a Homogenous Stress Field

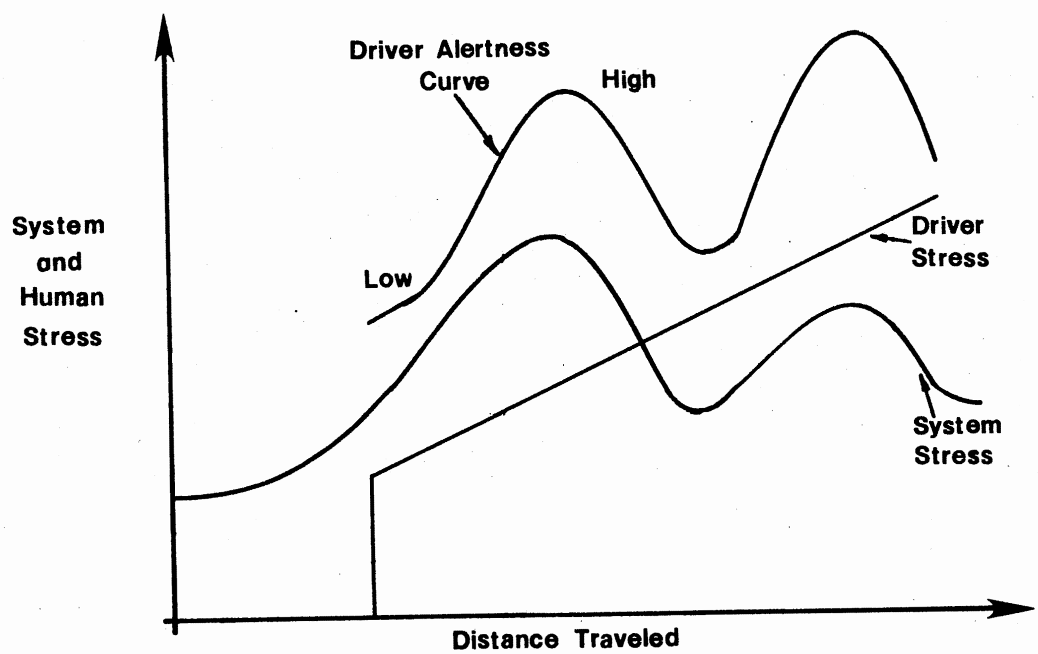


Figure 13. The Driver-Vehicle System in an Areally Differentiated Stress Field

Explanation of Hypotheses

1. Analysis of both the residence to crash site distance parameter and the "system stresses," suggests that the peak stress point should be close to the residence. If one considers the operation of system stresses on an urban to rural continuum, then system stress should operate differently to human stress in the sense that the relationship is inverted. The residence to crash site distance is itself part of the cumulative distance traveled. Thus, while human stress would be expected to increase with residence to crash site distance, system stress was expected to decline the longer the residence to crash site distance. From earlier statements it was mentioned that since fatalities occur closer to home, then system stresses would be relatively higher nearer the home than further away.

2. Differences in system stress and residence to crash site distance along the urban-rural continuum implies the existence of high frequencies of short residence to crash site distances and a low frequency for further distances. This led to a hypothesis concerning urban-rural residence to crash site distance differences. The short residence to crash site differences which were expected to prevail in urban areas of Oklahoma are associated with high levels of SIDE or system stresses, for example, Average Daily Traffic. Figure 14 shows the hypothesized relationship for urban areas. Conversely, where the SIDE or system stresses are low, as in rural areas of the state, residence to crash site distances were expected to be relatively longer (as shown in Figure 15). Although system stress is low in rural areas, the possibility existed that the alertness of fatality victims may have

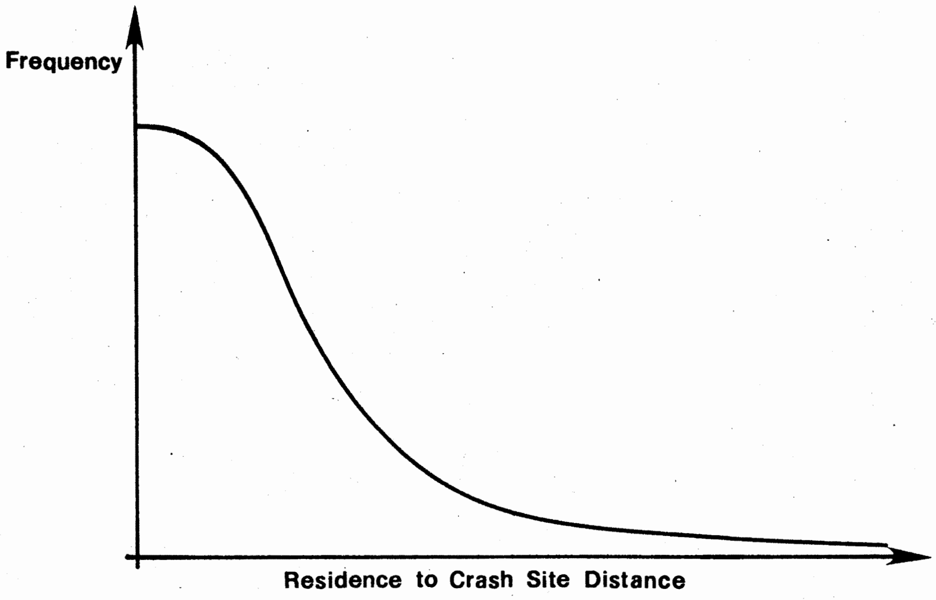


Figure 14. Urban Residence to Crash Site Distances

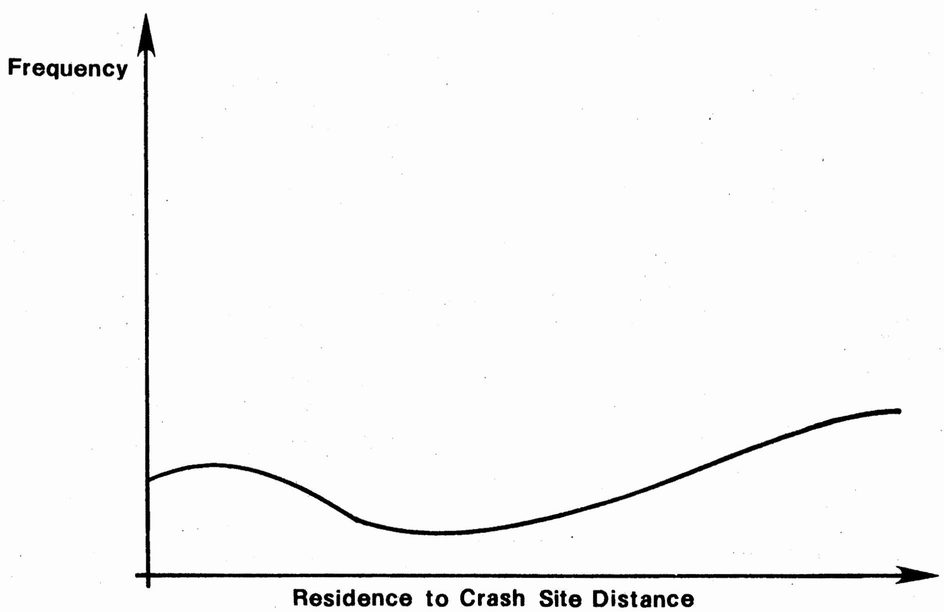


Figure 15. Rural Residence to Crash Site Distances

been even lower. In addition to the above hypothesis, two additional questions were examined, (1) were there significant differences between classes of residence to crash site distances and the level of stress for those distances? and (2) were there urban-rural differences in residence to crash site distances that varied with stresses as well?

3. Mean residence to crash site distances were expected to vary by time of day as well. With residence to crash site distance on the horizontal and a combined human system stress on the vertical (Figure 9), it was hypothesized that residence to crash site distances would be shorter in the morning hours; for example, journey to work times. As time passes during the day, the greater the residence to crash site distances. Generally speaking, morning hours are characterized by fewer automobiles on the road, lower traffic volumes and by trips directed at work destinations. Conversely, the afternoon hours are composed of additional types of drivers besides journey to work trippers. Additional drivers include women on shopping and social-recreation trips, traveling salesmen, delivery people and drivers undertaking return home journeys. Thus, with additional traffic and traffic volume in the afternoon hours, both system stress and human stress would be expected to be relatively higher. This relationship was examined using a t-test procedure. Since preliminary results indicated acceptance of the null hypothesis of no significant difference, the hypothesis was no longer pursued.

Residence to crash site distance alone does not tell one anything about the relationships hypothesized above. To test the outlined hypotheses, it was necessary to examine the mean residence to crash site distances for auto-driving and motorcyclists. Several assumptions are implicit in both the hypotheses and theoretical statements, (1) that a fatal accident can occur at any place where the driver-vehicle system is located, (2) interdependence among stresses and residence to crash site distances, and (3) that there are unexplainable portions of the fatal traffic phenomenon.

Definition of the Model and Variable Selection

In summary, the statements thus far have, (1) stressed the variations in SIDE or system stresses with residence to crash site distances, and (2) stressed residence to crash site distance as being an important geographic property of fatal traffic accidents. Given this format, two stages of analysis became apparent.

Stage 1. Stage 1 of the analysis involved testing several hypotheses. From Chapter I, they refer to, (1) expected differences between urban and rural counties of Oklahoma as regards the residence to crash site distance for groups of involvees, (2) the impact of stress on the urban and rural residence to crash site distances, (3) that traffic fatalities tend to cluster in space, especially where the SIDE are at a peak, and (4) that levels of stress also influence the general category of long and short residence to crash site distances. In hypotheses one, two and four, the chi-square analysis was used. For hypothesis three, the method used was simple dot location maps and residence to crash site distance maps. In the former hypotheses, counties within the State were grouped according to an urban or rural designation, and the distances were categorized as long and short. The stress variable was grouped into a high-low category.

Stage 2. Where residence to crash site distance was used as the dependent variable in a least squares regression model, called Model 1. Independent variables were the SIDE; average daily traffic, population of the county in which the fatality occurred, land use at fatality site and direction of travel. Here the objective was to try and determine what caused the short residence to crash site distances of fatality victims and whether the SIDE have any significant impact upon the total journey to death.

Definition of the Model

A list of the dependent and independent variables used in the model appear in Table I below. Each of the variables dealt with all the traffic fatalities used in the sample and were measured for the year 1976 only.

Testing the Model

In order to test the validity of the model, ordinary least squares regression was used. Least squares regression was chosen as the appropriate technique because of the need to establish a casual relationship between residence to crash site distances and the SIDE. For the model, the time period was the year 1976. The model was calibrated for only two groups of involvees, (1) auto-drivers, and (2) motorcyclists. Pedestrians were excluded from the analysis because of the nature of pedestrian fatalities. It was not valid to include a group where the residence to crash site distance was not affected by system stress. In addition, it was the driver who struck them, so that system and human stress was upon the driver, not the pedestrian.

TABLE I

DEPENDENT AND INDEPENDENT VARIABLES IN THE MODEL

Dependent Variables	Independent Variables
Log Residence to Crash Site Distance	Average Daily Traffic (measured in Million Vehicle Miles)
	Population of the County of fatality occurrence
	Type of land-use surrounding the crash site
	Direction of Travel of the vehicle before fatality occurrence
	Type of Highway upon which the fatality occurred

Separate calculations were essential in the model, since the residence to crash site distance varied for each group. The SIDE affected all groups during the "journey to death," but with varying levels of intensity. Such an approach was not new for a similar methodology was attempted by Moellering.[25] His use of AID analysis was unique, for many of the models developed in the traffic accident field employ multiple regression analysis. A more detailed discussion of the two methodological stages follows in Chapter III.

Choice of Variables

The independent variables chosen for the model came from the Official Police Traffic Collision Report forms which are used by police departments throughout the State (a copy appears in Appendix A). All variables pertained to the actual traffic accident, the involvee and the circumstances surrounding the accident. Most of the variables employed in the model were selected because of their likelihood in yielding significant results.

FOOTNOTES

[1]Richard M. Michaels, "Human Factors in Highway Safety," Traffic Quarterly Vol. 15 (1961), pp. 586-99.

[2]John C. Snyder, "Environmental Determinants of Traffic Accidents: An Alternate Model," Transportation Research Board (1976), Washington, D.C.

[3]K. R. Agent, "Relationships Between Roadway Geometrics and Accidents," Transportation Research Record No. 451 (1975), pp. 1-11.

[4]B. F. Goeller, "Modeling the Traffic Safety System," Accident Analysis and Prevention Vol. I, No. 2 (1969), pp. 167-204.

[5]Julie A. Cirillo, S. K. Dietz and R. L. Beatty, "Analysis and Modeling of Relationships Between Accidents and the Geometric and Traffic Characteristics of the Interstate System," U.S. Department of Transportation Federal Highway Administration, Bureau of Public Roads, August 1969.

[6]Ibid., p. 7.

[7]J. A. Head, "Predicting Traffic Accidents from Roadway Elements on Urban Extensions of State Highways," Highway Research Board Bulletin No. 208 (1958).

[8]David N. Schoppert, "Predicting Traffic Accidents from Roadway Elements of Rural Two-Lane Highways with Gravel Shoulders," Highway Research Board Bulletin No. 158 (1967).

[9]Ibid., p. 4.

[10]Ibid., p. 4.

[11]Kersey H. Antia, "Biographical and Medical Data About the Automobile Driver: A Review of Literature," Highway Research News No. 31 (1968), pp. 51-61.

[12]Michaels, ibid.

[13]Ibid., p. 591.

[14]Ibid., p. 593.

[15]R. C. Vanstrum and G. B. Caples, "Perception Model for Describing and Dealing with Accident Involvement in Highway Accidents," Highway Research Record No. 365 (1971), pp. 17-24.

[16]Ibid., pp. 19-20.

[17]R. A. Woods, "A Spatial Analysis of Fatal Traffic Accidents in North Carolina, 1964" (M.S. Thesis, Department of Geography, University of North Carolina at Chapel Hill, 1964).

[18]John C. Snyder, ibid.

[19]H. Moellering, The Journey to Death: A Spatial Analysis of Fatal Traffic Crashes in Michigan, 1969 (Michigan Geographical Publication, Department of Geography, University of Michigan-Ann Arbor, 1974).

[20]Ibid., p. 26.

[21]Michaels, ibid., p. 587.

[22]Ibid., p. 587.

[23]Bruce F. Goeller, ibid.

[24]Ideas for the discussion in this section came from Professor James H. Stine.

[25]H. Moellering, ibid., p. 30.

CHAPTER III

DATA, STUDY AREA AND METHODOLOGY

Introduction

The previous two chapters of this thesis have outlined the objectives and scope of the study, and the theoretical framework upon which the study was based. Given the nature of the topic and of the data used it was imperative to discuss data sources, the data and its limitations, study area and methodology. As this was the second study of its type within the discipline of geography, it was also necessary to note the problems associated with obtaining such sensitive information, and to guide future researchers towards the appropriate State agencies for data retrieval. This discussion is contained in Appendix B of the thesis. The appendix discussion also mentions what was available at the appropriate State agency and the nature of the research pursued by those organizations.

Study Area and Study Year

The study area for this research was the State of Oklahoma. It was chosen for practical reasons, similar type of research in another state would have entailed difficult data collection problems. Hence, the nature of the research and data availability confined the study to the state of the author's residence. Since only residents of the State composed the traffic fatality set, then focus was upon the State as a spatial unit rather than a region of the State or some metropolitan area. The type of spatial unit selected for this research differs from that of most other traffic accident studies.[1] Since most studies to date have been very parochial, the spatial unit has been small in size, usually focusing upon a metropolitan area,[2] rural region[3] or section of a highway.[4] In addition, these studies did not consider the total traffic accident set, but only a small sample of involvees. By utilizing all dead auto-drivers and motorcyclists that were residents of the State, it appears that conclusions and statements regarding hypotheses would be more credible than statements based on studies limited in scope.

Volume of data availability limited the study to a one year time period. A time series study covering several years would have been more interesting and valuable, but given the time period allowed for this research, one year had to suffice. When data collection became paramount in December 1977, the Official Traffic Collision Report forms for 1977 had not been completely tabulated. Thus, it was decided to select the year 1976. Choice of a year was not expected to influence the findings of the research. It was the author's suspicion that residence to crash site distances between the period 1974 and 1977 were basically similar for different groups of involvees. Yet, one would have expected significant differences for the period 1972 to 1973; due to the impact of the energy crisis on distances traveled.

The Data and Its Limitations

Appendix A contains an Official Police Traffic Collision Report form for the State of Oklahoma. As mentioned earlier, various types of information are recorded on the form relating to location, driver, injury, fatality circumstances and causes. Past studies have used such data in a framework that encompasses pre-crash, crash and post-crash phases of traffic accidents. Most studies attempt to relate one or other phase to human, vehicle, road or environment characteristics. Table II provides a taxonomy of Highway Safety Research and is indicative of how the data has been utilized.

TABLE II

A TAXONOMY OF HIGHWAY SAFETY RESEARCH

	Human	Vehicle	Road	Environment
Pre-Conditions	1-1	1-2	1-3	1-4
Pre-Crash	2-1	2-2	2-3	2-4
Crash	3-1	3-2	3-3	3-4
Post-Crash	4-1	4-2	4-3	4-4

Source: Snyder, John C. Environmental Determinants of Traffic Accidents.

Two dimensions form the structure of the matrix, (1) the time element pertaining to an individual accident, and (2) the contextual element. According to Snyder's review, most highway research efforts can be placed in one or more of these cells.[5] For example, cell 1-1 would include studies involving driver skills and knowledge, cell 2-2 would encompass vehicle condition studies, and cell 2-1 would include studies of driver impairment just prior to an accident.[6] On the official report itself, pre-crash circumstances could be evaluated by considering the following, (1) speed of vehicle before contact, (2) vehicle condition, (3) condition of driver(s), etc., (4) light and weather conditions, and (5) the collision diagram. Similarly, crash and post crash phases could be determined by the collision diagram and, remarks and injury sections. In some cases, a supplementary collision report form is attached describing in detail the patrol officer's investigation (usually if the fatality is alcohol or manslaughter related) and includes eyewitness testimony.

Research Limitations

Despite the apparently detailed nature of the information collected on the collision report forms, several aspects of the forms limited their usefulness for research purposes. The limitations can be classified under two categories, (1) errors in recording data, and (2) philosophy and purpose behind the report. Inaccuracy as regards the location of the fatality was a common occurrence. In several cases, where residence to crash site distance was being measured, the location and measurements specified on the collision diagram did not coincide with distances and locations as specified at the commencement of the report. In such cases the report was discarded. Additional problems ranged from illegible writing and spelling errors, to discrepancies between given distances from nearest city limits and county of fatality occurrence.

Rationale of Data Collection

The purpose and philosophy behind the collision report forms suggests that their use is limited to a certain clientele. The primary objective and raison d'etre of the report form is to provide its users (courts, insurance companies, litigants and their attorneys) with details about accident location, time, names, addresses, certain biographical information, and a description of the vehicles, etc. By aggregating such information it is possible to classify groups of involvees according to sex, age, time of day and location, etc., as well as calculating involvement rates. The point has been made that information of this type is of limited value, and can be misleading, if not accompanied by additional information, such as the mileage driven by the various groups of involvees.[7] On the other hand, the value of the information depends on the purposes and types of research.

Application Limitations of the Data

Associated with the above problem is the limited information concerning those factors or combination of factors which account for the occurrence of a fatal accident. It has been argued that, because of background and training, police officers equate "traffic violations" with "accident causation."[8] Collision reports contain a host of contributing factors which in essence are traffic violations, for example, unsafe speed, failed to yield/stop and left of center passing, etc. Although collision reports contain a list of environmental, road and vehicle factors, the evaluation of their relative contribution to the initiation of the fatality is not undertaken by the Police Officer, nor by the Department of Public Safety during the tabulation stage. Consequently, both police and bureaucrats view the accident phenomenon as a human problem. Wright and Baker state that,

> too often, traffic safety researchers have assembled the blind men and the elephant, each drawing conclusions only partly right, and none being able to describe accurately the true nature of the factors which contribute to crashes.[9]

This philosophy is evident in the publication, Oklahoma Traffic Accident Facts. A section is included indicating contributing causes of statewide, city and rural accidents. Contributing causes embodies the traffic violation-accident causation syndrome where each contributing cause is a traffic violation. No mention is made of the environmental vehicle or road factor information from the collision reports. In contrast, this thesis stressed the holistic approach whereby the road, environmental and vehicle factors were considered. In essence, the aim of the research was not to account for fatal accidents but to explain and analyze the residence to crash site distances of fatality victims.

Methodological Approach

In examing the relationship between residence to crash site distance and SIDE, the method employed, in combination with presence or absence of such relationships, will determine the level of success. In having assumed that a relationship existed, the purpose was to determine the level of impact which the SIDE had on residence to crash site distance. By concentrating on the relationship between residence to crash site distance and SIDE, one is, in fact, studying geographic variations in road stress and traffic friction, and the involvees' response to these conditions. It remained to be seen just how this relationship operated and what particular SIDE predominated in the association.

Data Sorting and Residence to Crash Site Distances

Prior to the implementation of the above approach, it is imperative to discuss the way the data was treated, transformed and used, and how it was used in the model. Three stages were involved in extracting the desired information from the collision report forms. Stage one involved sorting the forms into groups of involvees. The groups desired were automobile drivers and motorcyclists. A further complication in the report forms was the presence of train fatalities and non-traffic fatalities (tractor deaths, private property deaths and heart attacks, etc.). These types of reports were not included in the research because they have no relationship to the study nor the groups involved. Furthermore, many of these fatalities did not occur on the State's road system, so that residence to crash site distance would not be directly influenced by SIDE. As regards heart attack fatality victims, the fatality cause was obvious.

Exclusion of Involvees

Additional sorting was required because of the presence of out-of-state involvees, and fatalities where the driver was not killed. The exclusion of these two groups not only reduced the size of the fatality numbers but affected the residence to crash site distances for involvees. Including out-of-state residents would have grossly skewed the distance distribution to the right, especially with involvees from states such as California, Michigan, South Dakota and Illinois. An accurate measure of residence to crash site distance for the State of Oklahoma would not have been ascertained. Fatalities where the driver was not killed were also excluded from the study, yet in this type of fatality other vehicle occupants were killed instead. While it could be argued that random elements determined whether drivers or occupants were killed, it was important to assume that the combination of SIDE and the non-vehicle-highway system affected the driver and not the occupants.

The end result was a data set reduced by 50 percent. This was still thought to be a sufficient number for research purposes. Under the sorting procedure, 379 dead automobile drivers and 39 motorcycle deaths remained; this was slightly in excess of half the total number of fatality victims for 1976. In reiterating, these numbers were composed solely of Oklahoma residents who died in a traffic accident fatality in Oklahoma in 1976. Table III summarizes the final set, in addition to what was included and excluded. Aggregated totals did not reach 838, the official traffic accident fatality figure for 1976, because many non-traffic fatalities and fatalities where the driver was not killed were multiple fatalities, i.e., two or more individuals dying in a traffic fatality. Of the 418 deaths, only six were the result of multiple fatalities.

The conclusion to Stage one came with the calculation of residence to crash site distances for the 418 involvees. Distance, as used in this research, referred to straight line distance measured in miles. A digitizer was employed for the calculations; the advantages of a digitizer over conventional methods was in accuracy. Many collision reports indicated rural route numbers as the involvee residence. Since this was the official designation of residence, the victims involved were includ-ed in the study.

TABLE III

THE FINAL DATA SET

Included in Study	Total	Excluded from Study	Total
1. Dead auto drivers	379	1. Bicycle/Pedacycle Victims	8
2. Dead Motorcyclists Resident in Oklahoma	39	2. Out of State Victims	68
		3. Train Fatality Victims	19
		4. Fatalities where Driver Not Killed	129
		5. Non Traffic Fatalities	32
		6. Miscellaneous	
		7. Dead Pedestrians	83
	418		343

Source: Author computations, based on data supplied by ODPS.

Plotting Residence to Crash Site Distances

Stage two necessitated plotting each residence to crash site distance for map evaluation purposes. It was intended that vector maps be produced which showed trips that were taken for auto-drivers and motorcyclists for 1976. The function of the maps was to indicate the variations in distances traveled and to indicate either clustering, randomness or dispersion of the residences and crash sites, etc. All these maps were hand drawn. Computer mapping programs did not suffice due to the time element involved in obtaining coordinates.

The Rural-Urban Hypotheses

As seen from Chapters I and II, there are two hypotheses which relate to rural-urban differences in residence to crash site distances traveled. Firstly, the question of whether significant differences exist between classes of residence to crash site distances (short and long) with the level of stress for those differences? This hypothesis was tested using a chi-square analysis. A 2 x 2 chi-square table was constructed whereby two levels of stress (high and low) formed the rows and two levels of residence to crash site distance (short and long) formed the columns. The cut-off points for the levels were determined from descriptive statistics generated for the respective variables. For the stress variable, the surrogate variable used was Average Daily Traffic. Determining high and low categories of stress was completed by obtaining plots of Average Daily Traffic and residence to crash site distance; a similar procedure was used for the distance cut-offs.

The second hypothesis, that there existed rural-urban differences in residence to crash site distances, necessitated the identification of urban and rural counties. Urban counties in Oklahoma, in 1976, were identified by their presence of SMSA's. In 1976, three SMSA's existed within Oklahoma's boundaries: (1) Oklahoma City, (2) Lawton, and (3) Tulsa. The Fort Smith-Arkansas SMSA was excluded because the higher proportion of SMSA population is on the Arkansas side. A total of 13 counties were included in the three SMSAs. Oklahoma City included Canadian, Cleveland, McClain, Oklahoma and Pottawatomie counties; Lawton included Comanche county, and; Tulsa included Creek, Osage, Mayes, Rogers, Tulsa and Wagoner counties. These official SMSA counties were taken from the FBI Uniform Crime Reports, 1977.[10] Following this, residence to crash site distance was matched to each urban or rural county of occurrence, and the stress variable (high and low) was used to construct a chi-square table for analysis.

Summary

The basic objective of this chapter was to discuss the data sources attained, the data and its limitations, and reiterate research methodology. Despite data shortcomings, a large enough sample remained to make the research topic a viable one. A total of 418 fatalities were considered for the State of Oklahoma in 1976. This data set included all fatalities where involvees were residents of the State. The conceptual framework was outlined in the proposed model. This model was calibrated twice to represent dead automobile drivers and motorcyclists. Pedestrian fatality victims were excluded due to the nature of a pedestrian fatality. What follows includes a description of the fatal traffic accident problem in Oklahoma and an analysis of both results and findings of the research.

FOOTNOTES

[1]For example, see J. A. Deacon (et al.), "Identification of Hazardous Rural Highway Locations," Transportation Research Record No. 543 (1975), pp. 16-33.

[2]J. T. Duff, "Road Accidents in Urban Areas," Institute of Highway Engineers Journal Vol. 15, No. 5 (May, 1968), pp. 61-73.

[3]J. M. Bruggeman, "Accident Investigation on Rural Expressways" (unpub. Ph.D. dissertation, Northwestern University, Dept. of Civil Engineering, 1968.)

[4]J. H. Kihlberg, and K. J. Thorp. "Statistical Analysis of Accident Rates and Geometry of Highway," Highway Research Record No. 188 (1967).

[5]John C. Snyder, "Environmental Determinants of Traffic Accidents: An Alternate Model," Transportation Research Board (1974).

[6]Ibid., p. 4.

[7]Paul M. Wright, and E. J. Baker, "Causes of Traffic Accidents," Traffic Engineering Vol. 43, No. 9, pp. 41-45.

[8]Ibid., p. 43.

[9]Ibid., p. 43.

[10]United States Department of Justice, FBI Uniform Crime Reports, 1977.

CHAPTER IV

RESULTS OF THE ANALYSIS, PART 1

The Locational Distribution of Fatal Traffic Accidents in Oklahoma, 1976

Introduction

While the bulk of the analysis for this thesis was undertaken using multivariate methods, it was felt that the identification of the spatial distribution and pattern of fatal traffic accidents would prove a valuable exercise. Delineation of the spatial pattern was essential for an understanding of, (1) the relationship between residence to the crash site distance, (2) the location of fatality sites, (3) the residence to crash site distances, and (4) the occurrences of fatal traffic accidents on Oklahoma's highways. In addition, such an analysis was thought to enhance the theoretical framework of the thesis by confirming or undermining earlier statements regarding the relationship of SIDE and residence to crash site distances.

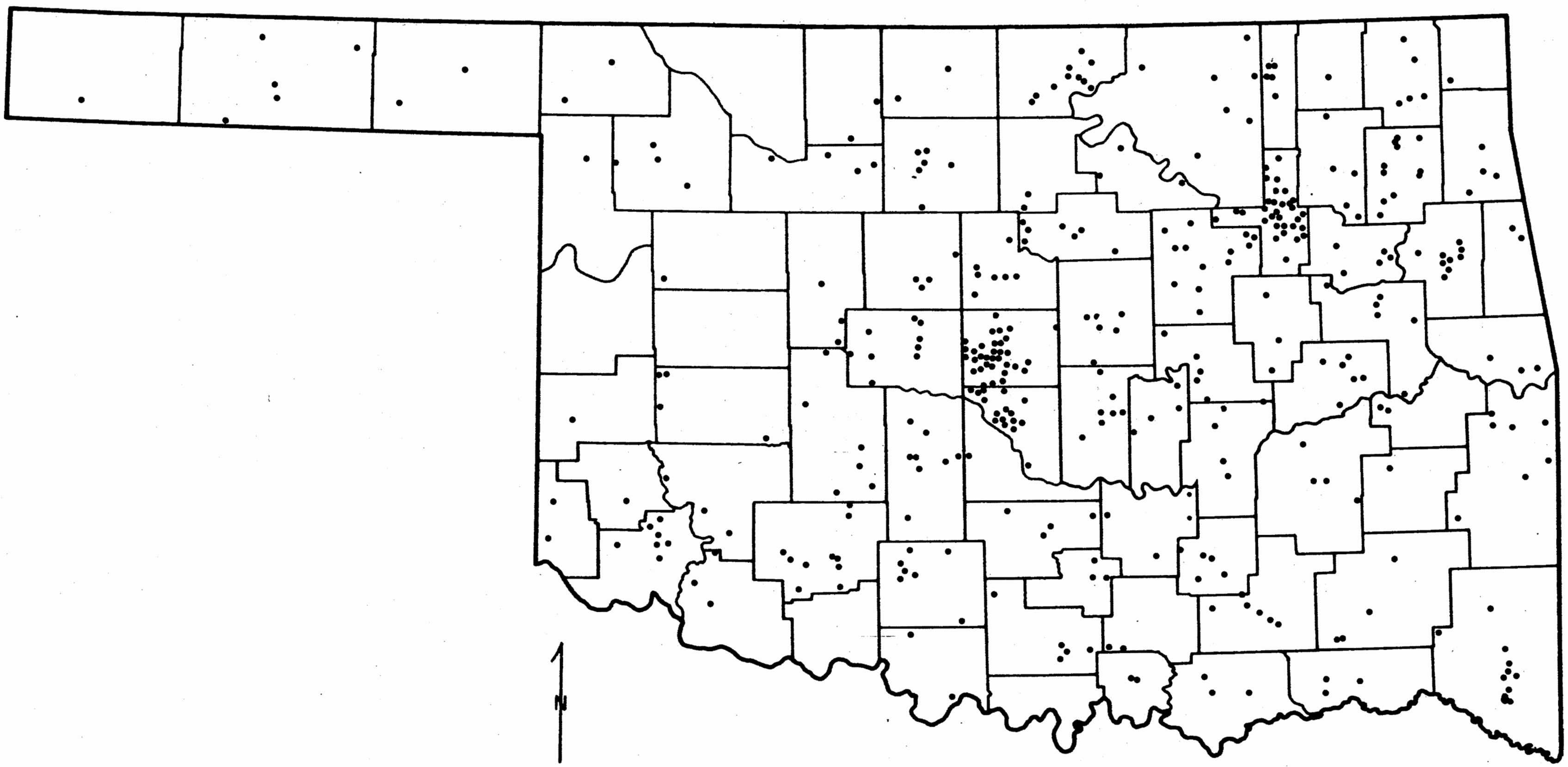
The 418 fatal traffic accidents analyzed (automobile, motorcycle, and pedestrian) were mapped using several techniques. First, a dot map was produced showing the location of fatalities by county of occurrence. Locational data for construction of this map came from the Official Police Traffic Collision Report Forms. This information was then transferred to an overlay sheet with a Department of Transportation Official

State Map of Oklahoma 1976, as the base map.

The Distribution and Spatial Pattern of Fatal Traffic Accidents

The distribution and spatial pattern of fatal traffic accidents is shown in Figure 16. Generally speaking, there was a nonrandom pattern to the distribution of fatalities. Although the pattern was uneven it did conform to the population distribution of the State. Fatality concentrations occurred in the two largest cities of Oklahoma City and Tulsa. Other smaller sized cities such as Altus, Enid, Ponca City, Tahlequah and Bartlesville stood out as smaller concentrations. Because of higher population densities, the impact of the larger urban centers was substantial.

Spatial Concentrations of Fatalities. According to official statistics, 69 percent of all traffic deaths occurred in rural areas.[1] On the other hand, 78 percent of all accidents in 1976 occurred in urban areas.[2] If one were to remove the effect of Tulsa, Oklahoma and the three Panhandle Counties, the emergent distribution would appear uniformly spaced. Frequency counts by county, for group of involvee, demonstrated that rural-urban differences in the locational distribution patterns of fatalities did exist. This relationship appears as Table IX in Appendix C. From the sample of 418 fatalities, many rural counties recorded high fatality counts. For example, Kay, Logan. McCurtain, Mayes and Cherokee Counties had relatively high fatality counts. This indicated that many of the fatal rural trips had both origins and destinations in rural counties, and that trip movements were in an inter-city



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10 0 20 40 60 80 100
MILES

Figure 16. The Distribution and Spatial Pattern of Traffic Fatalities in Oklahoma, 1976

pattern as opposed to an intra-city pattern.

In addition, Figure 16 showed that high accident frequency rural counties displayed distinctive characteristics in terms of the locations of fatalities. In Logan and Kay counties, the impact of I-35 was apparent. Both of these counties experienced high million vehicle miles traveled figures (216,000,000 and 164,900,000 respectively). In McCurtain County, U.S. Highway 259 stood out clearly as a fatality occurrence route, with a focus being the town of Idabel. Similarly in Mayes County, State Highway 33 showed concentrations along its route. Within Cherokee County, the city of Tahlequah showed high concentrations. Tahlequah is at the hub of three State Highways (10, 82 and 15) and it is in the midst of a tourist area,

Fatality Location Clusters Along Routes. Another feature of Figure 16 was the clustering of fatality locations along certain roadways. Interstate 35, North and South, could be discerned clearly, as could the Turner Turnpike between Oklahoma City and Tulsa. Interstate 40 East was also apparent, but fewer fatalities occurred on the western portion. In the Southeastern and Southwestern portions of the State, the influence of State Highway locations was apparent. From Jackson County across to McCurtain County, an east-west cluster of fatality locations occurred; especially along State Highways 5, 53 and 32. Even in the northern part of the State, the cluster was evident.

A characteristic of Figure 16 was the distance-decay effect for fatality occurrences away from the SMSA counties. Counties surrounding Oklahoma County showed significant drops in fatality locations. Similarly for Tulsa County, where a corresponding drop in million vehicle miles traveled per county occurred. Such an observation added meaning to earlier statements regarding the relationship of SIDE and residence to crash site distances. A spatial clustering of fatalities in urban counties indicated the existence of high stress conditions. Thus, in large urban areas, the fatality crash sites appeared to be engulfed in high stress fields. Conversely, rural fatality locations were associated with low system stress, as measured by Average Daily Traffic, and it appeared that type of highway, highway condition and distance traveled may have been important factors in accounting for fatality locations.

SIDE and Residence to Crash Site Distances

Characteristics of Involvees

Sex of Involvees. Fatality victims in Oklahoma for 1976 were predominantly male. Of the 418 cases analyzed, auto-drivers comprised 75 percent of the fatality victims. Within the sample, 59 percent of victims were female. These figures were correlated with figures released by the Department of Public Safety, where 77 percent of drivers killed were male and 23 percent female. Motorcycle fatality victims were all males. This group of involvees comprised only eight percent of the total.

Age of Involvees. Mean age was used as the appropriate measure. For autodrivers killed in fatalities the mean age was 40 years. This reflected the slightly older age structure of the rural population. On the other hand, the mean age of motorcyclists was 24 years. Undoubtedly this reflects the young adult attraction to "fun machines."

An interesting relationship was evident in the relationship of age with residence to crash site distances traveled. Figure 17 shows two peaks. First, there is a peak at 20 years of age. The area under the curve included both motorcyclists and auto-drivers. The second peak reached a maximum at 60 years of age and declined rapidly as residence to crash site distance increased. Hence, a "young" and "old" effect was present in the age of involvees with distance, whereby younger traffic fatality victims died further away from their residence than did older victims. Furthermore, the majority of victims of all ages had residence to crash site distances of less than 20 miles. Generally speaking, the younger the age of involvee, the longer the residence to crash site distance.

Time of Day. The time of occurrence of the 418 fatalities did not show a stable pattern. Instead, the fatality occurrences displayed definite trends. Figure 18, for example, revealed a high peak after midnight, in particular at 1:00 A.M. Fatality occurrences at this time may have been the end result of a journey with origin at an alcoholic establishment. Peak morning hours, or journey to work hours, did not appear to be fatality prone times. Rather, the afternoon emerged as the lethal time for fatality occurrences, especially during the peak hour between 5:00 P.M. and 6:00 P.M. Several reasons were forwarded as explanations for this phenomenon, (1) levels of traffic and traffic volumes are higher in the afternoon hours, thereby elevating system stresses and SIDE to higher levels, (2) it is generally the time when worker fatigue or "the hard day at the office" syndrome, makes the driver's attention span narrower, and (3) it is when the "perceptual

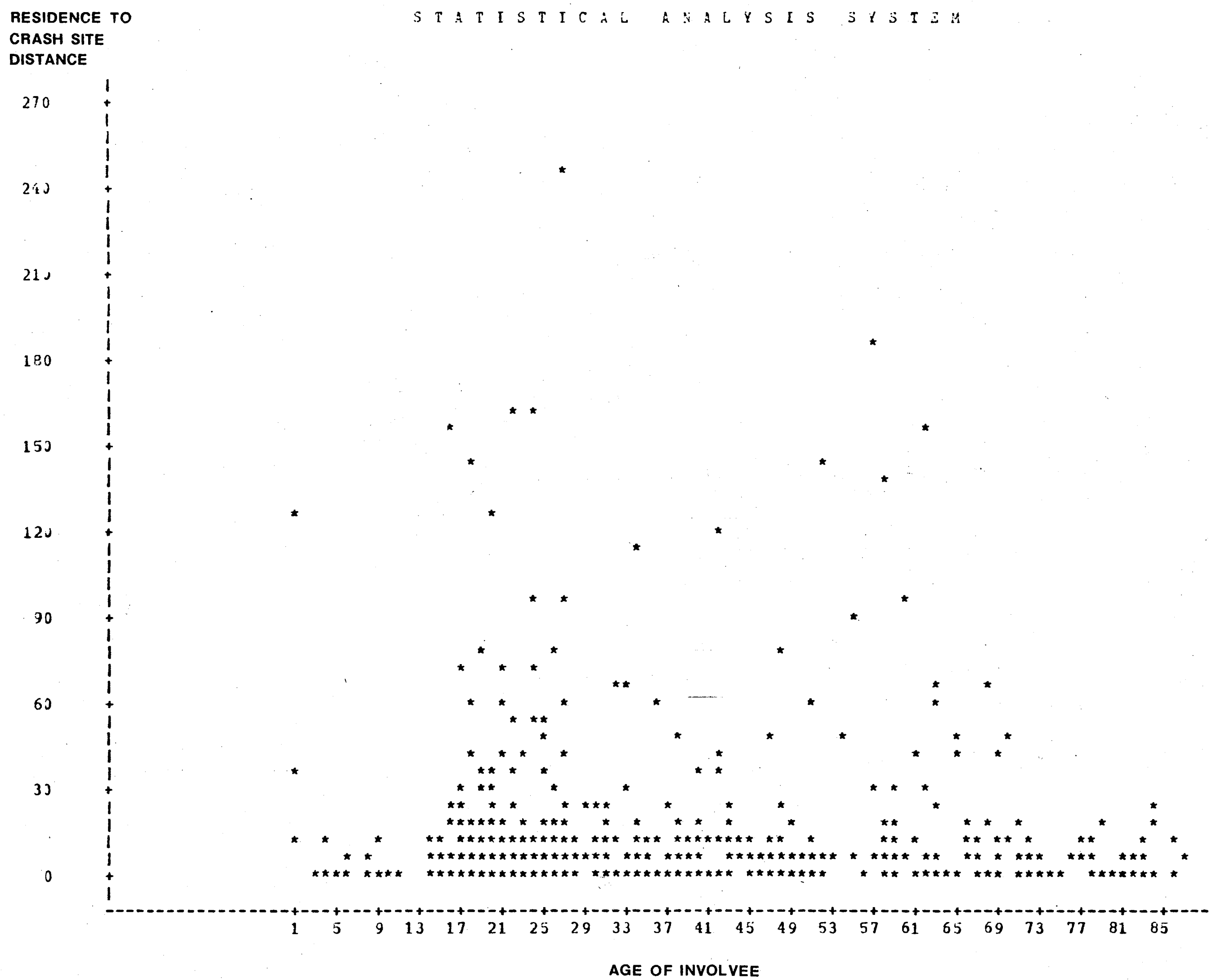

Figure 17. Age and Residence to Crash Site Distance

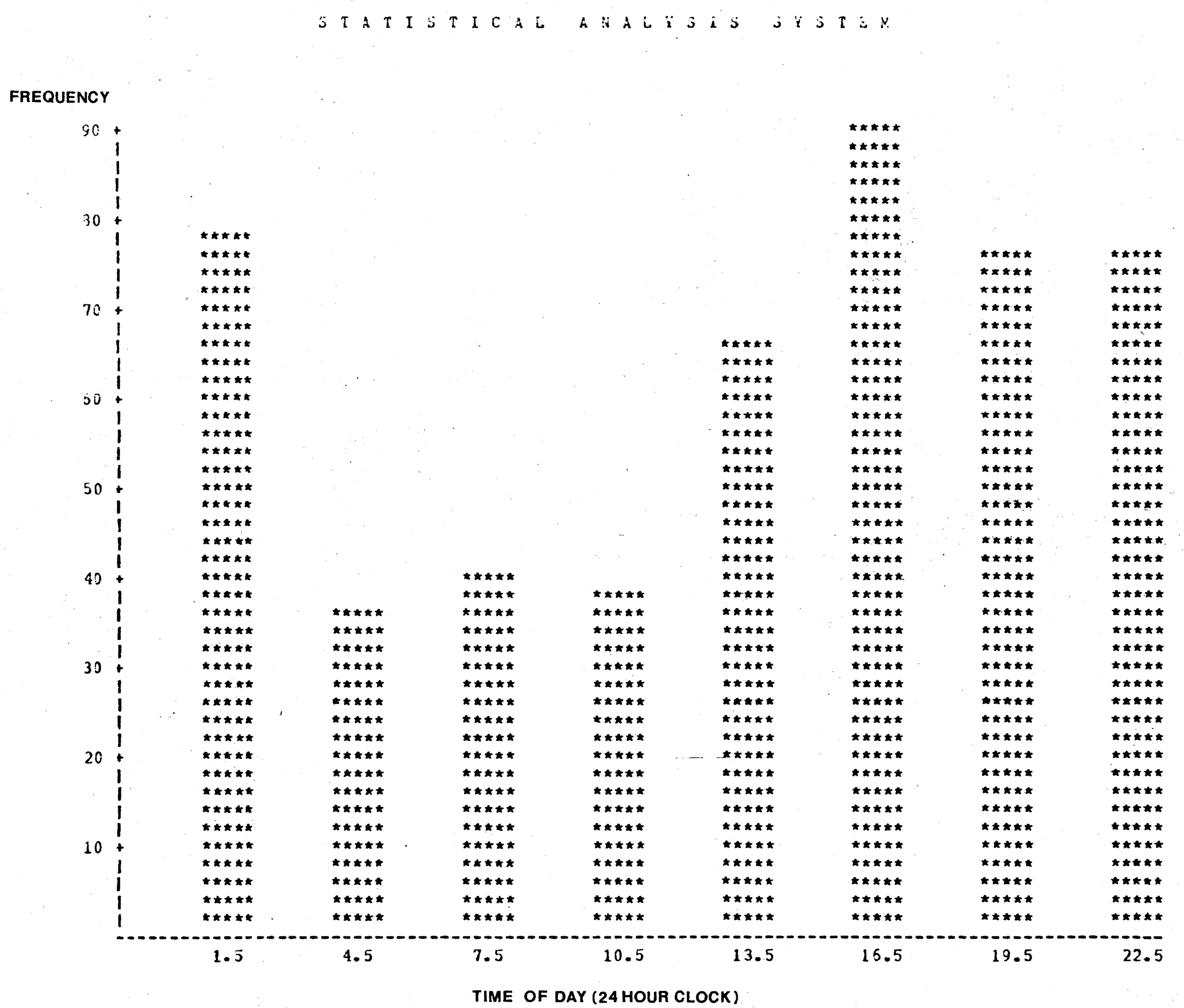

Figure 18. Time of Day of Traffic Fatalities

decision motor capactities" of the driver are reduced, thereby decreasing the margin for error.

Day of Week. The weekend predominated as the high frequency fatality occurrence period. More fatalities occurred on Sunday than any other day of the week (see Figure 19). The month of May was the high frequency occurrence time of year. As mentioned above, the time of day of occurrences suggested fatalities during the return home work journey and after bar closing time. Since weekends were high fatality occurrence periods, then it suggested differences in trip purpose. In the latter, pleasure trips and social recreation trips would certainly be large components of traffic fatality trips. Alcohol related weekend fatalities may be another type of trip. Only 22 percent of all fatal traffic accidents in Oklahoma, in 1976, resulted directly or indirectly from drinking.

Residence to Crash Site Distances for Groups of Involvees

To reiterate, residence to crash site distance as used in this thesis referred to straight line distance in miles. It was calculated for evey fatality and for each group. Similarly, mean residence to crash site distances were calculated for each group for comparative purposes. In addition, means were calculated to test the conventional wisdom regarding the distance from residence at which most fatalities occurred.

Automobile Drivers. The mean residence to crash site distance for dead automobile drivers was 16.09 miles. This figure differed from the

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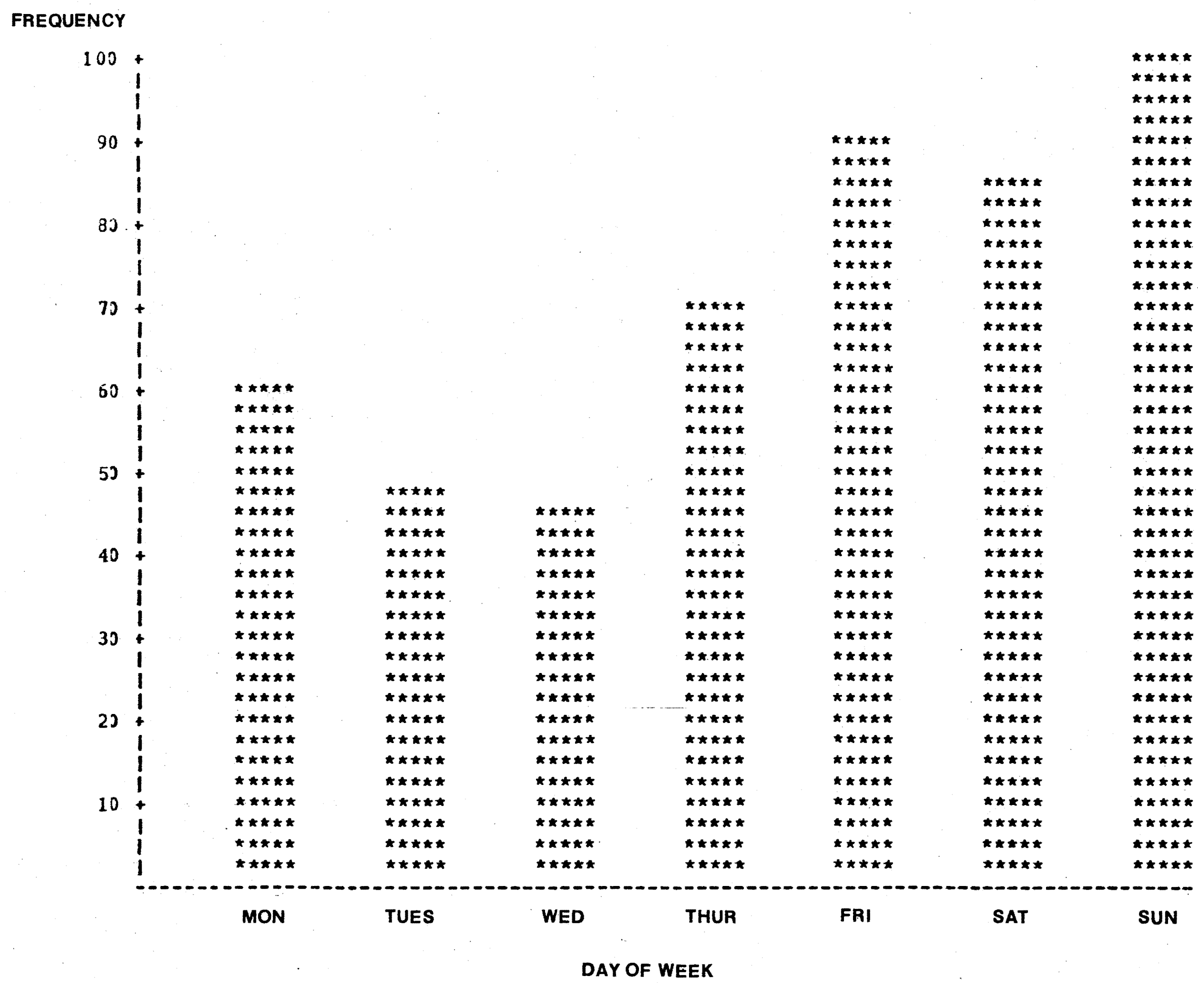

Figure 19. Day of Week of Fatality Occurrences

mean distance traveled by dead Michigan auto-drivers in 1969, where a mean of 30.87 miles prevailed.[3] This discrepancy was suggestive of, (1) differences in amount of traveling undertaken and length of travel, and (2) the impact of different levels of urbanization. It appeared that existing differences in the urban hierarchy, or in the size and spacing of central places, may have affected residence to crash site distances. In general, the Michigan urban system differs from that of Oklahoma. In the former, a more mature hierarchy exists with more large cities and comparatively more intermediate-sized cities. Such a hierarchy, therefore, affects spatial trip movement direction and length. Longer residence to crash site distances in Michigan indicated predominantly more intra-metropolitan trips and trip lengths as opposed to the inter-metropolitan type. In Oklahoma, the predominance of smaller sized towns, (both in terms of numbers and the close spacing between them) and fewer large cities, indicated more inter-urban travel. This inter-urban travel (spatial trip movement from central place to central place) was of relatively short distance. As shown by Figure 20, a high percentage of auto-driver fatalities occurred within five miles of the residence and 50 percent of the distances were less than 15 miles from the residence. Sixty percent of the victims were within 20 miles of the residence.

The distance distribution for auto-drivers was highly skewed, with very few involvees having long residence to crash site distances. Figure 21 shows residence to crash site distance vectors for dead auto-drivers. Oklahoma and Tulsa County were apparent as clusters of concentration. In general, a chaotic pattern emerged, with rural spatial journeys to death predominating. Many of the origin and destination

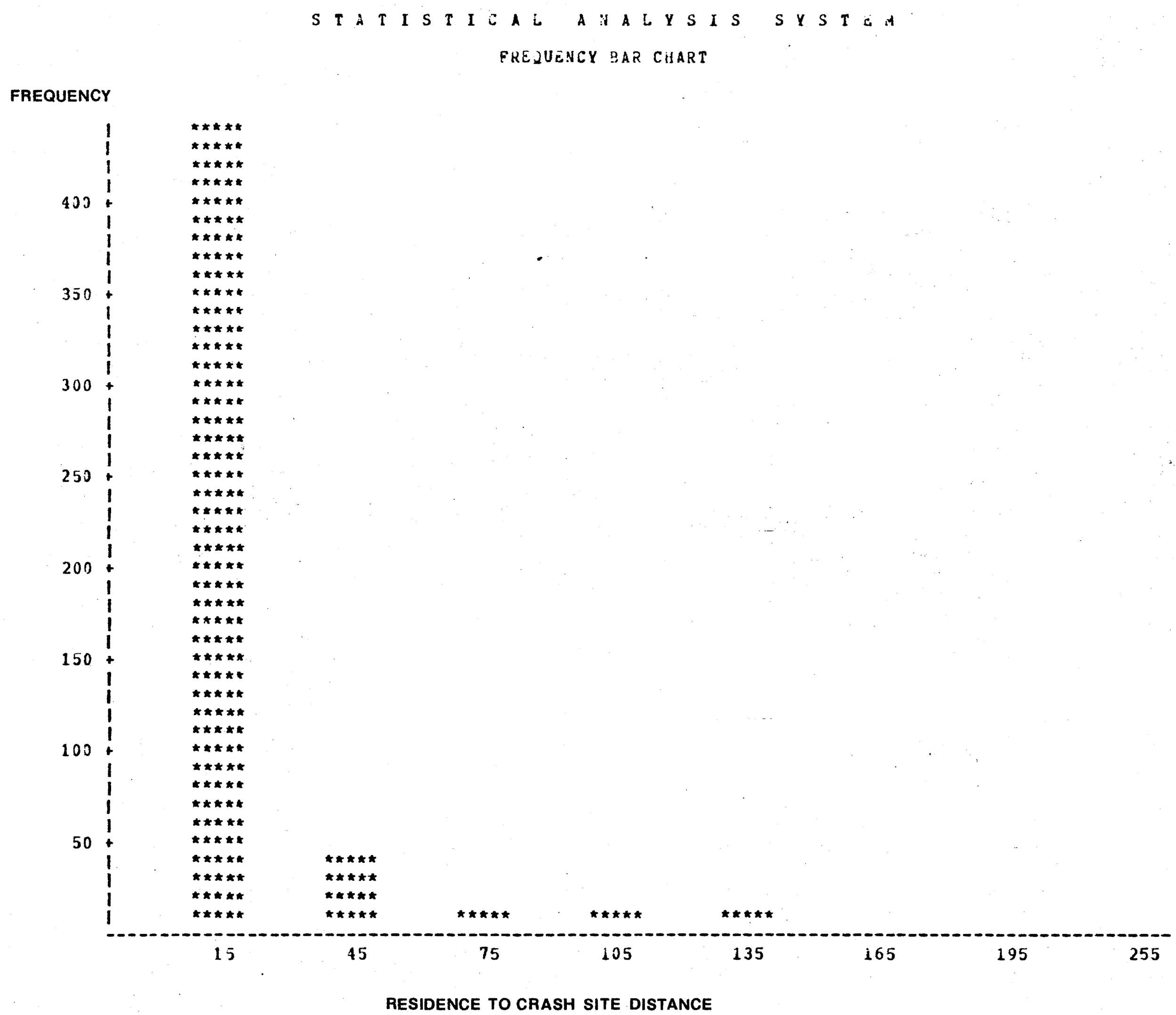

Figure 20. Residence to Crash Site Distance in Miles, Autodrivers

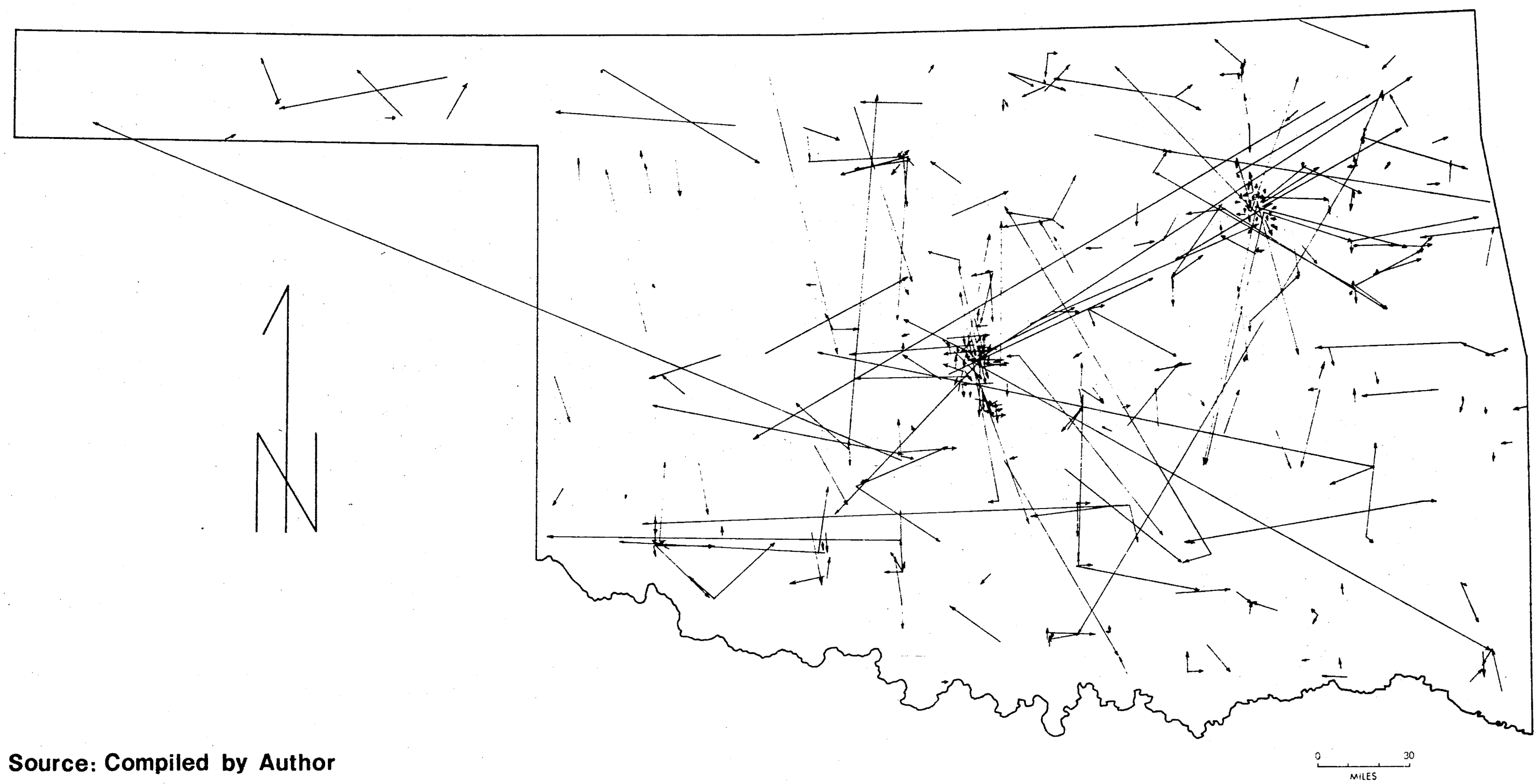

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Figure 21. Residence to Crash Site Distance Vectors, Autodrivers

points were small to medium sized rural towns, particularly in the Central, Northeast and Southeast portions of the State. This confirmed the earlier statement regarding inter-urban trip movements of short distance. In addition, not many fatal trips were rural-to-urban or vice-versa. A clear demarcation existed between urban and rural generated fatal traffic trips.

Motorcyclists. Mean residence to crash site distance for this group of involvees was 16.10 miles. This figure did not differ greatly from that of dead Michigan motorcyclists where mean distance was 13.01 miles.[4] As mentioned earlier, motorcyclists comprised only 7.60 percent of the sample. Mean age of involvee was 24 years and mean time of occurrence was late afternoon. Figure 22 shows the frequency of residence to crash site distances. As can be seen, 60 percent of motorcycle fatalities occurred within five miles of the residence, while 78 percent occurred within 10 miles of the residence. Hence, fatal trips were comparatively short for this group.

The spatial pattern of residence to crash site distances is shown in Figure 23. Again the pattern indicated Oklahoma, Tulsa and Comanche Counties as the high motorcycle fatality occurrence areas. The direction of spatial movement is both intra-urban and inter-urban. Only eight of the fatalities had lengths beyond 20 miles. Rural motorcycle fatalities did not show any alignment to the State highway system. Many fatalities occurred on rural roads or city streets. With time of occurrence considerations, it appeared that many victims were on pleasure outings, "riding for fun" on rural county section roads, or on city streets returning from work.

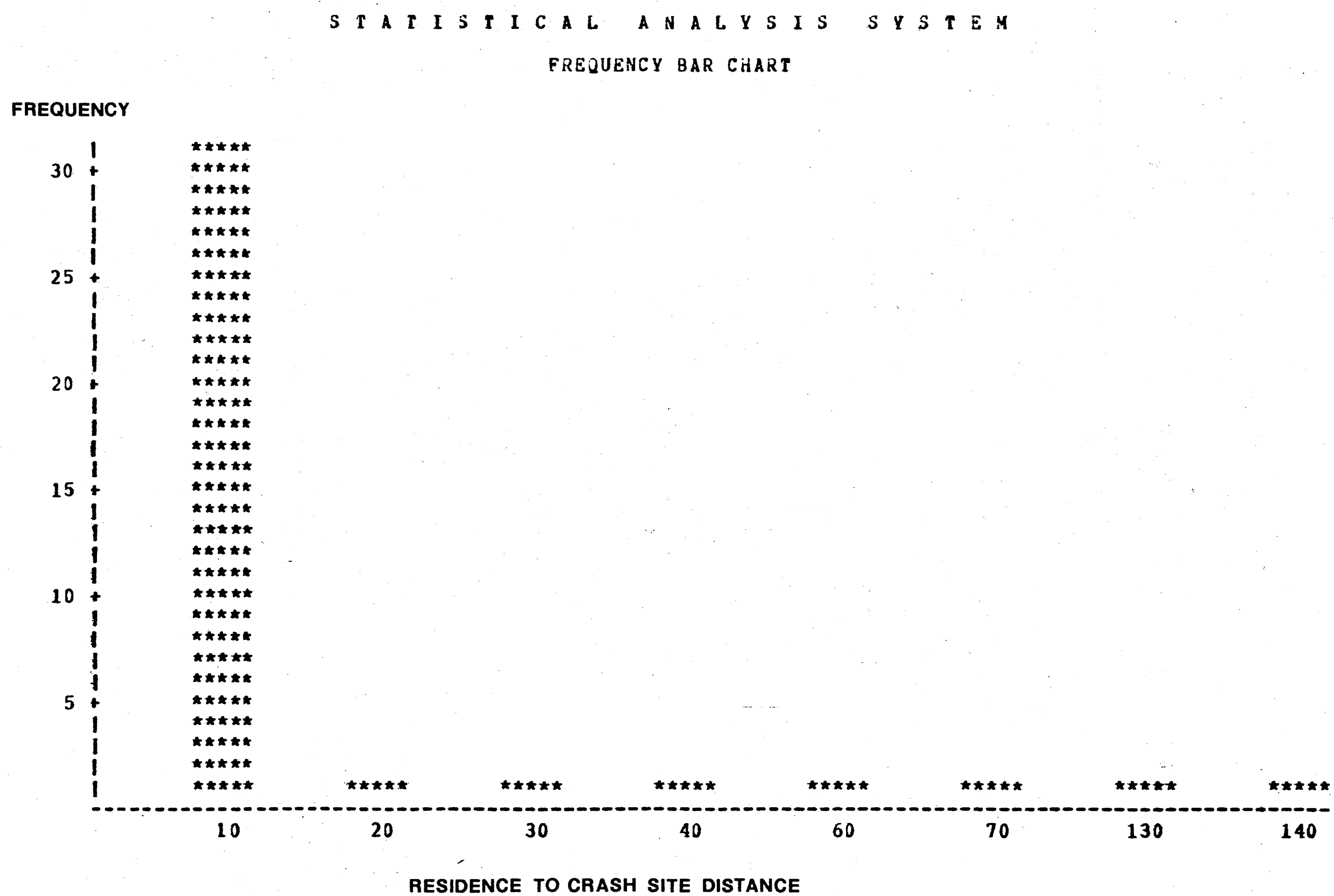

Figure 22. Residence to Crash Site Distance in Miles, Motorcycles

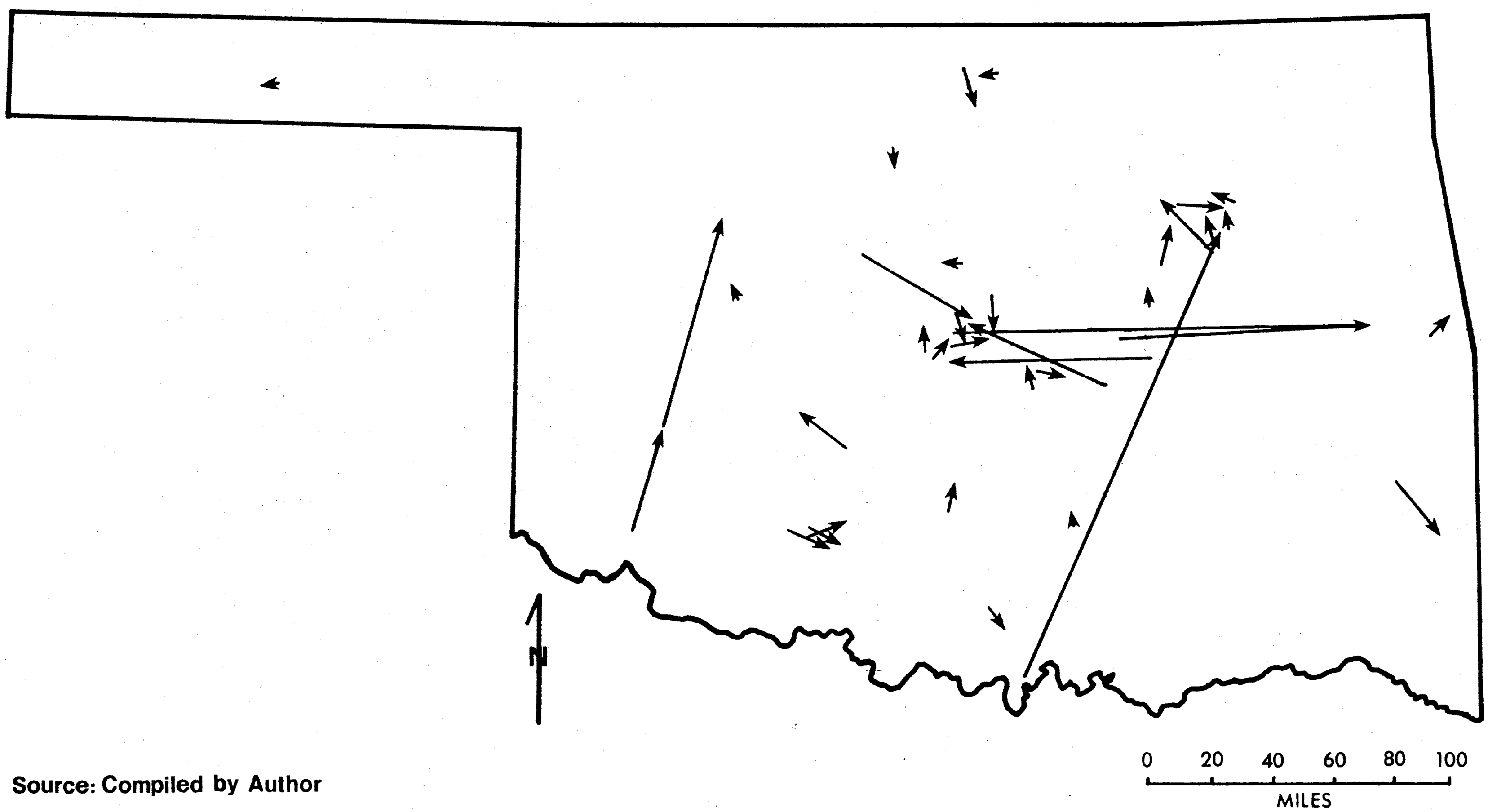

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Figure 23. Residence to Crash Site Distance Vectors, Motorcycles

Summary. A summary table of residence to crash site distances for the two groups of involvees appears in Table IV.

TABLE IV

RESIDENCE TO CRASH SITE DISTANCE IN MILES BY GROUP OF INVOLVEE, OKLAHOMA; 1976

	Auto-drivers	Motorcylists
N	379	38
Distance in Miles (Mean)	16.09	16,10

Source: Calculations by Author.

The results and findings of the initial analysis were summarized as follows:

(1) A highly skewed distance distribution for the groups of involvees confirmed the popular belief that most fatalities occur within 25 miles of the residence. Within this range, there was no substantial variation in terms of residence to crash site distances for the two groups. Hence, the supposedly random elements which determine accidents assure that death will be close to home, for some very close. This suggested that high stress fields are closer to the residence.

(2) When compared to the Michigan study, the lower mean distances

indicated the existence of different travel patterns within the urban heirarchy.

(3) The predominance of inter-urban travel movements among the victims, especially movements between small towns. Very little movement occurred between rural and urban areas.

Distance and Stress: Empirical Results

It was mentioned in Chapter II that the residence to crash site distance was considered to be an important geographic property of traffic fatalities. From the results thus far, a characteristic of this property was the predominant distance decay effect displayed for all groups of involvees. At this level of analysis, the only interpretation was that most victims lived close to their residence and that fatal spatial movements were predominantly on an inter-urban scale. When residence to crash site distance was compared to other variables, additional relationships emerged. Figure 26 displays the relationship of system stress with residence to crash site distance. Generally speaking, the shorter the residence to crash site distance the higher the level of system stresses or SIDE. Average Daily Traffic, as measured by highway segment, was used as a surrogate measure of stress for the greater the level of interaction between people and places, the higher the levels of traffic volume.

Interaction Between "Stresses" and Distance

The further the residence to crash site distance, the lower the level of system stresses. Hence, not all traffic crashes were sites where system stresses culminated. Other factors determined the "journey to death" in such cases. By returning to Figure 10 it could be seen that human physical-psychological stress was a factor in those cases where residence to crash site distances were relatively longer. Conversely, both high levels of stress at short distances from the residence and the high frequency of fatalities at short distances, indicated that while human physical stress was low, the system stresses were high.

Were the short residence to crash site distances of Figure 26 urban or rural fatalities? Given the higher levels of stress it was postulated that most were urban fatalities. A plot of the population of the county of occurrence by residence to crash site distance appears in Figure 27. It showed that the majority of short journeys to death occurred in counties of population below 70,000. The next higher order counties were Comanche, Garfield, Tulsa and Oklahoma. Examination of county of residence and residence to crash site distance revealed that the majority of fatality victims resided in counties of population below 50,000. Larger population sized counties (Oklahoma and Tulsa) experienced both short and long residence to crash site distances. Hence, urban fatalities were included in the category of short distance/high system stress.

Levels of Stress and Urban-Rural Residence to Crash Site Distances

Classes of Distance and Levels of Stress

This analysis is related to the hypothesis derived from Figure 14. The distance variable was divided into two categories, long and short.

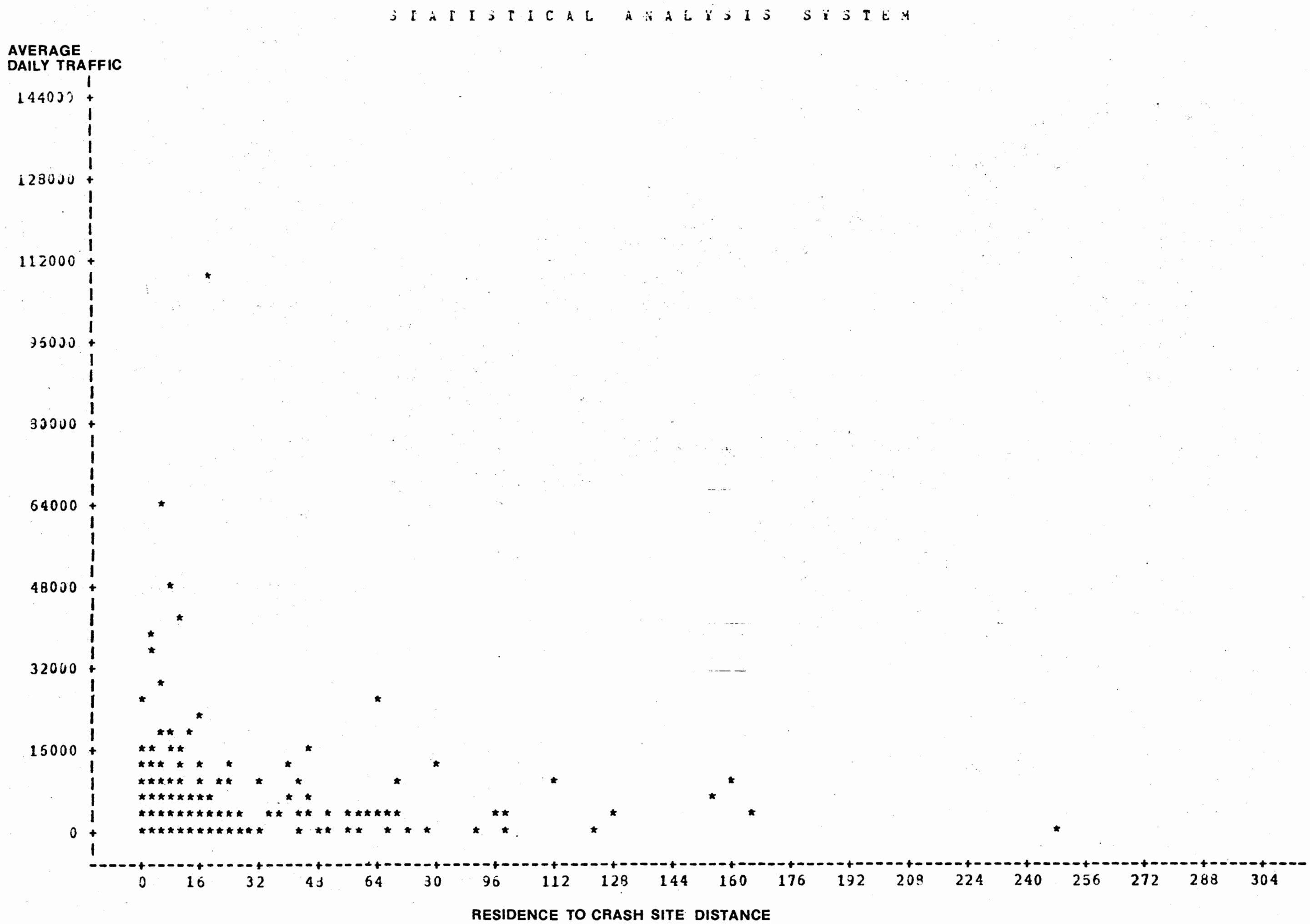

Figure 26. System Stress and Residence to Crash Site Distance

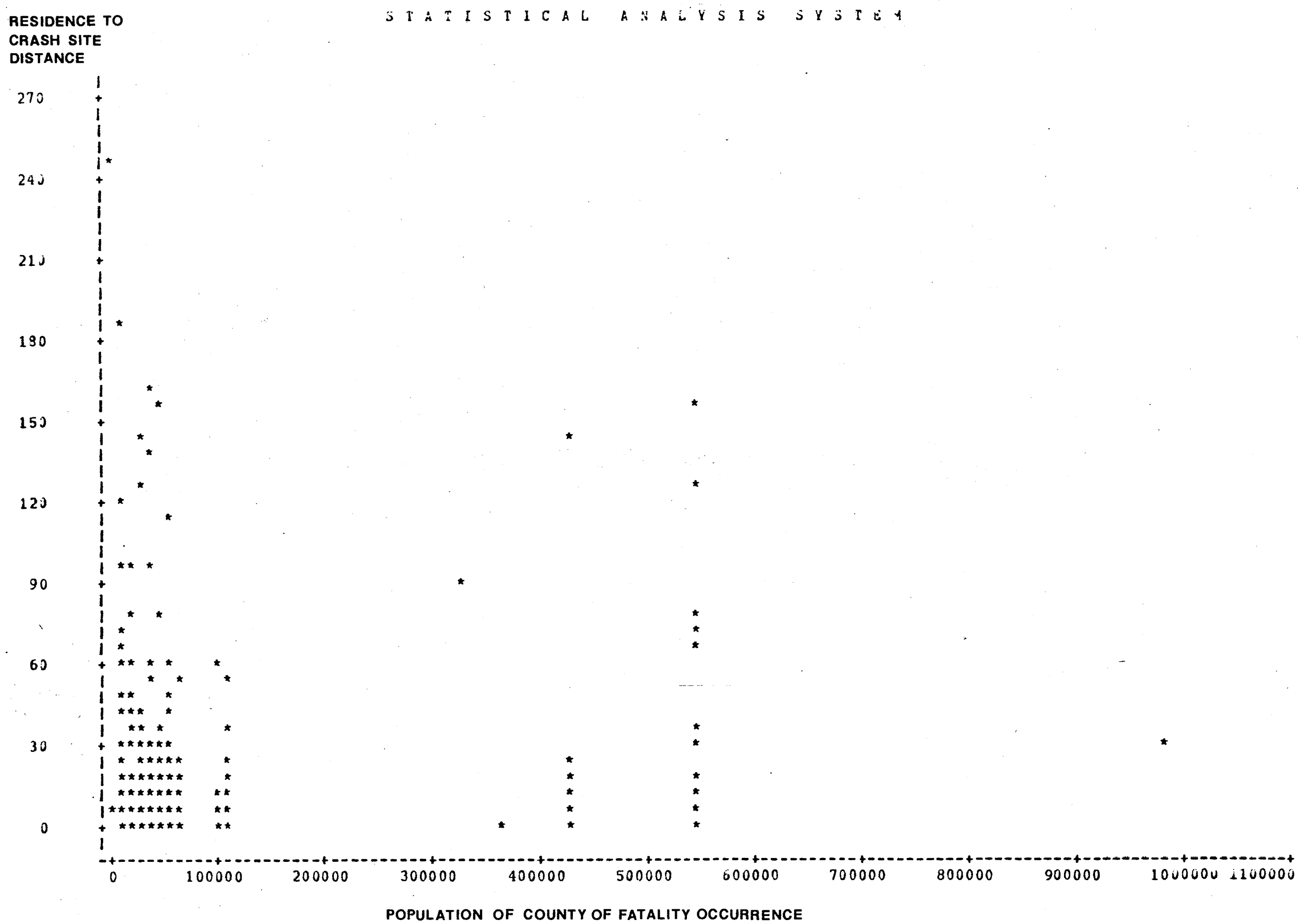

Figure 27. Residence to Crash Site Distance by Population of County of Fatality Occurrence

Average Daily Traffic, used as a measure of stress, was partitioned between high and low. A chi-square analysis was performed and the null hypothesis of no significant difference between classes of residence to crash site distance and levels of stress was accepted. ($X^2 = 0.0004$ with 1 df at $\alpha = .05$). Hence, the level of SIDE or system stress did not affect the residence to crash site distance or "journey to death." Yet the SIDE were certainly present within the system, at varying intensities, when the fatalities occurred. What remained was to determine whether urban or rural residence to crash site distances were affected by stress levels.

Urban-Rural Differences in Residence to Crash Site Distances

Many fatality-related travel distances in both urban and rural counties of Oklahoma were short and long. In large urban areas such as Oklahoma City, residence to crash site distances could be long due to the physical expanse of the city. The hypothesis was that there existed basic distance differences between urban and rural "journeys to death." A t test procedure was employed. At a significance level of 0.5, the null hypothesis of no significant difference was rejected. Hence, there existed a distance difference between urban and rural residence to crash site distances. Mean distances in the urban areas of Oklahoma (SMSA counties) was 14.72 miles, whereas in the rural counties it was 18.01 miles. While spatial trip lengths differed, the urban fatal trips were relatively long, indicating significant intra-metropolitan movements.

Levels of Stress and Urban-Rural Distances

Although the level of stress declined with longer residence-to crash-site distances, the level of stress did not affect the length of the residence to crash site distance in urban or rural areas. A chi-square test was used to determine the effect of two levels of stress (high and low) on long and short urban and rural distances. In both cases the null hypothesis of no significant difference was accepted. Such a finding invalidates earlier theoretical statements. It appeared that residence to crash site distances were not a reflection of SIDE. Figure 27 shows the relationship of stress to distance traveled. While both human and system stresses were certainly present, the fatal traffic accident site was not the location where system stresses were maximized. Clearly, there existed a combination of other factors which must have determined the residence to crash site distance. This problem is dealt with in more detail in Chapter V.

Summary of the Results, Part 1

Several significant findings may be summarized at this point. With regard to residence to crash site distances and their spatial pattern, two findings were of importance:

(1) The existence of differences in mean residence to crash site distances for auto-drivers in Oklahoma and Michigan revealed polarized urban system development, with attendant affects upon patterns of fatal spatial movements. Hence, urban hierarchy influenced the length of "journey to death."

(2) Shorter residence to crash site distances were predominantly inter-urban trips. Movement was mainly from a rural origin to a rural

destination, and from urban origins to urban destinations. There occurred minimal interaction effects (as shown by fatality distances) between urban and rural areas. Indirectly, this suggests that interaction between the man-vehicle-highway system was occurring at short distances from the origin points. Also, it was indicative of the small travel fields of people engaged in the spatial interaction process.

Results of Hypothesis Testing. A total of five hypotheses were tested up to this point.

(1) The first hypothesis states that fatal traffic accidents will tend to cluster in space, especially where the SIDE are at a peak.

Clustering was only evident in the urban counties of Oklahoma, but the percentage of fatalities occurring in these locations did not make the urban counties predominant. When their effect was removed, the spatial pattern of fatalities appeared quite uniform.

(2) The second hypothesis expected there to be differences between the urban and rural counties of the State of Oklahoma as regards the residence to crash site distance for groups of involvees.

This hypothesis was accepted as it was shown that mean distances differed substantially. A difference of four miles in the means indicated that intra-metropolitan trips were long in proportion to the rural counties.

(3) Hypothesis three was concerned with the impact of levels of stress upon long and short residence to crash site distances. The belief was that SIDE were reflected in the residence to crash site distances.

This hypothesis was rejected, thereby indicating that system stresses or SIDE did not influence the length of the distance traveled to death. Yet a plotted relationship showed a definite distance decay effect between stress and distance traveled. Thus, a combination of other variables must have determined why the fatality victims died so close to home.

(4) Hypothesis four concentrated upon the impact of differing levels of stress on urban and rural distances traveled.

This hypothesis was also rejected. Apparently it did not matter whether both long and short residence to crash site distances were urban or rural. The level of system stress was not associated with distance.

FOOTNOTES

[1] Oklahoma State Department of Public Safety, Traffic Accident Facts, 1976 (Accident Records Division), p. 1.

[2] Ibid., p. 1.

[3] Hal Moellering, The Journey to Death: A Spatial Analysis of Fatal Traffic Crashes in Michigan, 1969, Michigan Geographical Publication No. 13, Department of Geography, University of Michigan (1974), p. 30.

[4] Ibid., p. 30.

CHAPTER V

RESULTS OF THE ANALYSIS, PART 2

The Model

As outlined in Chapter II ordinary least squares regression was used to test the model. The first model was of the form,

$LOGDXR_i = f(ADT_i, POPCOOC_i, LU_i, DOT_i, HIGHCL_i)$

Where: $LOGDRX_i$ = the log of the residence to crash site distance for fatality i;

AST_i = average daily traffic at fatality site i;

$POPCOOC_i$ = population of the county of fatality;

LU_i = predominant land-use at fatality site i;

DOT_i = the direction of travel of vehicle(s) involved in fatality i;

$HIGHCL_i$ = highway class on which fatality i occurred;

was used to test the hypothesis that the SIDE were factors in determining the residence to crash site distance of individuals involved in fatal traffic accidents. A log transformation of the residence to crash site distance variable was used because of its highly skewed nature. A complete log transformation of the model was not possible because not all variables lend themselves to transformation.

Three class variables were used in the model. Land-use, direction of travel, and highway class were measured on several levels. For example, land-use was measured on six levels with each level corresponding to a land-use surrounding the fatality site. The land use classes were; residential, business, industrial, school, not built-up and rural. Similarly, direction of travel was measured on three levels; towards home, away from home and not known. Finally, highway class was measured on five levels; interstate route, U.S. Highway, State Highway, county/section road and city street. Information for all variables come from the Official Police Collision Report forms for 1976.

Results of the Model for Automobile Drivers

The R^2 value for this group of involvees was 0.19. Hence, the coefficient of determination indicated that the independent variables accounted for only 19 percent of the variation about the mean of the dependent variable. This was not a respectable statistic for 81 percent of the variation remained unexplained. Therefore, it can be concluded that there was no relationship between residence to crash site distance and system stresses. A significance test (f statistic) was made which tested the null hypothesis of no linear relationship ($r = 0$). At a significance level of .05 the null hypothesis was accepted. Hence, the R^2 value of 0.19 could have arisen by chance even with no association among the variables.

Clearly, the specified model did not fit the traffic fatality data well for auto-drivers. The correlation matrix which appears in Table V below does not reveal any startling findings. All correlation coefficients are below 0.5. Yet certain statements can be made regarding interrelationships among the stress variables. The relatively high correlation between type of Highway Class and Population of County of

Occurrence indicates the presence of different roads for different population sized counties. Land-use and Highway Class display the highest correlation while the correlation between land-use and population of county reveals changing land-uses as population decreases. Average Daily Traffic experienced very low coefficients when correlated with all variables. Thus, it appears that only Land-use, Highway Class and Population of County were variables of any significance in the correlation analysis.

TABLE V

CORRELATION COEFFICIENTS MATRIX - AUTO-DRIVERS

	LOGDRX	LNDUSE	HIGHCL	DIROFTR	ADT	POPCOOCC
LOGDRX	1.0000	0.17613	-0.28421	0.01048	-0.02086	-0.11819
LNDUSE		1.0000	-0.45561	-0.14843	-0.16979	-0.33007
HIGHCL			1.0000	0.11879	0.04132	0.43409
DIROFTR				1.0000	0.02598	0.05158
ADT					1.0000	0.23738
POPCOOCC						1.0000

In order to determine some association among the variables, simple regressions were attempted using residence to crash site distance as the dependent variable and five independent variables. It was thought that this procedure would reveal some characteristics in the association of distance and SIDE that remained obscure both in the model and correlation matrix. Table VI reveals the results of this additional analysis. When individual regressions were performed, low R^2 values still predominated.

TABLE VI

RESULTS OF THE SIMPLE REGRESSIONS UTILIZING LOGDRX AS DEPENDENT VARIABLE - AUTO-DRIVERS

Dependent	Independent	X_i	R^2
LOGDRX	ADT	0.000	0.000
LOGDRX	POPCOOC	-0.000	0.040*
LOGDRX	HIGHCL		0.221*
LOGDRX	LU		0.119*
LOGDRX	DOT		0.074*

*Significantly different from zero at 95 percent level.

It was hypothesized that long residence to crash site distances on an urban-rural continuum would be associated with low levels of system stress. Such was not the case in a regression situation since the R_2

value was essentially zero. The plot in Figure 27 displayed no definite distance-decay effects. From earlier analysis it was shown that levels of system stress had no effect upon long or short urban-rural distances. Two additional SIDE, population of county of fatality occurrence and land-use, both had low R^2 values. The coefficient for POPCOOC showed that as residence to crash site distance increased the population of the county of fatality occurrences decreased. This identified long residence to crash site distances in rural counties. In spite of this there occurred no corresponding decrease in ADT levels. Highway class showed the strongest R^2 value indicating that the type of road traveled on may influence the length of the "journey to death." For example, fatalities on an interstate would indicate victims had been traveling longer time periods and longer distances relative to fatality victims on city strees.

Results of the Model for Motorcyclists

The model fared much better for this group of involvees. The R^2 value was 0.44, so that 44 percent of the variation about the mean of the dependent variable was accounted for by SIDE or system stresses. This was a respectable statistic which indicated that the model may have had more meaning for motorcyclists than auto-drivers. The correlation matrix which appears in Table VII displays no high correlations among the stress variables. All correlations are below 0.5. No patterns have emerged from inspection of the correlation matrix.

The influence of individual variables was determined by simple regressions using the independent variables singularly. Table VIII presents the results of the simple regressions. When this procedure

TABLE VII

CORRELATION COEFFICIENTS MATRIX - MOTORCYCLISTS

	LOGDRX	LNDUSE	HIGHCL	DIROFTR	ADT	POPCOOCC
LOGDRX	1.0000	0.08921	-0.19484	0.07310	-0.23080	-0.04544
LNDUSE		1.0000	-0.29930	-0.15596	-0.34254	0.07347
HIGHCL			1.0000	-0.28988	-0.07845	0.36934
DIROFTR				1.0000	0.22495	-0.21946
ADT					1.0000	0.32998
POPCOOCC						1.0000

TABLE VIII

RESULTS OF THE SIMPLE REGRESSIONS UTILIZING LOGDRX AS DEPENDENT VARIABLE - MOTORCYCLISTS

Dependent	Independent	X_i	R^2
LOGDRX	ADT	-0.000	0.09*
LOGDRX	POPCOOC	-0.000	0.00
LOGDRX	HIGHCL		0.10*
LOGDRX	LU		0.21*
LOGDRX	DOT		0.04*

*Not significantly different from zero at 95 percent level.

was used several differences emerged between the impact of SIDE on motorcyclists and auto-drivers. While all R^2 values were very low only one was significantly different from zero.

The negative beta co-efficients for average daily traffic showed that the hypothesized relationship was in the hypothesized direction; as motorcylist residence to crash site distance increased, the average daily traffic decreased. This occurred with the population of the country of fatality occurrence as well. Why were motorcyclists influenced by such SIDE as ADT and POPCOOC when auto-drivers were not? This question was answered in a later section. More importantly, the effect of land-use on the residence to crash site distance became apparent for motorcyclists. Type of highway or route had no immediate influence. Hence, for both groups of involvees several SIDE operated differently. Understanding why this occurred can only be accomplished by examining the importance of individual SIDE variables and by returning to Figure 7.

The Importance of Individual Variables in the Model and Their Relationship to the Conceptual Model of the Dysfunction Process in Spatial Movement

The rationale of the Conceptual Model as presented in Figure 7 was to examine the fatal movement process within the content of SIDE. It attempted to define a fatal journey with origin at the residence and an unknown destination. In each of the three conditions, the auto-driver or motorcyclist is affected by both human and system stresses. The location of fatality occurrence was dependent upon trip purpose, directional movement pattern, type of road system and the dysfunctional elements surrounding the man-vehicle highway system. The results of the model indicated that the Conceptual Model of the Dysfunction Process in Spatial Movement did not fit the data well and that the dysfunction process affected motorcyclists differently from auto-drivers.

Average Daily Traffic (ADT). This measure of system stress had no significant impact upon the residence to crash site distance for automobile drivers or motorcyclists. As indicated earlier, the case of auto-drivers revealed no relationship at all in the simple regression example. Only for motorcylists did the negative coefficient indicate low levels of ADT with longer LOGDRX. The direction of the relationship and strength of the relationship suggested that ADT was not of sufficiently high levels to influence the residence to crash site distance traveled. Hence, while the spatial movement process may not be affected by SIDE, previous studies have shown that traffic volume and traffic density do affect the number of accidents, especially at intersections.[1]

In the State of Oklahoma, both urban hierarchy and types of trips would determine the levels of system stress and SIDE. From an earlier statement, relatively few large cities and predominant inter-urban movement means lower levels of system stress when averaged over the system. High levels of ADT do exist in Oklahoma and Tulsa Counties, but in all probability they do not cause fatalities, only accidents, due to the reduced speeds of the man-vehicle system. Secondly it suggests that human stress may be of greater importance in the residence to crash site distance traveled than originally thought. As seen from Figures 8 through 12, the longer the distance traveled the more the combined stresses. Hence, the perceptual decision motor capacities of the driver slow down, decaying alertness ensues and the probability of a fatality increases.

Population of County of Occurrence (POPCOOC). Being another measure of system stress, the hypothesized relationship was in the right direction for both groups of involvees. The insignificant but negative beta co-efficient indicated that longer residence to crash site distances were associated with low population counties. This was not surprising since the longest distances traveled were recorded in rural counties. Many short distance fatal journeys were undertaken in high population counties, but also in relatively low population counties. Since only four fatalities occurring in rural counties have extremely long journey, the regression procedure forced the relationship to the right direction.

Type of Highway Class (HIGHCL). As mentioned earlier, this variable was significantly different from zero for auto-drivers, but not for motorcylists. Based on the levels or types if highway class, auto-drivers who were killed on interstates were probably more likely to be longer distances from their residence than those killed on city streets or state highways, etc. Furthermore, interstate users face higher ADT volumes than travelers on city streets or highways due to the concentration of traffic on one route. Therefore, long distance drivers on interstates were probably subject to greater levels of system stress than auto-drivers on other types of roads. For motorcyclists, this relationship did not emerge because of shorter mean distances between residence and crash site, and the predominance of fatalities on city streets.

Land-Use (LU). This variable contributed much of the variation in the final R^2 value (0.41) for motorcyclists, and it was significantly different from zero (0.21) in the simple regression procedure. For auto-drivers, the co-efficient was not as strong. In interpreting this effect, it became apparent that type of land-use at the crash site was of greater importance for motorcylists than auto-drivers. To an automobile driver traveling along a city route, for example, the changes in land-use along the route may not affect him unless corresponding changes in levels of traffic volume and types of vehicles are extremely high. Even then he may be forced to reduce speed and be more alert of the situation around him. Thus, a certain amount of stress (Figure 11) is necessary to keep the driver alert. On the other hand, a motorcyclist traveling along the same route would be affected to a greater extent by sudden changes in land use and corresponding increases in traffic volume and vehicle types.

The motorcylist traveling from a residential to industrial area of the city will experience increased traffic volumes and heavier commercial type vehicles on the road. It is here where trucks and motorcycles become incompatible elements on the road system. System stresses, in such a case, affects the motorcyclists much more than the auto-driver, yet the motorcyclist may be as alert as other drivers around him. The size of the motorcycle in relation to vehicle size makes it harder to be seen and identified; with lane changing this is a potential danger for the motorcyclist. Since margins for error are reduced in such situations, the motorcyclist has a higher chance of being struck by automobiles or heavier commercial vehicles.

Direction of Travel (DOT). This variable was not statistically significant for either group of involvees. It was thought that direction of travel (away from home or towards home) would influence how far people had fatalities from their residence. Since a high percentage of fatalities occurred at short distances from the residence, the direction of travel did not matter. Furthermore, it was hoped that direction of travel would be important in identifying those fatalities which occurred at peak traffic periods during the day. For example, were fatalities which peaked at 1:05 A.M. a group of victims traveling towards the residence, and similarly for fatality victims between 5:00-6:00 P.M.?

Summary of Results

Despite the low ability of the model, several statements can be made concerning possible relationships among dependent and independent variables. For automobile drivers it was shown that residence to crash site distance traveled was not a function of SIDE or system stress. Yet residence to crash site distance did appear to be related, in minor ways, to the type of road the involvee was traveling on. Average daily traffic did not influence the journey to death in any way. As mentioned earlier, the possibility existed of insufficient levels of system stress in contrast to high levels of human stress in accounting for journeys to death. Since most distances were short, mean of 16.0 miles, then perceptual decision motor capacities of drivers broke down close to home. Conversely, this indicates that fatality victims are not alert at short distances; for example, trips to a supermarket or quiktrip. Hence, two sets of conditions apply for short and long distance trips.

For motorcyclists, the model had a higher predictive ability due to the influence of land-use as a contributor to the explained variation. In general, it appeared that SIDE affected motorcyclists residence to crash site distance. This would appear correct, since motorcyclists are more exposed to SIDE. Despite a respectable association for this latter group of involvees, system stresses were not of sufficient magnitude to affect the residence to crash site distance. The cumulative stress surface was not varied sufficiently to affect all dis-distances, instead its concentration at specific locations and at particular times meant that it affected a small percentage of fatalities. Thus, it appears that fatalities are short distance phenomena which indicate a short trip distribution and low levels of both human and system stress.

The findings, thus far, have not confirmed or contradicted the findings of Moellering.[4] Instead they have helped to shed light on the geographic nature of the residence to crash site distance. Moellering's study identified, (1) population of the county of residence, (2) highway class, (3) the crash site, and (4) Michigan State Police District as important spatial variables in the journey to death. Their only importance was in defining the journey to death. This research identified the importance of highway class and land-use as influences upon the journey to death. In addition, the findings of Chapter IV shed light on the impact of urban systems differences and trip lengths on differences in residence to crash site distances traveled. The final chapter summarizes the study and discusses the implication of the research findings.

CHAPTER VI

SUMMARY, IMPLICATIONS AND FURTHER RESEARCH

Summary

This thesis was undertaken because of the concern with the persistently high traffic fatality statistics in the United States. Too many people are being killed unnecessarily on our roads and highways. In addition, the traffic accident phenomenon has been a problem of major proportions in the U.S.A. for many years. As a contribution to the understanding of the fatal accident problem, the focus and objectives of this thesis were two fold. First, to focus upon the notion of distance as it related to fatal traffic accidents, it was primarily concerned with the anatomy and characteristics of residence to crash site distances traveled. Second, to examine the relationship between residence to crash site distance traveled and SIDE or system stresses in the road and travel environment. The State of Oklahoma was chosen as the study area and the state's fatal traffic accidents for 1976 composed the data base. Information on 1976 fatal traffic accidents was obtained from the Official Police Collision Report forms at the Oklahoma Department of Public Safety.

In order to carry out the objectives of this thesis, several models were developed which attempted to construct a theoretical framework. The Conceptual Model of the Dysfunction Process in Spatial Movement was the main model which attempted to define the residence to crash site distance in terms of origin, destination and SIDE. From this model were developed several sub models which took into consideration aspects of residence to crash site distance and "stresses." Distinctions were made between the types of stresses, human and system stress, and their impact on distance traveled and residence to crash site. This process culminated with the development of a systems model which attempted to establish an association between system stress and residence to crash site distance. While the theoretical development phase was new and innovative, the results of the modeling efforts were not as expected.

Trends in the Spatial Pattern and Distribution of Fatalities

Evidence from Chapter IV demonstrated the spatial pattern and distribution of fatalities in 1976. Major clustering of fatality locations was not evident, except for the apparent clusters in Oklahoma and Tulsa County. The clustered fatalities comprised only 30 percent of all fatalities, the remainder were rural. Small country towns, in particular Altus, Tahlequah, Ponca City and Ada, etc. did appear in small clusters on the rural landscape. In general, the pattern was more uniform than clustered. In addition, it was graphically evident that urban residence to crash site distances differed from those of rural areas. Urban distances appeared short on the vector maps, but several long residence to crash site distances existed. In rural areas, the distances appeared relatively longer, yet many short distances prevailed. Basically, the locational distribution pattern followed trends in population distribution, but there was evidence of fatality clusters along particular routes. For example, in McCurtain County, U.S. 259 was dotted with fatalities in 1976 as was State Highway 33. Interstate 35 and the Turner Turnpike were other linear surfaces dotted with fatalities.

The graphic analysis illustrated that certain counties and roads of the State had higher proportions of fatalities than warranted by their population or traffic volume. Such information could be of value to State Highway and Transportation Departments in identifying problem areas within the State and in particular, high frequency fatality routes. It is such areas that display the dysfunction elements in the movement process and hamper the efficient operation of the man-vehicle-highway system. While the solutions may finally depend on highway engineering, one objective would always be to improve the "perceptual decision motor capacities" of the driver.

Residence to Crash Site Distances and Their Spatial Patterns

Several important findings emerged from: (1) the calculation and analysis of residence to crash site distance means for the groups of involvees, and (2) analysis of the spatial patterns. First, the residence to crash site distance means were calculated for two groups of involvees, auto-drivers and motorcyclists, in order to determine the relative lengths of the journey to death. For both groups, the means indicated very short residence to crash site distances. Frequency distributions showed that in all cases, more than 50 percent of fatalities occurred within 10 miles of the residence and that a high percentage occurred within five miles of the residence. Thus, fatal spatial trips for fatality victims in Oklahoma were very short. Mean distance for dead automobile drivers was 16.01 miles, for motorcyclists the mean distance was 16.10 miles. Mean distances for both groups was consistent with findings from an earlier study, but that of auto-drivers revealed interesting differences.

The spatial pattern of fatality movements was revealed as being on an inter-urban basis rather than intra-urban. Fatal movements in space were predominantly movements between rural towns; there was little movement between rural and urban areas. In urban counties, intra-metropolitan movements were apparent. A lower distance mean for dead auto-drivers in Oklahoma, as compared to those of Michigan, revealed differences in urban system development and spatial travel habits. In Michigan, the existance of a more developed urban heirarchy generates greater amounts of intra-urban movement due to the presence of intermediate sized cities. Thus intra-urban travelers would be at longer distances between their residence and all probable crash sites within a metropolitan area in Michigan. In Oklahoma, on the other hand, the existence of an urban system characterized by fewer large cities, no intermediate sized cities, and the predominance of small sized towns, both in terms of numbers and the close spacing between them, indicated inter-urban movements. Shorter distances prevailed because trips were linear and were direct. This finding raised interesting questions concerning the impact of urbanization on fatalities and residence to crash site distances.

Results of Hypothesis Testing

Four hypotheses relating to the nature and characteristics of residence to crash site distance were tested. The rationale behind hypothesis testing was to further explore the geographic property of residence to crash site distance. One geographic property was the difference in length between urban and rural residence to crash site distances and their variations with levels of stress. The hypotheses indicated the existence of distance differences between urban and rural areas. Urban residence to crash site distances were substantially longer than rural distances, suggesting the effect of intra-metropolitan movement. A related hypothesis attempted to discern the impact of levels of stress or SIDE upon urban and rural distances traveled. This hypothesis was rejected so that it did not matter whether urban-rural distances were both long or short, the level of system stress did not affect the "journey to death."

All residence to crash site distances for the 418 cases were categorized into short and long and a test was made of the assertion with high and low levels of system stress. This hypothesis was also rejected indicating no association at all between distance traveled to death and the level of system stress. These findings were the opposite of what was expected based on earlier theoretical developments. The findings indicated that on an urban-rural continuum, stress was not maximized at the fatality site, and that system stress was not of sufficient levels to affect the "journey to death." While system stresses were not reflected in the residence to crash site distance, their presence at the fatality site cannot be discounted. From the discussion in Chapter II it was argued that a high probability of fatality occurrence was likely at the point where cumulative human and system stress was low, i.e. where the driver is least able to cope with hazards on the road. The empirical evidence would seem to fit this model well.

Implications of the Results of the Model

One model was tested in this thesis which dealt with residence to crash site distance and system stresses. Residence to crash site distance was used as the dependent variable. The aim was to determine why people died so close to their residences. Naturally, the system stresses formed the independent variables. It was hypothesized that the residence to crash site distance was a function of average daily traffic, land-use, direction of travel, type of highway class and population of the county of fatality occurrence. These variables were taken to be measures of system stress and to be the SIDE associated with fatalities. The model was tested on two groups of involvees, auto-drivers and motorcyclists.

Results indicated that, contrary to the hypothesized relationship, the residence to crash site distance was not totally associated with the chosen system stresses. For auto-drivers the R^2 value was 0.19, while for motorcyclists it was 0.44. Simple regressions were attempted to discern some magnitude of strength amongst the variables. With the former group of involvees, a simple regression of log residence to crash site distance and highway class revealed a significant relationship (R^2 = 0.221). On the basis of this result, the variable highway class was accepted as a significant factor in residence to crash site distance lengths. Auto-drivers appeared on different types of roads, but it seems that different distances were associated with a particular type of road. Users of interstates would, in all probability, be traveling longer distances while users of city streets, particularly in rural towns, would indicate shorter distances between origin and destination, etc. For example, rural farm to market distances would be included in the latter category, as would commuting from suburbia to the CBD (or the journey to work).

For motorcyclists, the model fared much better with 44 percent of the variation being accounted for by system stresses. While the mean residence to crash site distance was not very different to that of auto-drivers, the motorcyclists had a higher frequency of shorter distances thereby reducing the variation in the model. Many motorcycle fatalities were in Oklahoma and Tulsa County where higher levels of stress prevailed. In essence, the model captured differences in system stress along the urban-rural continuum and indicated that in urban areas system stress affects motorcyclists journey to death. Simple regressions were run to determine the influence of individual variables. Predominant land-use at the crash site was a significant determinant of log residence to crash site distance. Clearly, changes in land-use affect the man-vehicle-highway system and this change is more pronounced for motorcyclists whose exposure to the road environment make them vulnerable objects.

Thus highway class and land-use emerged as significant system stresses in their relationship with the journey to death. They do, in part, define the journey, for the highway is the road traveled on and land-use is part of those elements which influence the vehicle-driver reactions, alertness and driver stress.

Implications

Two levels of implication arise from the results of this thesis. The first relates to what State Highway and Transportation Departments should do as a result of the analysis regarding time and day of week of fatality occurrences, and the influence of land-use and highway class on predominantly short residence to crash site distances. The second level relates to questions that arise about the implications of changes in Oklahoma's urban hierarchy for the locational distribution of fatalities and the spatial patterns of fatal trips.

Earlier analysis revealed that patterns arose in the time and day of week of fatality occurrences for the 418 cases. Peaks in time of occurrence were prevalent at 1:05 A.M. and between 5:00-6:00 P.M. It was mentioned that the former peak may be composed of fatalities where victims were returning from alcoholic establishments, dance halls, clubs, or late night movies. There appears to be a higher number of vehicles on the road at this time of morning. To reduce the fatality toll at such an hour, police and highway patrol units would need to concentrate manpower on major arteries of cities and towns. In addition, random breath tests would remove drivers who pose hazards to other motorists. Such policies would appear appropriate on weekends as opposed to weekdays. During the period between 5:00-6:00 P.M. a further high fatality occurrence time occurs. Here, motorists on return home journeys, women returning from social recreation trips and motorists returning from day trips become most of the peak traffic volumes generated at this hour. Hence, traffic fatalities are a direct result of the urban transportation problem for those time periods.

Reductions in levels of SIDE can only be achieved through integrated transportation and land-use planning. It is at the peak traffic periods that the man-vehicle highway system breaks down. Both stronger controls and law enforcement on the highways, and planning maneuvers to reduce traffic volume and traffic density would achieve a substantial reduction in traffic fatalities. Findings from the model revealed two particular areas where improved planning may be required; the areas of land-use and type of highway. It was revealed that motorcyclists, in particular, were affected by changes in land-use. This would indicate that abrupt changes in land-use affect the fatality site and thus, the residence to crash site distance. Spatial distributions within cities and the locations of various economic activities, generate negative impacts by attracting heavier traffic volumes and diverse vehicle types. The exposed motorcyclist who travels through such spatial arrangements, pays the consequences.

Type of highway traveled on influenced the residence to crash site distance for auto-drivers. Essentially, this implied different users and different trip purpose for types of highway. It is generally known that interstates carry drivers on interstate routes or who undertake relatively long inter-urban trips. These travelers are those most likely to be fatigued and bored with the driving experience. Attempting to allocate more manpower on such routes may not reduce the fatality toll because of the random locations of fatalities along the route. Instead, a system of warning signs, eating places, and rest stops will help to keep the weary driver alert. More importantly, both high school driver training programs and highway safety courses should include material on the effects of distance traveled or cumulative human stress.

Future Trends

What are the implications of Oklahoma's increased urbanization trends on the locational distribution of fatalities and the spatial pattern of fatal trips? It was revealed in Chapter IV that basic urban system differences between Oklahoma and Michigan affect the mean residence to crash site distances and the spatial pattern of fatal trips. With continued population and economic growth in Tulsa and Oklahoma County, and the growth of smaller urban centers, many central places, will ascent the urban hierarchy. This will entail substantially more intra-urban travel patterns and longer residence to crash site distances. Hence, the spatial pattern of fatal trips will alter from an inter-urban to intra-urban pattern. As for the locational distribution of fatalities, the percentage occurring in urban areas of the State of Oklahoma will increase.

Slowing down the rate of urbanization would stop the trend, but would not eliminate the traffic fatality pattern. Hence, traffic law enforcement will need to become strong in the urban areas of Oklahoma. Also, as new transport infrastructure is built and land-use plans come into effect, there is need for a coherent policy and strategy to be aimed at reducing the negative impacts of changes in land-use upon the man-vehicle-highway system. The path of I-35 between Edmond and Oklahoma City is a case in point. There occurs a dramatic change along the route south from flat countryside to commercial strip development with accompanying increases in traffic density. Further on, the driver's confusion is added to for he must decide which fork of the interstate to pursue. Such hodge-podges of land-use should be avoided at all costs along heavily traveled routes.

Further Research

Research by various government departments and organizations into the traffic accident problem has been continuing since the turn of the century. Research results to date have been seen in improved highways, automobiles and higher safety standards, etc. This thesis did not focus upon the automobile or highway, rather it concentrated upon examination of the characteristics of residence to crash site distances traveled for groups of traffic fatality involvees. This form of research was upon a fundamental geographic property of traffic fatalities. Findings and implications of the research may not assist in reducing the traffic fatality toll, but the research has pointed to other areas which should enlighten our understanding of traffic fatality occurrences. Further research in the following areas would be appropriate.

(1) As suggested earlier, the concept of distance and cumulative human stress needs to be explored further so that we may determine the levels at which driver stress and alertness decline. Levels of stress affect drivers differently, so that research may identify drivers whose inability to cope is much lower than others.

(2) In order to better understand the impact of land-use changes along routes for fatalities and residence to crash site distances, research should focus upon driver perception and reaction to such changes along routes. Comparison studies between driver perceptions and land-use owner perceptions may be beneficial in identifying conflicts

of interests and expectations about the urban and traffic environment.

(3) Studies relating to the impact of urbanization on fatalities will benefit future road users. These studies should focus upon changes that will occur in growing urban centers in relation to spatial trip distribution and fatality locations. While the research may add another notch to the evils of urbanization, it should stress the integration of planning for the users of transport infrastructure and for the users adjacent to the transport routes.

(4) Further research which examines the relationship of residence to crash site distance traveled, fatality locations and the locations of hospital and ambulance services may assist in reducing the time spent traveling from fatality site i to hospital location j. Of interest would be the time savings between ambulance service notification of an auto accident and arrival at the accident scene, and time savings between departure from the accident scene to hospital location. A further area of research would be to examine the impact of rural hospital closure in Oklahoma upon the distances which fatality victims have to be transported for emergency medical services.

Undertaking each of these avenues of research will not eliminate the fatal traffic accident problem, instead they should contribute to the overall understanding of factors causing fatal traffic accidents. Finally, they should also contribute to improvements in the man-vehicle highway systems and to reductions in traffic fatality death tolls.

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APPENDIX A

AN OFFICIAL POLICE TRAFFIC COLLISION REPORT

INCIDENT REPORT Sheet of Sheets FATALITY = yes

OFFICIAL POLICE TRAFFIC COLLISION REPORT

OKLAHOMA

Reporting Agency :

Do not write in this space

No.

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

Distance From Nearest City Limits — Miles — N S E W

Name of Nearest City (If outside city limits)

STATE HIGHWAY CODES

Hwy Class — Control No. — Int. I.D. — Location

County No.

County Section Line Grids Or City Street Codes — East — North

City No.

Spec. Feat. — Collision Codes — Inter. Pop. Cl.

LOCATION

IN — city or town

ON — name or number of street or highway

AT — name of intersecting road or landmark

NOT AT INTERSECTION — ft. — mi. — North — South — East — West — OF — show nearest intersecting street or highway

OF: Control Location

MTR. VEH INVOLVED

Number Injured

Number Killed

Time Notified: Date : Hour : AM PM

Arrived At Scene: Date : Hour : AM PM

Unit 1 — Occupants — 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: Sex: Age: Date of Birth : Mo. Day Year — Highschool Driver Training Yes No

Vehicle: color year make model style

Veh. ID No. ( ) = { 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 contact — Burned? No Yes — $ estimated damage

Veh. removed to: by:

Unit 2 — Driver / Pedestrian / Animal / Train, etc. — Occupants — AFP

last first middle phone no.

Address: street or RFD city and state zip code

License: exp. yr. state number — Operator / Chauffeur / Other

Race: Sex: Age: Date of Birth : Mo. Day Year — Highschool Driver Training Yes No

Vehicle: color year make model style

Veh. ID No. ( ) = { 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 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; Pinned? Yes No; Ejected? Yes No	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; Pinned? Yes No; Ejected? Yes No	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; Pinned? Yes No; Ejected? Yes No	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; Pinned? Yes No; Ejected? Yes No	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 Driver #1 % Driver #2 % — HIT & RUN Yes No

Name: 1. last first middle — Citation: — Citation No.

2. last first middle — Citation: — Citation No.

District — Division — Reviewed by: Initials & Badge No. — Date of report:

SIGN HERE– (officer's rank & name) (badge number)

DPS 67-1 Revised May 1976

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
		11. Const. zone
		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

OBJECT STRUCK BY VEHICLE OR LOAD ON FIRST CONTACT

Unit 1	Unit 2		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

POINT OF FIRST CONTACT ON VEHICLES

Unit 1	Unit 2	TOP	Unit 1	Unit 2	BOTTOM
		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

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

	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

Unit 1	Unit 2	VEHICLE CONDITION	TIRE CHECK U 1	TIRE CHECK U 2
		1. Apparently normal		
		2. Brakes (Abnormal)		
		3. Steering (Abnormal)		
		4. Headlights (Abnormal)		
		5. Rearlights (Abnormal)		
		6. Tires (Abnormal)		
		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

Indicate North by Arrow

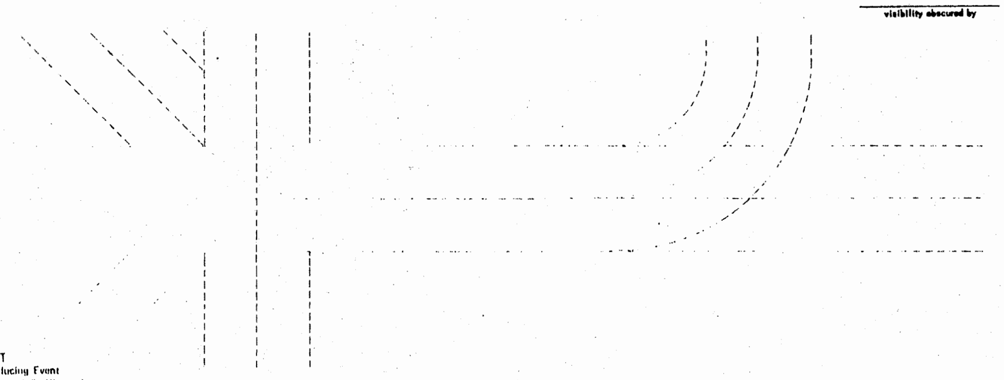
DIRECTION OF TRAVEL

Veh. 1 N [ ] S [ ] E [ ] W [ ]

Veh. 2 N [ ] S [ ] E [ ] W [ ]

______ visibility obscured by

COLLISION DIAGRAM



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

Yes [ ] No [ ]

______ Defect in Road/Oversize Vehicle

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. Other (describe)				6. Changed Lanes Unsafely	
		2. Failed to Yield/Stop				7. Unsafe Vehicle	
		3. Followed too Closely				8. Left of Center/Passing	
		4. Unsafe Speed				9. Not Known – or – No Improper Action	
		5. Made Improper Turn				10. Pedestrian/Bicycle Action	

APPENDIX B

A NOTE ON DATA SOURCES

Much information exists at the state and national level pertaining to fatal traffic accidents. At the national level summary statistics are available for the various states so that inter-state comparisons can easily be made. Within the State of Oklahoma, traffic accident statistics are collected, tabulated and published by the Oklahoma Department of Public Safety. The Accident and Enforcement Records division of the Department of Public Safety publishes the Oklahoma Traffic Accident Facts on a monthly and annual basis. This publication provides aggregated information on contributing causes of accidents, accidents by time periods, traffic deaths by county, age and sex distributions of involvees, and rates per MVM, etc. Because of the aggregated nature of this data little is of direct use to this research.

The primary source of data for this research comes from traffic accident report forms. In fact, the aggregated data of Accident and Enforcement Records is compiled from accident report forms. Every accident, fatal or non-fatal, where a law enforcement official has been notified, is recorded on an accident report form (see Appendix A). Tabulation of the accident report form then takes place at the Department of Public Safety. Varied types of information are available on these forms:

(1) specific information relating to the location of the accident, time of day, day of week, etc.

(2) driver residence, age, sex, type of vehicle and license information.

(3) nature and type of injury data or a 'K' designation.

(4) information pertaining to road and weather conditions, condition of vehicle, type of land use, and direction of

travel, etc.

(5) officer's estimate of cause of fatality.

(Detailed discussion on these forms appears in the following section.)

Copies of all fatal traffic accident report forms were obtained for the State of Oklahoma for the year 1976. It was kindly provided by the Department of Public Safety after a long process of bureaucratic refusal. Sensitivity of the information, an apparent state privacy policy on such documents and suspicion of academic researchers were the main reasons for the delay. Once attention was directed towards the Commissioner's Office, the payoff was evident. To researchers of the future, a similar strategy is suggested if results are desired.

The data obtained included all automobile fatalities, non-traffic, pedestrian, motorcycle, and bicycle/pedacycle fatalities. For this research, only those accident report forms pertaining to automobile, pedestrian, and motorcycle fatalities is used. This information was not available in computerized form at the Department of Public Safety. Furthermore, Accident and Enforcement Records does not engage in statistical analysis of its data, which led the author to conclude that no research was carried out within the State. Further discussion with other agencies dispelled such fears and uncovered the presence of computerized traffic accident forms.

Similar information to that available on the traffic accident report forms is also available from the State Department of Transportation in computerized form. The Research Division of this department maintains on tape the original information plus additional variables which are deemed important in their research efforts. This source was not utilized for two reasons. Firstly, the printouts would have entailed

Socio-economic data, apart from race, sex and age information, is not available for the various groups of involvees. Through intensive research and discussion, no other agencies, apart from those listed, provide the data used for this research. Hence, the raw data is the fatal traffic accident report forms.

APPENDIX C

TRAFFIC ACCIDENT FATALITIES BY COUNTY

OF OCCURRENCE 1976

TABLE IX

TRAFFIC ACCIDENT FATALITIES BY COUNTY OF OCCURRENCE; 1976

County	Auto-drivers	Motorcyclists	Pedestrians
Adair	2		1
Alfalfa	3		
Atoka	5		
Beaver	2		
Beckham	1		
Blaine	2		
Byran	3		
Caddo	6		1
Canadian	11		1
Carter	6	1	
Cherokee	8		2
Choctaw	3		
Cimarron	1		1
Cleveland	1		1
Coal	13	1	3
Comanche	5		
Cotton	9	3	4
Craig	5		
Creek	12	2	3
Custer		1	1
Delaware	3		3
Dewey	1	1	
Ellis	2		
Garfield	7	1	1
Garvin	3	1	1
Grady	6	1	2
Grant	2		
Greer	1		
Harmon	2		
Harper	2		
Haskell	2		1
Hughes	3		
Jackson	6		
Jefferson	2		
Johnston	3		
Kay	10	2	3
Kingfisher	4		
Kiowa	3	1	
Latimer	1		
LeFlore	7	1	
Lincoln	5		2
Logan	6	1	3
Love			

TABLE IX (Continued)

County	Auto-drivers	Motorcyclists	Pedestrians
McClain	2		
McCurtain	7		3
McIntosh	5		2
Major	3		
Marshall	2		
Mayes	13		
Murray	3		3
Muskogee	8		3
Noble	1		
Nowata	1		
Okfuskee	4		1
Oklahoma	33	8	16
Okmulgee	3		2
Osage	7		2
Ottawa	1		
Pawnee	3		1
Payne	9		
Pittsburg	4		2
Pontotoc	4	1	1
Pottawatomie	8	2	1
Pushmataha	4		
Roger Mills			
Rogers	6		1
Seminole	3		1
Sequoyah	3	3	
Stephens	7		1
Texas	5	1	
Tillman	3		
Tulsa	31	6	8
Wagoner	5		
Washington	5		1
Washita	4		
Woods			
Woodward	3		1
TOTAL	378	38	83

VITA[2]

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