An Analysis of One-Car Accidents

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Subsequent to a study concerning causation factors in one-car accidents an approach has been developed which proposes a general mathematical expression of the interrelationship of the three major factors involved in every accident, namely, the driver, the highway and the vehicle. The methodology of data collection developed and utilized in the previous study is suggested as a means of amassing sufficient data to permit the correlations necessary to evaluate the constants and express the variables in the proposed equation.

If experimental data verify the proposed concept, a means of predicting accident probability would be at hand. Testing methods and devices could then be developed to predict accident probability for individual drivers. The mathematical expression would also be valuable for estimating the potential effect of highway improvements on accident probability.

A method of classifying driver characteristics, which are factors of accident causation, to enable an intelligent estimate of the cost and effect of correction programs is proposed. The ultimate objective of any comprehensive research in highway safety should be directed toward developing the requisite knowledge to accomplish the maximum effect with the funds available for any recommended corrective program.

The potential of a study based on the concept and methodology proposed here justifies the recommendation that such a project should be inaugurated and pursued to the ultimate end.

● THE CIVIL ENGINEERING Research Group of the Engineering Experiment Station at Ohio State University has been engaged in studies in the field of one-car accidents during the past three years. The data collection and initial analyses were sponsored by the Ohio Department of Highway Safety. The presentation of data and the discussions of findings of previous analyses were contained in reports (1, 2, 5) published by the Engineering Experiment Station and theses (3, 4) by staff members of the Station. A summary of the final report (5) was published as a non-technical version entitled "Highways or Dieways?", Circular 59 (6) of the O. S. U. Engineering Experiment Station.

The present study is sponsored by a supplemental grant from the Station. Robert F. Baker, Associate Professor of Civil Engineering, is project supervisor and Emmett H. Karrer, Professor of Highway Engineering, is consultant. Richard W. Bletzacker, Research Associate is the principal investigator, and Thomas G. Brittenham, Research Associate, is the sociological consultant.

BACKGROUND

The basic philosophy of the study is that all one-car accidents are the result of the failure of the driver to exercise proper judgment. The factors which affect the driver's ability to exercise proper judgment are the combined characteristics of the driver, the highway, and the vehicle. The accidents caused by "acts of God" would necessarily be excluded from consideration, because they could be considered unavoidable. These accidents would include such conditions as: trees blown down immediately in front of or upon a moving vehicle; broken steering mechanism or faulty brakes on a new vehicle; and pavement "blow-ups" (rigid pavement expansion failures) that occur simultaneously with the approach of the vehicle.

If the basic concept can be accepted, the following corollaries may be developed: (1) the perfect driver on the perfect highway will not have an accident; (2) the perfect driver on the imperfect highway will not have an accident; (3) the imperfect driver on the perfect highway may have an accident; and (4) the imperfect driver on the imperfect highway may have an accident. The term perfect driver as used here is defined as a driver who is exercising the proper judgment required to cope with any driving situation. The term imperfect driver is defined as a driver who at a given instant fails to exercise the proper judgment required to cope with the driving situation. The perfect highway is defined as a roadway which does not present any unsafe characteristics with which drivers must cope. The imperfect highway is a roadway which does present unsafe characteristics.

The basic concept and the four corrollaries, as applied to one-car accidents, may be expressed in the general mathematical expression:

$$a = x^{y^{-n}} \qquad (1)$$

in which

a = driver judgment
x = evaluation of driver characteristics
y = evaluation of highway and vehicle characteristics
n = a constant that reflects the relative importance of the highway and vehicle.

Driver's judgment, as used here, is defined as that collection of driver actions which are the result of his evaluation of proper driving procedures required to cope with any driving situation. The quantitative evaluations of x and y must result in values between the limits of zero and one for the mechanics of the equation to follow the proposed concept.

OBJECTIVES

The objective of the study is to develop further a method of evaluating the interrelationship of the major variables involved in highway accidents, namely, the driver, the highway, and the vehicle. It is further proposed that with this technique an index of accident probability of an individual driver could be developed.

PROCEDURES

Eq. 1 is an attempt to express the interrelationship of the three major variables and their combined effect on driver judgment. The exact form of the expression and the evaluation of the constant n must be developed from and based on experimental data.

The data available from the previous studies included 183 one-car accidents, for which a driver interview was conducted, as well as an investigation of the highway characteristics at the accident location. The previous study was not specifically designed to yield the information necessary to make the evaluation proposed herein and, therefore, a rather subjective study of the data and subsequent evaluation were necessary. In order to illustrate the methodology of developing the interrelationship of the major variables, an analysis of each of the 183 one-car accidents was made by evaluating the driver characteristics and the highway characteristics.

The driver interview schedule contained over 80 questions, but, for the purpose of this study, only 27 were considered pertinent. Of interest here are only those factors which effect a negative or subtractive influence on the driver's ability to cope with the driving situation faced at the time of the accident. The data shown in Table 1 were classified as physiological, psychological, trip data, driver training and experience, and driver action, opinion, and attitude. Although the opinion and attitude information could not be shown to have contributed directly to the accident it was particulary useful and often significant as corroborating material.

In order to assess the influence of each negative driver characteristic, the following qualitative terms were used: (1) primary factor, (2) secondary factor, and (3) tertiary

TABLE 1

CLASSIFICATION OF NEGATIVE DRIVER CHARACTERISTICS

I. Physical Characteristics
   A. Age
   B. Amount of sleep prior to trip
   C. Alertness on trip
   D. How driver felt on trip
   E. Amount of alcohol consumed on trip
   F. Illness or injuries (recent)

II. Psychological Characteristics
   A. Anxiety on trip
   B. Personality type

III. Trip Data
   A. Familiarity with the highway
   B. Number of close calls encountered on trip

IV. Driver Training and Experience
   A. Method of learning to drive
   B. Driving examination information
   C. Length of experience with driving license
   D. Average mileage driven
   E. Number of previous accidents
   F. Number of previous arrests

V. Driver Action
   A. Distractions within vehicle
   B. Distractions outside of vehicle
   C. Average speed on trip
   D. Speed at time of accident
   E. Reason for arrest (this accident)

VI. Driver's Opinion
   A. Judgment as to speed at time of accident
   B. Driver's opinion of cause of accident
   C. Amount of alcohol that can be consumed without affecting driving
   D. Driver's opinion of his ability as a driver
   E. Driver's opinion of his need for improvement
   F. Attitude toward driving as measured by Siebrecht Test

factor. A primary factor was defined as any driver condition, situation, or behavior which directly contributed to the cause of the accident, that is, without the presence of this (these) factor(s), the accident could not have occurred. A secondary factor was any driver condition, situation, or behavior which indirectly contributed to the cause of the accident. These factors were considered to be conducive to creating a hazardous or unsafe driving situation. A tertiary factor was described as a driver condition, situation or behavior which constituted or reflected an undesirable driving situation but no direct relationship could be shown between it and the accident.

Each of the 183 one-car accidents was reviewed and the evidence of each negative driver characteristic was evaluated as to its effect, that is, primary, secondary, or tertiary. The degree of the effect of a particular factor was not constant; for example, the fact that a driver had two beers might be a tertiary factor in some cases yet might be evaluated as a secondary factor in another instance. Each primary factor was arbitrarily assigned a numerical value of 1.0, each secondary factor a value of 0.33, and each tertiary factor a value of 0.1.

The numerical values in each accident were summed, and converted to values of x by the equation:

$$x = e^{-1.8z} \tag{2}$$

in which

e = base of natural logarithms (2.71828)

z = sum of negative driver characteristic factors

Eq. 2 was developed to convert the value of z to values of x which followed the tenets of the proposed concept.

Obviously, had some other method of evaluating the driver characteristics been used which would have yielded numerical values of x between zero and one, Eq. 2 would not have been necessary. However, the method used here seemed to have certain advantages and permitted a reasonable degree of objectivity in making the required evaluation.

The report of the highway conditions at each accident location was studied and an evaluation of the highway characteristics was made. The evaluation was based upon the geometric standards of the AASHO (7) for design speeds of 60 mph, lane widths of 12 ft, and shoulder widths of 7 ft. The condition of the highway from the standpoint of maintenance was also considered, as were adequate warning and advisory signing.

Table 2 lists the highway characteristics under the two major classifications of design geometrics and maintenance. Each major classification was given equal weights with a potential value of 100. The minor classifications and their subdivisions were subjectively assigned weighted values, as indicated after each characteristic. The

TABLE 2

CLASSIFICATION OF ROADWAY CHARACTERISTICS

I. Geometrics - Design			100
A. Alignment		40	
1. Vertical	10		
2. Horizontal	30		
a. Safe speed			
b. Passing sight distance			
c. Obstructions			
d. Distractions			
B. Pavement Width		20	
C. Shoulder Width		10	
D. Change in Geometric Conditions		30	
II. Maintenance			100
A. Road Surface Conditions		30	
1. Pavement type	10		
2. Rideability	20		
B. Road Friction		20	
1. Surface roughness	5		
2. AASHO brake distance	10		
3. Surface condition	5		
C. Shoulder Conditions		20	
1. Relative elevation	10		
2. Surface type	5		
3. Surface irregularity	5		
D. Warning Conditions		30	
1. Sign adequacy	15		
a. Size			
b. Condition			
c. Type			
d. Obstructions			
2. Center line marking adequacy	15		
a. Condition			

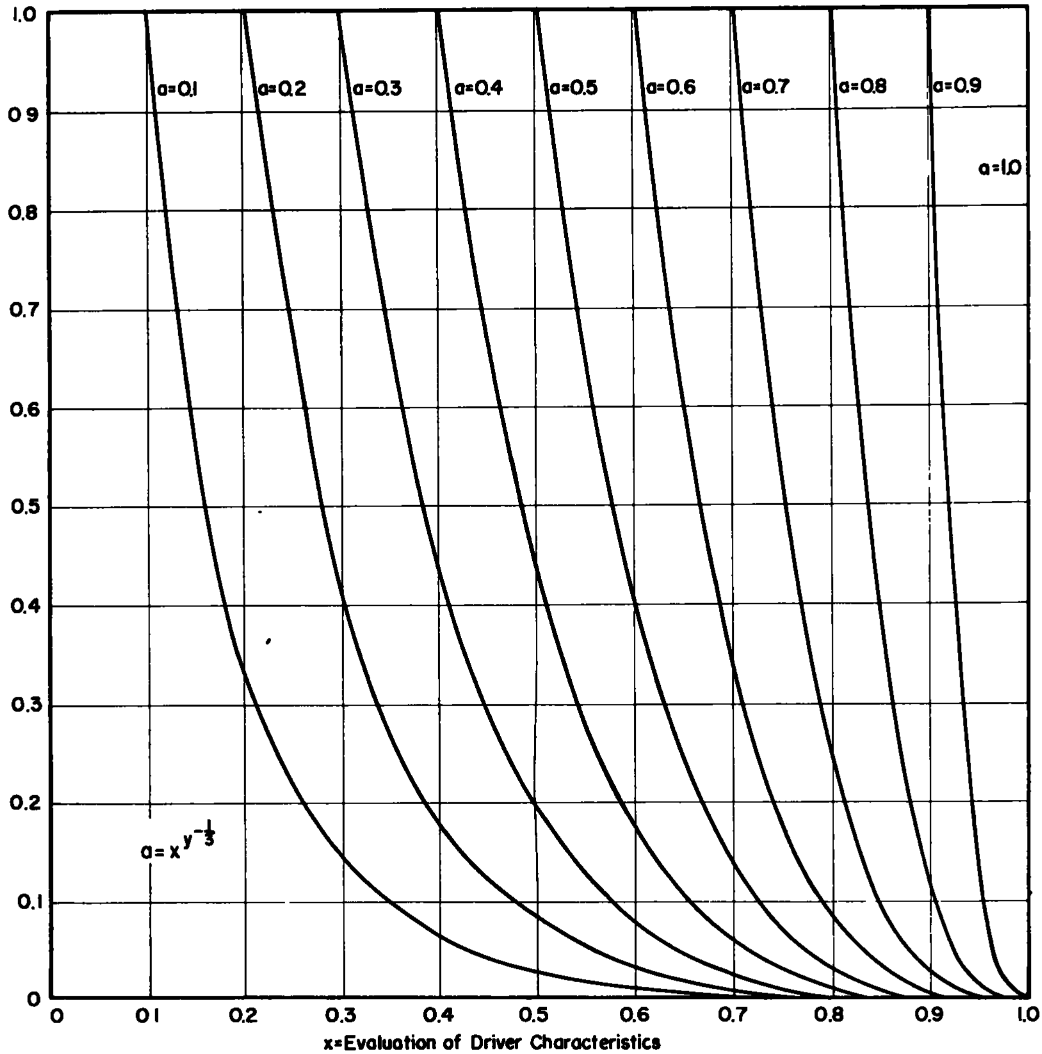

Figure 1. Family of curves of driver ability.

evaluation of the design standards and the maintenance conditions for each accident location were combined by a geometric rather than a straight arithmetic mean, and then divided by 100 to reduce the value within the limits of zero to one. The geometric mean was used because of the consideration that a well designed road poorly maintained, or a poorly designed road well maintained was not equivalent to some average road with average maintenance.

The previous study did not provide any significant data on vehicle characteristics, and no attempt was made to evaluate this variable in the present analysis. No inference should be made, however, that the vehicle influence would not enter into future studies.

The accomplished evaluations of driver and highway characteristics indicate that there were various factors in each characteristic which combined in such a way as to cause an accident. The inference is that some drivers were exercising better judgment than others and that accidents occurred on highways with evaluations encompassing the whole range from safe to unsafe. Data are needed which will permit analyses yielding quantitative values of judgment. To fit an equation to the data would then be relatively

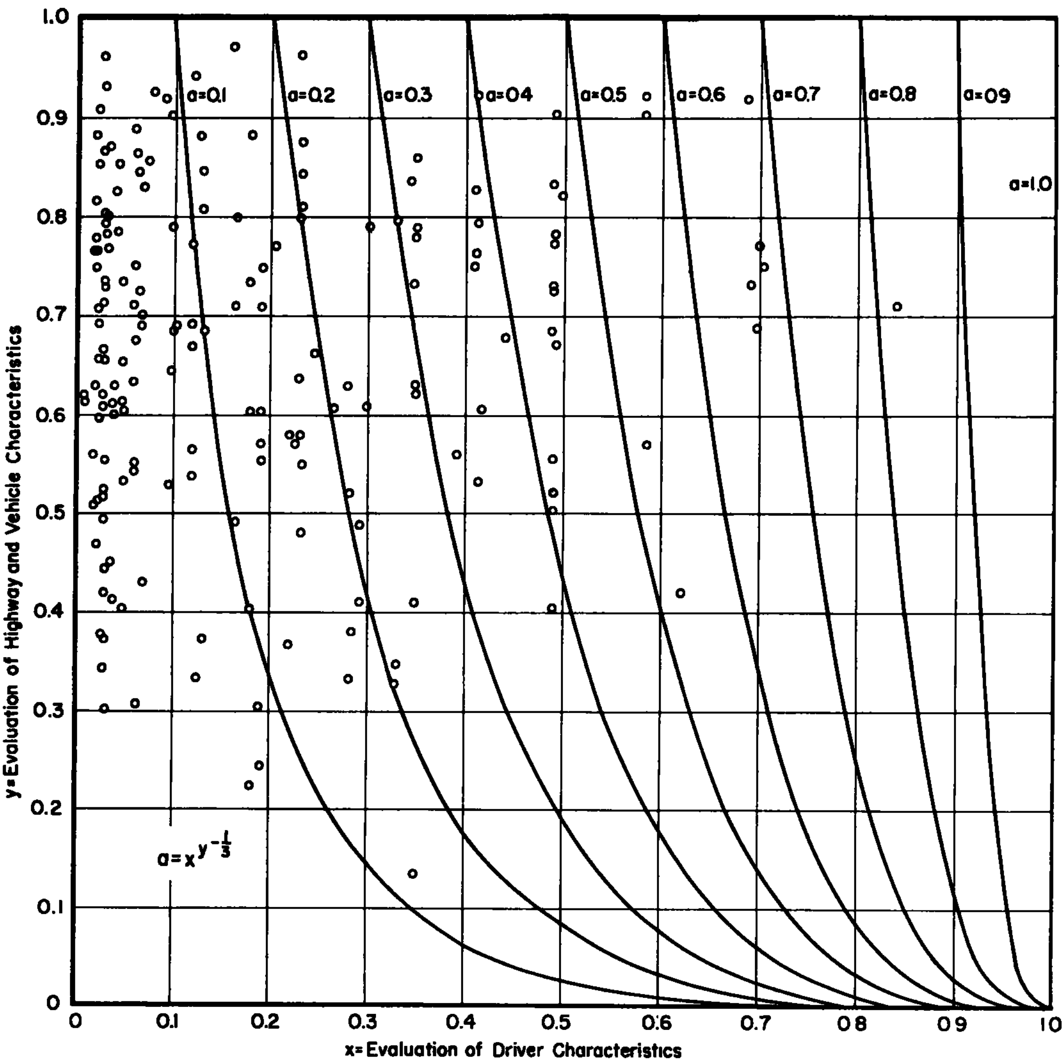

Figure 2. Plot of 183 one-car accidents.

simple and, specifically, it is proposed that the equation would follow the general form of Eq. 1.

Assuming a value of n, and for various values of a, the relationship between x and y is illustrated in Figure 1. By definition, the perfect driver is depicted when a = 1, which can only be valid when x = 1. In this instance, y has no influence. If the value of driver judgment is thought of as similar to topographic elevations, then the values of a = 0.1, a = 0.2, etc., are actually contours joining points of equal elevation or in this case equal driver judgment.

The values of x and y in each of the 183 one-car accidents were plotted, as shown in Figure 2, on the same graph containing the family of curves illustrated in Figure 1. There is no intention to infer that this evaluation would result, necessarily, in n being equal to $\frac{1}{3}$. These curves were merely used to illustrate the principle.

DISCUSSION OF METHODOLOGY

The proposed concept and methodology appears to have merit in the analysis of a number of problems encountered in highway safety. The utilization of Eq. 1 is dependent on establishing a means of properly evaluating x and y in such a way as to yield some level of driver judgment demonstrated in each driving situation. Data could be collected on a number of driving situations in which some of the factors could be held constant, in some cases resulting in accidents and the rest in non-accidents. An example is a male driver who, on a clear day, failed to negotiate a sharp curve at 45 mph. An interview produced data on factors which influenced this driver's judgment. If a group were stationed at this location and attempted to match the apparent factors found in the accident situation, data might be gleaned which would point up the influence of the unsimilar factors. With sufficient data of this type collected, correlations could be performed which should produce significant results. Obviously, this procedure would entail a rather comprehensive and long-range project but there is good reason to believe that the cost would be justified.

In analyzing data collected on accident and non-accident driving situations, it is reasonable to expect that the accident situations would plot in the lower ranges of a values while the non-accident situations would plot in the higher ranges. Of interest is the fact that, in Figure 2, assuming Eq. 1 to be valid in the form indicated, 96.7 percent of the accidents occurred when the driver's judgment was less than 0. 6, 94. 5 percent when a was less than 0. 5, and 87. 5 percent when a was less than 0. 4.

For the one-car accident case there must be a curve which would delineate between that value of driver judgment which will result in an accident and that which will be sufficient to avoid an accident. This curve will probably lie somewhere in the middle range of a. Such delineation may actually be a band of some width but this situation will result from an inaccurate evaluation.

It is also reasonable to expect that the necessary data on multi-car accidents could be analyzed by the concept proposed here. There would not, however, be a clear delineation between the value of a which would result in and the one which would be free of an accident. The theory of probability could be utilized to predict how many times a near-accident situation would have to be presented to a driver capable of a certain level of judgment before an accident might occur. This technique would permit the development of testing devices and procedures which would evaluate an individual and yield a determination of his accident potential.

The shape of the curves produced by Eq. 1 is of interest to the highway engineer. This concept could permit estimates of the highway improvements on driver judgment. Assume $n = {}^1/_{10}$ and the range of questionable driver judgment were between a = 0. 5 and a = 0. 6. For drivers who had driver characteristics (x values) of 0. 6, a would equal 0. 5 when y = 0. 046, whereas, y would equal 1. 0 when a = 0. 6. This situation indicates that a vast change in the combined highway and vehicle characteristics would have to be made to improve driver judgment by only ten percent. If n = 1.0 is assumed and the other conditions constant, the same improvement of a would be effected by changing y from 0. 735 to 1. 0. Such a change might be economically feasible in this instance. This principle is shown by comparing the families of curves illustrated in Figures 3 and 4.

A concept accepted and used in the field of instrument surveying to classify the inaccuracies of measurements (namely, errors, mistakes, and blunders) could be used to classify the detractive characteristics of the driver which restrict the driver's ability to exercise proper judgment. Driver error is defined as the static physical, psychological, or mental characteristics of a human which inhibit the judgment required to correctly cope with a driving situation. Driver mistake constitutes the failure of a human to have knowledge of the laws, rules, principles, and procedures required to cope with a driving situation. Driver blunder involves the transitory physical, psychological, or mental characteristics of a human which inhibit the judgment required to cope correctly with a driving situation.

Driver error reduces any human from perfection to some idealized level which he can maintain "most of the time." Those officials responsible for granting driving licenses must decide the minimum level which can be tolerated. Having established this level, the highways and vehicles must be designed to permit the minimum driver to operate a vehicle without undue jeopardy.

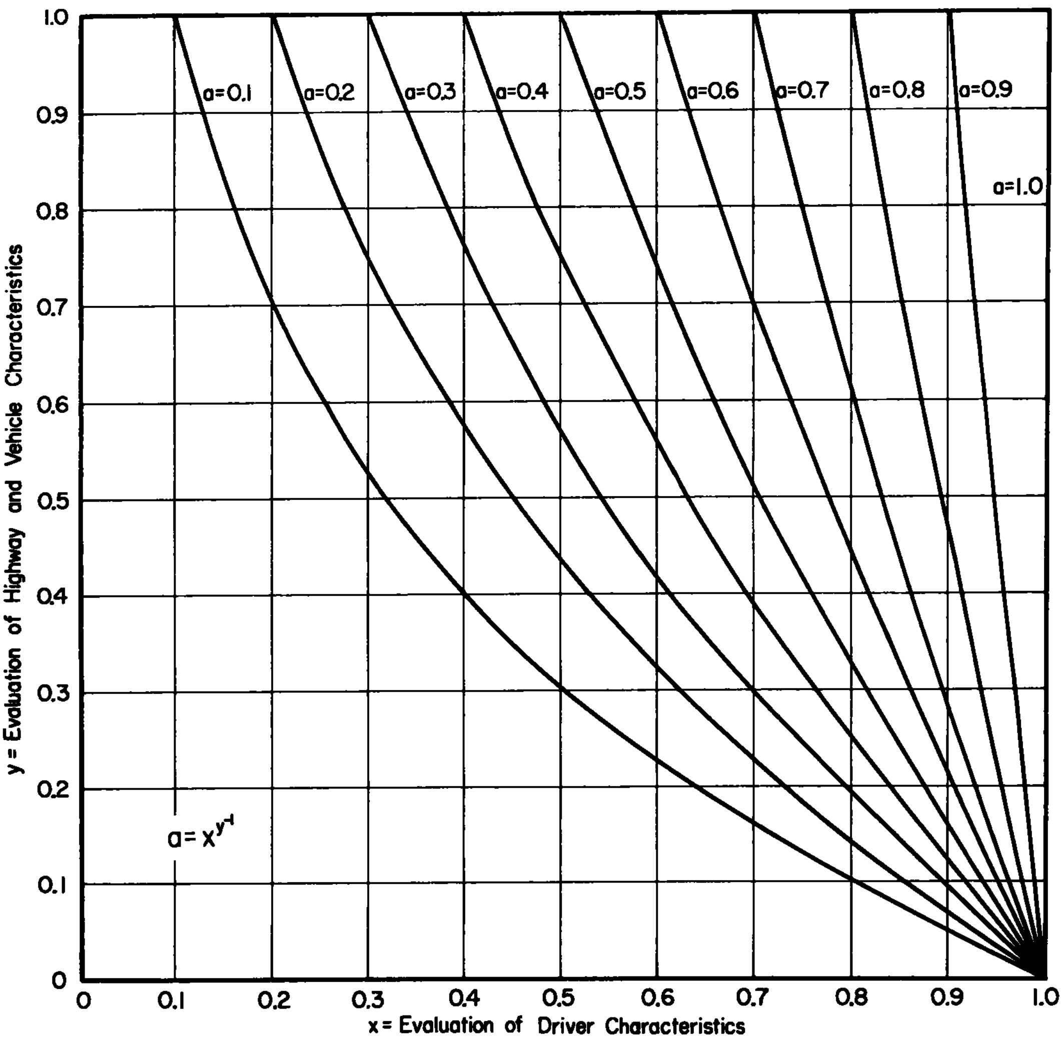

Figure 3. Family of curves of driver ability (n=1.0).

Driver error is the primary subtractive factor in evaluating a human's maximum capacity as a driver. Certain characteristics are capable of correction, such as faulty eyesight by use of glasses, but, in the main, driving error must be compensated for since correction is not generally possible. The compensation would take the form of driving-habit adjustments or limitations when or where a driver may operate a vehicle.

Driver mistake is the second subtractive factor in evaluating a human's maximum capcity as a driver. Obviously, an individual must possess a minimum knowledge to obtain a license to drive. However, this minimum is insufficient to permit a driver to cope with every driving situation. The driver who does not know, for instance, how to correct for a skid on a slippery pavement, or how to resist centrifugal force when he finds he is exceeding the safe speed around a curve has little chance to cope with these situations. The knowledge therefore is no assurance that he will possess the required skill to handle the situation, but it necessarily precedes skill.

The third subtractive factor in evaluating driver characteristics, driver blunder, is of two types: (1) periodic lapses into thoughtless or reckless actions caused by

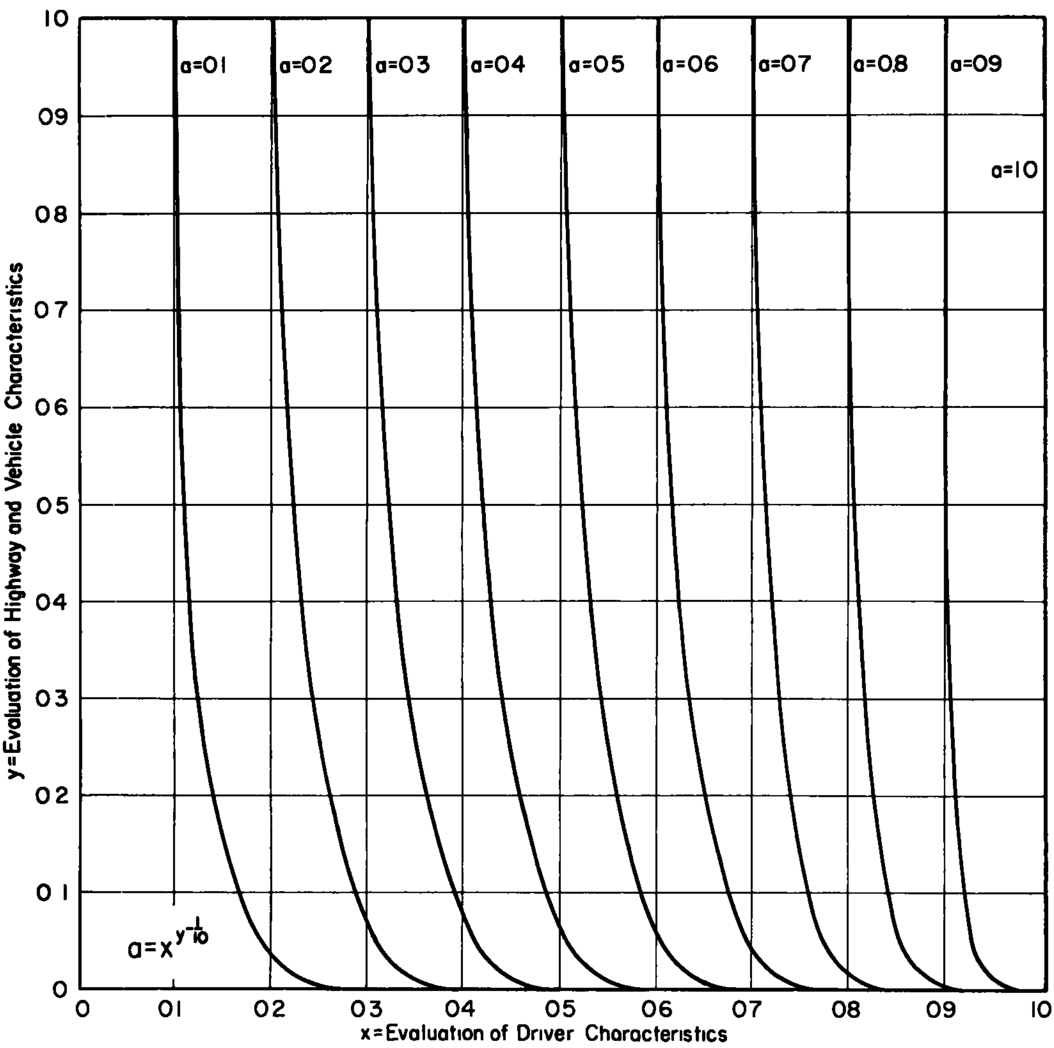

Figure 4. Family of curves of driver ability (n=0.1).

transitory characteristics, and (2) regular disregard of the laws, rules, or principles of safe driving. Correction of the first type might be accomplished to a degree by properly motivating the drivers. However, a certain amount of mental lapse is inherent in any human. The second type presents a problem for the enforcement agency and the courts.

Accident data classified as suggested here might permit insight into the most effective methods of implementing a highway safety program. Such a program usually includes education, enforcement, driver examination, and training. The ideal solution is to know which area to emphasize and to what degree.

CONCLUSIONS AND RECOMMENDATIONS

In the considered opinion of the authors, the proposed concept is a valuable base upon which to institute significant research in the field of highway safety. The methodology, incoporating a confidential personal interview with drivers and an investigation of highway conditions at accident sites, is a fruitful means of data collection. Data should be obtained on non-accident and near-accident situations as well as upon actual accidents. The proposed study should be confined to the one-car accident in the initial phases, but in any expansion multi-car accidents should be included.

The solution of the problem or, more realistically, the reduction of highway accidents lies in the efficient utilization of available funds. It would be foolhardy, for example, to expend billions of dollars on highway construction solely for the purpose of reducing accidents before knowing how fruitful the expending of comparable funds for driver training and education would be. It is essential, therefore, to conduct studies in accident causation directed toward a means of evaluating the interrelationship of the driver, the highway, and the vehicle so as to provide the most effective methods of accident reduction.

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