EVALUATING THE INFLUENCES OF PERSONAL CHARACTERISTICS ON THE TRAFFIC ACCIDENT EXPERIENCE OF TRANSIT OPERATORS

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SYNOPSIS

Many studies have been conducted of general group relationships between driver characteristics and traffic accidents, but most of them have been disappointing, with results more indicative than conclusive. The principal weakness of these studies appeared to be in the inability to reflect relative exposure hazards adequately, a weakness which possibly could be overcome in a study of transit operators. Consequently, a study of 482 street car operators of a large mid-Western transit company was undertaken.

As an initial step in developing a suitable accident criterion, a figure was derived for each individual operator representing the number of accidents he would be expected to have as the result of the individual mileage operated under the varying hazards of the several routes, during different periods of the year and at different hours of the day. This expectancy figure, when related to actual numbers of collision accidents, produced an Accident Index for each operator for the three-year period covered by the study. This Accident Index was used as the primary criterion against which 74 personal and medical items were related.

Of special significance was the finding that the frequency distribution of the expected numbers of accidents was highly symmetrical and very similar to a "normal probability" distribution. This indicates that traffic accidents—at least for street car operators—are governed by the usual or ordinary laws of chance. This conclusion is contrary to the beliefs of some students of the problem, and one that, as far as is known, has not heretofore been substantiated.

Analysis of group relationships between the accident criterion and the several personal characteristics produced no startling results. Reliable relationships were found; some were linear, some were curvilinear and some could have been either. These relationships were generally of low degree, but, in at least one instance, the correlation was found to be four times as great as that reported in one of the other more comprehensive studies. However, no relationships were found that would permit the results to be used for prediction.

Early in 1938 the American Transit Association inaugurated a program of accident research. This program was made possible by voluntary contributions from a group of transit companies for an initial period of three years and then for an additional two years. The purpose of the program was to 1) determine, for the benefit of the entire transit industry, approaches to accident problems which would be most productive, 2) develop methods of analysis and forms of procedure which could be used effectively and 3) perhaps arrive at actual corrective measures for specific difficulties.

This program consisted initially of a series of research projects, one of them being on the subject of "Accident Characteristics of Operating Personnel." This paper covers the more important features of that project.

JUSTIFICATION FOR THE STUDY

This type of study, dealing with the human element in traffic accident causation, is not new. Many such studies have been carried on, with two methods of approach generally prevailing. One method is the study of individuals in a "clinical" manner, while the other is the study of the characteristics of groups.

The "clinical" or individual approach is used, in one sense, by operating transit companies and commercial fleet operators in the routine day-by-day handling of accident problems. In other forms, it is being used successfully by some motor vehicle departments and police departments. Among the more comprehensive and special "clinical" studies are those by Bingham with Boston Elevated Railway and by the Metropolitan Life Insurance Company with The Cleveland Railway Company.

Experience with the clinical approach clearly indicates that personal characteristics are potent although remediable causes of accidents for individuals. This approach fails, however, to provide information on a group basis, information as to either the relative importance of personal characteristics as factors in traffic accident causation or the levels of efficiency at which specific characteristics begin to have broad and universal influence on accident experience.

Recognizing the importance and values that could be derived from such group information, many public and private agencies have attempted to obtain it. Studies of general group relationships between driver characteristics and traffic accidents have been carried on by a number of different agencies.[1] They have included the more easily obtainable personal data, some medical or physiological characteristics and ability tests of various sorts. Of these, perhaps the most comprehensive has been the one undertaken by the Highway Research Board in cooperation with the Connecticut State Department of Motor Vehicles, the Bureau for Street Traffic Research of Harvard University and Iowa State College.

While much thought and expert study has been given to this question, the results of studies to date are quite disappointing. They indicate generally that certain drivers are involved in more than their share of accidents, and thus might be considered "accident prone." Moreover, a large number of factors appear to be related to accident causation. However, in all of these studies the results have been predominantly indicative rather than conclusive. They show that a large number of factors apparently are related to accident causation, but the relationships invariably are found to be of very low degree.

Thus, although substantial value has been derived from these studies in an educational way, little guidance has come for legislative groups and motor vehicle departments in the establishment of sound standards for the licensing and control of drivers, for transit companies and other fleet operators in the selection of vehicle operators and for other agencies in the design of roadway facilities and in the establishment of traffic controls.

In considering the justification for conducting still another study of personal characteristics, under the Accident Research Program of the American Transit Association, careful thought was given to possible reasons why other studies failed to be more productive. Little fault could be found in the administration and conduct of the studies. However, a definite weakness did seem to exist in the criteria of accident experience that was being used, a weakness that conceivably could be overcome in a study of street car or bus operators in local transit service.

This weakness arose in two ways. First, data on the number of accidents for individuals being studied came from records of state motor vehicle departments. Standards of reporting, based primarily upon severity, automatically make these records incomplete. In addition, changes in standards of reporting and in administrative attention have caused variations in the completeness of reporting from period to period.

The second deficiency had to do with exposure and with relative hazards of exposure. In most studies, estimates of vehicle mileage from the individuals involved were used to convert numbers of accidents into accident rates on a mileage basis. This assumes 1) that these persons are equally able to give their driving mileage accurately and 2) that all of them are exposed to identical accident hazards per mileage unit. Both assumptions are highly questionable, even on a group basis. In one of the most inclusive and careful of these studies,[2] the primary criterion used in a

[1] These agencies include the National Research Council at Ohio State University, Iowa State College, Bureau of Street Traffic Research of Harvard University, Center for Safety Education of New York University and the Highway Research Board.

[2] The Highway Research Board study with the Connecticut State Department of Motor Vehicles, Iowa State College and the Harvard Bureau for Street Traffic Research.

special statistical analysis of 3,600 licensed drivers was "the number of accidents reported by any driver, divided by the number of his years of licensure," while in the first part of that study, when 25,000 accident reports were analyzed, a theoretical assumption was made as to the type of accident distribution which is to be expected of "normal" operators having different numbers of accidents during the period. This assumption was based on a mathematical function which implies that there is more chance of having a low number of accidents than of having a high number, and that the exposure or hazard for different individuals is a varying one. Both the criterion and the assumption are open to question, even while recognizing that they undoubtedly were the most logical and best obtainable under conditions of the study.

A study of local transit operators appeared to offer possibilities in overcoming these two deficiencies. In the first place, the completeness of reporting of all accident occurrences, irrespective of severity, is extremely high. Even if the operator himself fails to make a report, the person involved, or perhaps even just a witness to the occurrence, will invariably bring the accident to the attention of the company and it goes on the record. In the second place, a comparatively complete record of relative hazard to which each operator is exposed is available.

The record of relative hazard does not indicate the number of instances where a pedestrian stepped out into the path of a vehicle or the number of instances where a motorist ran through a red traffic signal light or a stop sign. However, records are available to give the exact mileage operated and the exact routes over which this mileage was operated. Accident data for all operators as a group can establish the relative hazards of each route on a mileage basis, and, in addition, relative accident hazards can be developed for different hours of the day, for different days of the week and for different periods of the year.

With a group of operators over which reasonably close supervision is exercised, with highly complete accident records and with logical and apparently complete data on relative individual exposure to acident hazards, it was believed that a study of transit operators was justified and that the results should be much more conclusive than those of other studies. Therefore, with complete cooperation from the management of a large mid-Western transit company, a study of "Accident Characteristics of Operating Personnel" was carried on covering 482 street car operators and their accident experience over a full three-year period—calendar years 1937, 1938 and 1939.

METHODS USED IN THE STUDY

Discussion of methods used in the study will be considered under the following headings: Selection of Study Group; Development of an Individual Accident Expectancy; Development of an Individual Accident Index; and Data on Personal Characteristics.

Selection of Study Group

When the study was inaugurated late in 1939, there were approximately 1,000 qualified street car, motor bus and trolley coach operators in the employ of the company. Approximately 500 men had operated street cars exclusively for the full five-year period of 1935–1939, approximately 100 men had operated only motor buses and the balance had operated more than a single class of equipment. Since accident characteristics differ somewhat among these three classes of vehicles, it was decided to restrict the analysis to the group of employees who had worked continuously and exclusively on either street cars or motor buses. The street car group was chosen because of the larger number of persons involved.

As a check, age and collision-accident frequency distributions for this selected group were compared with distributions representing the entire group of qualified operating personnel. Results indicated that the sample chosen was reasonably representative of the whole group. Also, it should be noted that collision accidents only were included, accidents involving passengers while boarding, alighting or riding within the vehicles being omitted.

Subsequent gathering of data for individuals in the selected group revealed certain gaps in pertinent information. Thus, when those with incomplete records were discarded, the study finally covered 482 street car operators who had worked solely on street cars during the five-year period from January 1, 1935 to December 31, 1939 inclusive.

Development of an Individual Accident Expectancy

In order to use individual accident data as the criterion against which to relate various medical and personal data, it was deemed necessary to eliminate, insofar as possible, all non-personal accident hazard factors. The factors which were considered to be non-personal in character, and which it was found could be eliminated for individual men, were the following:

1. Variations in vehicle mileage operated;
2. Variations in accident hazards among the several street car routes or lines;
3. Seasonal variations in accident hazards;
4. Day-of-the-week variations in accident hazards; and
5. Hourly variations in accident hazards.

Accordingly, records were obtained on each of these non-personal variables and, by means of tabulating punch-card methods, an estimate was made of the number of accidents which each of the 482 street car operators would be expected to have during the three years covered by the study, under his specific conditions of operation and in consideration of the total accident experience of the company. The three years covered were the calendar years 1937, 1938 and 1939, selected to coincide with the periods when the most complete medical and personal data were available.

The first step was to establish the number of accidents which each operator would be expected to experience as a result of the mileage he operated and considering the hazards of the routes or lines over which this mileage was accumulated. Taking the "mark-up" period[3] as the basic time interval, a route accident hazard figure was obtained by dividing the total number of collisions recorded for each route by the total mileage operated on the route during each period. In this manner, an accident rate on a mileage basis was obtained which, when multiplied by an operator's mileage, gave a figure for his expected accidents during that period on the basis of the average experience of each route. Thus, both mileage and differences of hazards among different routes, as well as differences in hazards among periods of the year, were accounted for.

Mileage for individual operators was most readily available on a yearly basis which necessitated proration of this mileage to a monthly basis in order that one, two or three route factors could be applied depending upon whether the "mark-up" period was for one month, two months, or three months in duration. In most cases, the length of the "mark-up" period was 3 months, thus necessitating the application of the route factor against three monthly mileage figures to arrive at total of expected accidents for the full "mark-up" period.

Having arrived at a raw total number of accidents for each operator, based upon his mileage and the accident experience of the route or routes over which he operated, the next step was to make a correction for variations in accident hazards by hour of the day. An hourly correction factor was derived from the total three-year accident experience of the company, with system totals for each hour being converted into percentage of the average hourly figure. By applying these percentages to the specific hourly distribution of work for each operator, an individual correction factor was obtained.

This hourly correction factor then was applied to the raw number of expected accidents, obtained for each operator from mileage and route factors, in such a way that, if the hours during which a man worked over the three-year period were those of average accident hazard, his expected accidents were multiplied by 100 per cent. On the other hand, if the hours during which he worked were of greater than average hazard, his raw score of expected accidents would be multiplied by a figure greater than 100 per cent and conversely, if less, by a figure of less than 100 per cent.

To this point, it has been shown how an expected number of accidents was obtained for each individual street car operator which reflected his mileage, the relative hazards of different routes, seasonal or "mark-up" period variations and variations by hour of

[3] A transit operator has the privilege of selecting a scheduled "run," or specific work assignment, at definite intervals, referred to as "mark-up" periods. This work assignment covers operation on a specific route during specific hours of the day and days of the week, and each operator holds this assignment until the next "mark-up." The "mark-up" periods in this study lasted for three months in most cases, although a few were only of one- or two-months duration.

the day. The fifth factor, day-of-the-week variations, was taken into account but no special correction was made on the assumption that, over the three-year period, differences in days off would probably rotate so that day-of-the-week variations would affect all operators equally.

While all detail as to the development of individual accident expectancy figures cannot be explained here, it should be noted that, of necessity, certain assumptions were made in deriving them. These assumptions were considered carefully and it is believed that they are reasonably sound. They included the following:

1. That seasonal variations as represented by variations among "mark-up" periods, would affect all men equally;
2. That day-of-the-week variations would affect all men equally;
3. That hourly variations in accident hazards would, on the average, be similar over the entire system, i.e., proportionately the same for the various hours of the day on the different routes;
4. That inequities from the use of a three-year hourly correction factor would balance out among all men; and
5. That variations between abilities of individual operators would average out equally on any given route as a result of the shifting of operators at the time of each "mark-up," thus allowing the use of an average accident rate for each route as a proper measure of relative accident hazard.

Development of an Individual Accident Index

To obtain the ultimate objective—a new criterion which might reflect variations in exposure to hazards more accurately—it was necessary to relate the raw number of accidents expected of each operator to the actual number of accidents that he had experienced. This relationship was labeled an "Accident Index" and was obtained by dividing the actual number of accidents by the expected number of accidents and multiplying the result by 100. Thus, a figure of 100 would indicate that a man had the exact number of accidents expected, whereas a figure of 150 would indicate that he had 50 per cent more accidents than would be expected on the basis of the hazards to which he had been exposed by his mileage, the routes over which he operated, the periods of the year in which he operated and the times of day that he worked. Conversely, a figure below 100 would indicate that he had fewer accidents than expected.

This ratio, therefore, furnished an index which had been corrected for as many of the non-personal accident hazard factors as seemed practicable and one which, it was hoped, would make the evaluation of medical and personal data constructive and perhaps conclusive.

Data on Personal Characteristics

Personal data for individual operators was obtained from the routine records of the company. These data included age, years of service, marital status, number of dependents, previous experience and educational background. However, except for age and years of service, the records were rather incomplete and consequently subsequent analyses were rather meaningless. Medical data, on the other hand, were quite complete as the result of accumulation of information from three annual periodic routine physical examinations given by the company during the years covered by the study. These data included information on height, weight, blood pressure, pulse pressure, vision, hearing, heart condition and other items normally covered in a thorough physical examination. Prior to the inauguration of the study, vision was recorded only from the use of the Snellen chart, but for purposes of the study, Keystone Telebinocular apparatus also was used, including the special DB Test for stereopsis. Likewise, records on strength of grip were available from the use of a hand dynamometer in the third medical examination.

All together, 88 personal and medical items were recorded for each of the 482 street car operators, of which 76 were used in the analysis of relationships between personal characteristics and accident experience. Reproductions, in Appendix A, of the two tabulating punch cards used in the analysis will give a more detailed picture of the personal and medical items considered.

ANALYSIS OF ACCIDENT EXPECTANCY AND ACCIDENT INDEX

Careful study and analysis were given to the accident expectancy figures and to the accident

index inasmuch as the success of the entire study was dependent upon the accuracy and soundness of the accident criterion used for the evaluation of personal and medical data. Furthermore, others interested in the subject might profit by the principle employed if the criterion could be supported with proper evidence in its favor.

Actual and Expected Accident Distribution

The frequency distribution of the numbers of accidents sustained by this group of street car operators, as shown in Figure 1, followed the pattern generally found for traffic accidents. The curve is skewed, showing a peak toward the left (low numbers of accidents) and a long tail toward the right (high numbers of accidents).

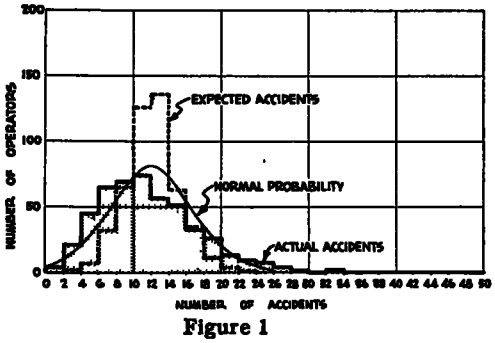


Figure 1

In contrast—and this seems to be of very definite significance—the distribution of expected numbers of accidents (with nonpersonal accident hazard factors eliminated) is highly symmetrical. It is very similar in this respect to the well-known "normal probability" distribution (see Fig. 1). This indicates that street car traffic accidents follow the laws of chance over a long period of time.

This conclusion, if accepted for vehicle operators other than street car operators, is contrary to an assumption made in some previous studies that the "normal" distribution for traffic accidents was a skewed distribution, similar in pattern to the distribution of actual numbers of accidents. Such an assumption, and the use of variations of actual distribution from this skewed theoretical distribution in the determination of "accident prone" driver groups, now appears to be questionable.

Again considering the distribution of expected accidents (Fig. 1), it can be noted that the peak is higher than that of the normal probability distribution. This compression toward the average conceivably could be due to the characteristics of the driver group studied, a group of street car operators who have been carefully selected and trained and who are subject to influences from educational efforts, disciplinary measures, retraining and uniform operating conditions. These influences should tend to eliminate many extreme cases from the group.

Comparison of the actual distribution with the expected distribution indicates the effect of skill in operation since the peak for the actual accident distribution has moved to the left, i.e., shows fewer accidents. By exercising care and skill, the operator can avoid, and in these cases did avoid, many of the hazards normally to be expected. Nevertheless, lapses of attention, care, or skill would cause the records to revert toward the higher accident end of the scale. Thus, instead of the usual or more or less accepted view that accidents are caused by certain unfortunate, or unlucky, characteristics of drivers, these results would lead to the view that the skillful operator avoids certain hazards to be expected on a normal probability basis, and that the causation of accidents results from lapses of attention, care and skill of greater or lesser degree. Therefore, the causation of any accident would depend upon the appearance of such a lapse on the part of the operator, and at the same time, on the occurrence of physical accident hazards at that particular time and place.

This analysis indicates, therefore, that the exposure to accident hazards on the transit system as a whole obeys the laws of normal probability or that street car operators are exposed to a large number of 50–50 chances of accidents, many of which may occur at the same time. Observation and common sense also indicate that a great many factors may be involved. Thus, it is to be expected that any one factor which can cause an accident may or may not appear in any given accident, and also, that it may appear together with a large number of other factors. For this reason, when any given characteristic is measured against traffic accidents, it can be expected that the relationship will be greatly diluted by a large number of other factors. In other words, when observed or measured

characteristics of operators are related to accident experience, the trend line would indicate consistent but not large relationships. Such actually has been the case in many studies and will be shown to be the case in this study.

Analysis of Accident Index

The distribution of the accident index ratings for the several operators is shown in Figure 2. From this it will be seen that the majority of the street car operators had less than the expected number of accidents, i.e., the index was below 100. Thus, the majority were relatively good operators. On the other hand, the long tail of the distribution to the right shows that a small number of operators had over twice as many accidents as they should have had.

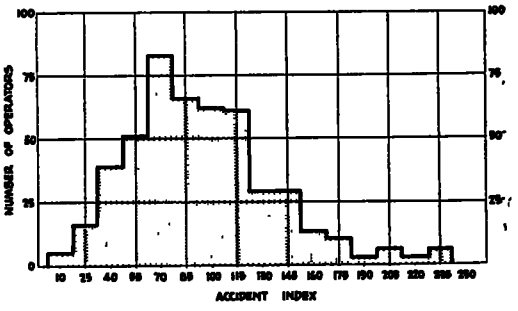


Figure 2

Further study of the distribution likewise brings out a feature of considerable significance. This is the definite and marked drop in the accident index distribution at the index point of 125 per cent. This would indicate that such a point could be a natural and logical point of division to use in studying the characteristics of high-accident operators and in segregating the normal and good operators from those to be considered as "accident prone."

Other tabulations were made to determine relationships that might exist between the accident index and such items as mileage operated, expected numbers of accidents, and actual number of accidents. Briefly, the following results were obtained from these studies:

1. There was a tendency for operators with the higher mileages to have somewhat lower accident indexes;
2. Operators with the highest numbers of expected accidents tended to have slightly lower accident indexes; and
3. The correlation between actual numbers of accidents and the accident index was relatively high, although there was enough scatter around the trend line to indicate that the use of uncorrected numbers of accidents would not give the same results as the use of the accident index.

Analyses likewise were made, using individual uncorrected accident rates on a mileage basis, i.e., numbers of accidents per vehicle mile operated, which is the accident rate most commonly used in analyses of traffic accident experience. From these it was found (see

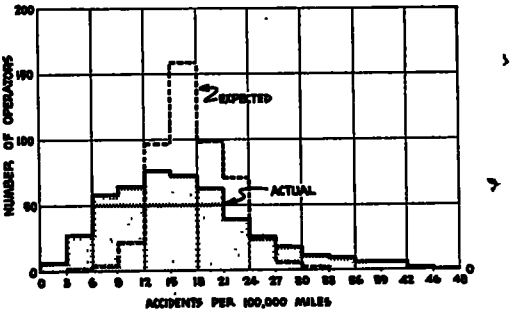


Figure 3

Fig. 3) that the relationship between the expected and the actual accident rates is very much the same as that between the expected and actual numbers of accidents (Fig. 1). However, it should be noted that the sharp break, or drop, in the accident index distribution at the 125 per cent point has no counterpart in the actual accident rate distribution.

Further analysis of actual accident rates on a mileage basis in comparison with the accident index showed a high correlation between the two, thus indicating that, in general, scoring by the two methods tends in the same direction. However, there were wide differences in individual cases, so it may be concluded that there are very definite differences between the two criteria. Moreover, the spread of the points around the trend line, when the two are tabulated against each other is great enough that, if the actual accident rate

were used instead of the accident index, the error of estimate involved would be some 30 to 40 points on the accident index.

A further indication of difference is the fact that there were a larger proportion of operators with low actual accident rates than there were with low accident indexes. Apparently some operators had low rates due to small exposure to hazard rather than to skill. This would seem to substantiate still further the conviction that accident rates uncorrected for non-personal accident hazards can be misleading and perhaps unreliable as a criterion in studying driver characteristics on a group basis.

ANALYSIS OF MEDICAL AND PERSONAL DATA

The primary objectives of this study were to determine, if at all possible, the relative importance of various personal and physical characteristics as elements in the causation of traffic accidents and, furthermore, to determine gradations of influence by individual characteristics which might guide transit managements in the establishment of critical points, or standards, for use in the selection of new operators or in the disqualification of present operators. For example, it was hoped that the full importance of visual acuity as a factor in accident causation could be established, and that evidence would be produced to indicate probable differences in subsequent accident experience when different selection standards for visual acuity were established, such as 20/40, 20/60 or 20/20, etc. Unfortunately, however, these objectives were attained only in a limited way. On the first point, the results were reasonably satisfactory but on the second point, the results were highly disappointing.

Two criteria were used for initial comparisons with the 76 personal and medical items mentioned previously and shown on the two tabulating punch cards in Appendix A. By use of tabulating machines, a total of 152 individual cross-tabulations were obtained between items of personal characteristics and accident criteria. Other correlations between various items might have been desirable but were impossible under limitations of time and cost.

As a starting point, regression lines, or the lines of relationship, were desired. For a rapid estimate of these regression lines, the median values of the accident index were determined for each column and an average line was drawn in by inspection. This is illustrated in Figure 4 which shows a comparative tabulation of the accident index and the actual accident rate on a mileage basis. Later, average values for each column in the tabulation were computed to give a better estimate of the regression lines for the more promising items.

This estimated regression line, or more accurately the smoothed line of average ordinates, represents the average relationship between the two items being compared for the group of 482 operators where the medical or personal data item is used to predict the

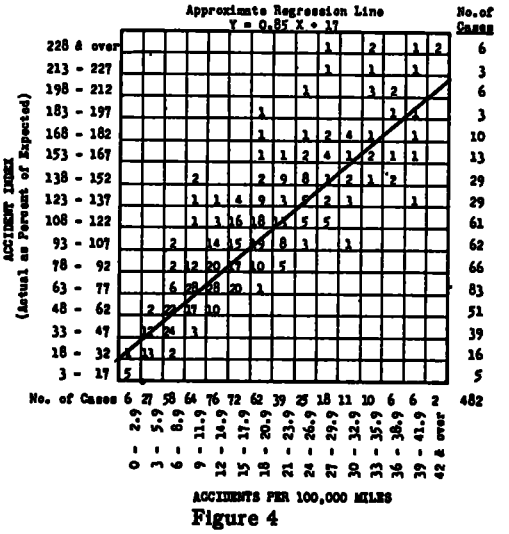


Figure 4

accident index. This relationship may take the form of a straight line in those cases where the accident index increases as the values in the test items increase, or vice versa. The relationship, however, may also be curvilinear, indicating that a middle value on the test item goes with a low accident index, while either high or low scores go with a higher accident index.

Variations in these relationships are illustrated in Figures 4, 5 and 6. As mentioned previously, Figure 4 shows a straight-line relationship. In Figure 6 the relationship is definitely curvilinear, but in Figure 5 the relationship might be either a straight-line or a curve.

To illustrate the practical meaning of these lines of relationship, tables of cumulative percentages were computed for a number of the items. These contained percentages of operators above various levels of the accident index for the several score groups of the particular test items. One of these tables was prepared for systolic blood pressure, the item illustrated in Figure 6, and it clearly demonstrated the curvilinear relationship shown by the line of averages. On this table, the lowest percentage of operators with a high accident index appeared in the systolic blood pressure ranges from 120 to 139. As the blood pressures both increased above this range and decreased below this range, the percentages of men with a high accident index likewise increased. In other words, the table shows a definite tendency for more of the operators with either high or low blood pressure to have a high accident index.

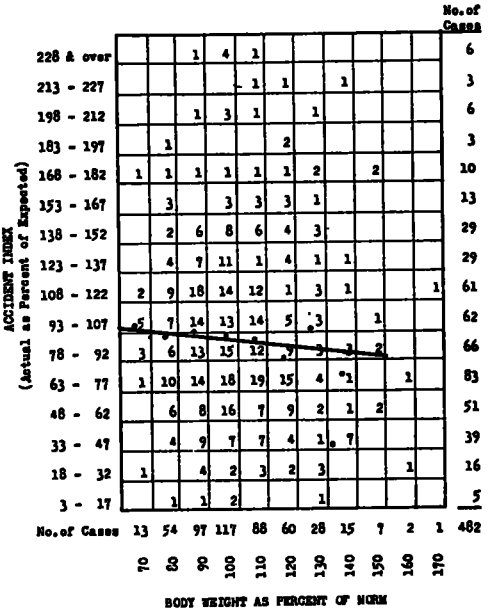


Figure 5

However, it should be mentioned that even in the highest blood pressure group there was a large percentage of operators having a relatively low accident index. Consequently, if the accident index were predicted from systolic blood pressure alone, on the basis of the average line of relationship, a large number of persons with good accident records would be rejected because of high blood pressure. Therefore, this measurement alone could not be used to predict which men would have poor accident records since the error of estimate is relatively large. The extent of the error of estimate, as well as the degree of average relationship, is important in determining whether a relationship which is found can be used for prediction, i.e., for establishing standards of selection.

The percentage values in the table showed a definite relationship similar to that of the line of averages but such percentages were known to be unreliable because of the small number of men in the high blood pressure

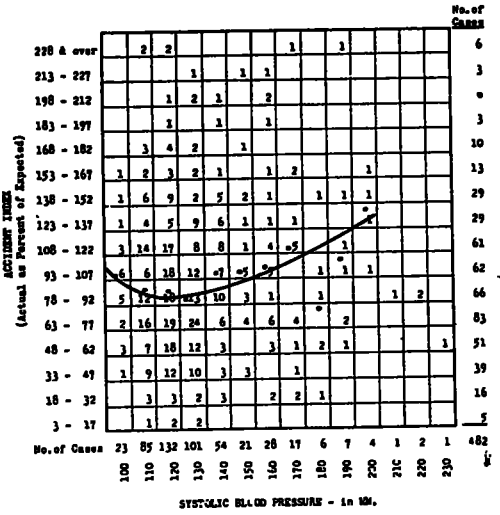


Figure 6

category. Thus, although the percentage figures demonstrate the meaning of the regression line, or the line of averages, there was doubt as to whether or not the relationship shown was a real or a chance one.

From inspection it was believed that the relationship for systolic blood pressure (Fig. 6), and similar trends in other charts were probably reliable, whereas that for body weight (Fig. 5) probably was not. It can be seen from the scatter of the scores that the error of estimate would be large in both cases. Therefore, the correlation ratio, an index which allows the testing of the reliability of curvilinear relationships, was computed on these two illustrative items.

The computation for systolic blood pressure gave a correlation ratio of 0.35, with a probable error of 0.040. Since the coefficient is over 8 times its own probable error, as compared with an acceptable 3.5 times, this indicated that the trend shown cannot be due to chance. Since this coefficient may be spuriously high, especially if the number of categories is large, a corrected coefficient was computed. This reduced the coefficient only slightly and indicated that the relationship shown could be obtained by chance in less than one out of 100 cases. Thus, the relationship is real even though relatively small.

The computation also showed the error of estimate to be approximately 43 points on the accident index. Therefore, although the relationship shown is real, indicating that systolic blood pressure is related to accident causation and of importance in preventive work, it cannot be used alone for prediction purposes, i.e., selection of new operators or disqualification of present operators.

A similar computation of the correlation ratio was made for body weight expressed as a ratio to the height and age norms. A correlation ratio of 0.08, with a probable error of 0.045, was obtained. In contrast to the results with systolic blood pressure, the coefficient obtained for the body weight ratio indicates that, as suspected, the relationship is not a real one but is probably due to chance.

From these two examples there was definite indication that a trend line indicating a relationship as large as that in Figure 6 is probably meaningful whereas one as small as that in Figure 5 is probably meaningless since it could be obtained by chance. Consequently, because of pressures of time and lack of personnel, analysis of the remaining charts of relationships for other items was made in this manner. It was believed that a reasonably good estimate of the importance of the several items could be had by a comparison with the two type examples, pending ability to make computations of correlation ratios and errors of estimate.

Consideration also was given to the possibility of increasing the magnitude of the relationships by combining them through a multiple correlation or multiple regression technique. Where the relationships are all linear, such a technique can be used with relatively simple mathematics involved. However, where curvilinear relationships appear, multiple regression becomes extremely complicated or else must be estimated by graphic methods. Consequently, while partial trial of linear regression was carried out no adequate trial of curvilinear multiple regression was made.

It should be recognized, however, that the probability of increasing the coefficient under the multiple technique is relatively low. The raw relationship on individual items is almost universally low even though reliable, and the error of estimate is large. Moreover, the number of items showing negative interrelationships is small so that there is little likelihood that the scatter in the correlation charts, and the resulting error of estimate, is due to the addition of negatively related items. Such conditions make very questionable any major increase in the correlation or in the predictive value by use of the multiple technique. Nevertheless, it is hoped that some day the use of curvilinear multiple regression may be tried out in one of these studies.

CONCLUSIONS AND SUGGESTED APPLICATIONS

From this study it has been possible to draw several significant conclusions and to suggest several practical applications of either the techniques or of the findings. These conclusions result both from the analysis of actual accident experience and its relation to individual accident expectancies and from the analysis of medical and personal items in relation to the accident criteria.

Accident Expectancy and Accident Index

From the general analysis of actual accident experience and of individual accident expectancies derived by the elimination of nonpersonal accident hazard factors, the following conclusions and applications are suggested:

1. For the transit company participating in the study, the average collision accident hazards to which street car operators are exposed occur with almost "normal probability." Such normal distributions are found in a great many fields but it is believed that they have not heretofore been reported or substantiated in traffic accident studies.
2. By the exercise of care and skill, the greater proportion of street car operators avoid many of the accidents to be ex-

pected on a normal probability basis and have a better accident experience than the expectancy figures would indicate. Conversely, due to physical shortcomings, lapses of care and attention, or other factors probably involving operating habits, a small proportion of the street car operators have a poorer accident experience than is indicated by the expectancy distribution and by their own expectancy figures.

3. Any single factor in traffic accident causation can be expected to exert its influence to a small extent only, and apparently skill on the part of the operator tends to reduce the probability that these factors will operate to cause accidents. Thus, a high degree of relationship cannot be expected when correlating various personal characteristics of operators with their accident records, and the prediction of an operator's accident experience from any one or two tests should not be contemplated. However, this does not mean that individual factors may not be important in traffic accident causation if they show a small but consistent and statistically reliable relationship to accidents.
4. The commonly used accident rate on a mileage basis, while convenient and sufficiently accurate for some purposes, has many shortcomings in that it does not correct for several non-personal accident hazard factors. An operator with a high accident rate on a mileage basis may actually be a safer operator than one with a low rate.
5. The accident index, as derived in this study, does correct for non-personal hazard factors beyond mileage by eliminating the influence of variations in hazards among routes travelled, variations in hazards between different periods of the year and variations in hazards among the hours of the day. Consequently, it is believed that such an accident index is a superior criterion for the evaluation of personal data, medical and physiological data, operating habits and other operating characteristics whether observed or measured by test.
6. The positive and sharp break in the accident index distribution curve at the 125 per cent point (where an operator has 25 per cent more accidents than would be expected) indicates that this could be a natural and logical division point for separating high-accident, or "accident prone," operators from normal or good operators for purposes of special attention and intensified applications of corrective measures.
7. The accident index, as derived in this study, should be found useful also by operating transit companies in evaluating mental ability tests, motor ability tests, and other measurements which are now being used increasingly in the selection of new operators.

Personal and Medical Characteristics

The analysis of relationships between personal and medical items and the accident criteria, for the group of 482 street car operators, resulted in the following general conclusions:

1. Approximately one-third of the 76 personal and medical items showed relationships to the accident index which are statistically reliable and which cannot be due to chance. Therefore, these personal characteristics are related to accident causation.
2. The relationships found were small when compared to the variations among individual operators and therefore to the error of estimates.
3. As already indicated, each of these characteristics probably enters the accident picture in combination with other variables studied as well as with many which were not included in the study. Due to the nature of these characteristics, there is probably relatively little chance of any one characteristic causing any given accident. Such a situation makes the small but consistent relationships quite understandable.
4. The curvilinear character of the relationships indicates that in many of these characteristics such as blood pressure, as an example, both very high and very low scores are unfavorable. On the other hand, certain factors such as visual acuity show a linear relationship indicating that on the average poor scores in the tests go with a tendency toward higher accident indexes.

5. The relationships obtained are somewhat similar in magnitude to those from other studies. However, the curvilinear trend lines shown are of special significance since they have not been generally reported and since they undoubtedly raise the relationships above those which would have been obtained from the use of the customary linear analysis procedure. For example, by the use of the hazard correction and the correlation ratio (curvilinear), the relationship of systolic blood pressure to accidents found in this study was more than four times as great as that found in the Highway Research Board study in Connecticut and approximately as large as the combined relationship found in that study from the use of 22 different variables. Moreover, such curvilinear relationships appear very logical in certain of these characteristics.
6. Most of the medical measurements included in the study are widely used and accepted as of importance in accident prevention. This acceptance based upon general experience is supported by statistical reliability of the average relationships found in this study even though the magnitude of these relationships is not dramatic and the error of estimate is too great for a single test to be predictive in individual cases.

Other General Conclusions

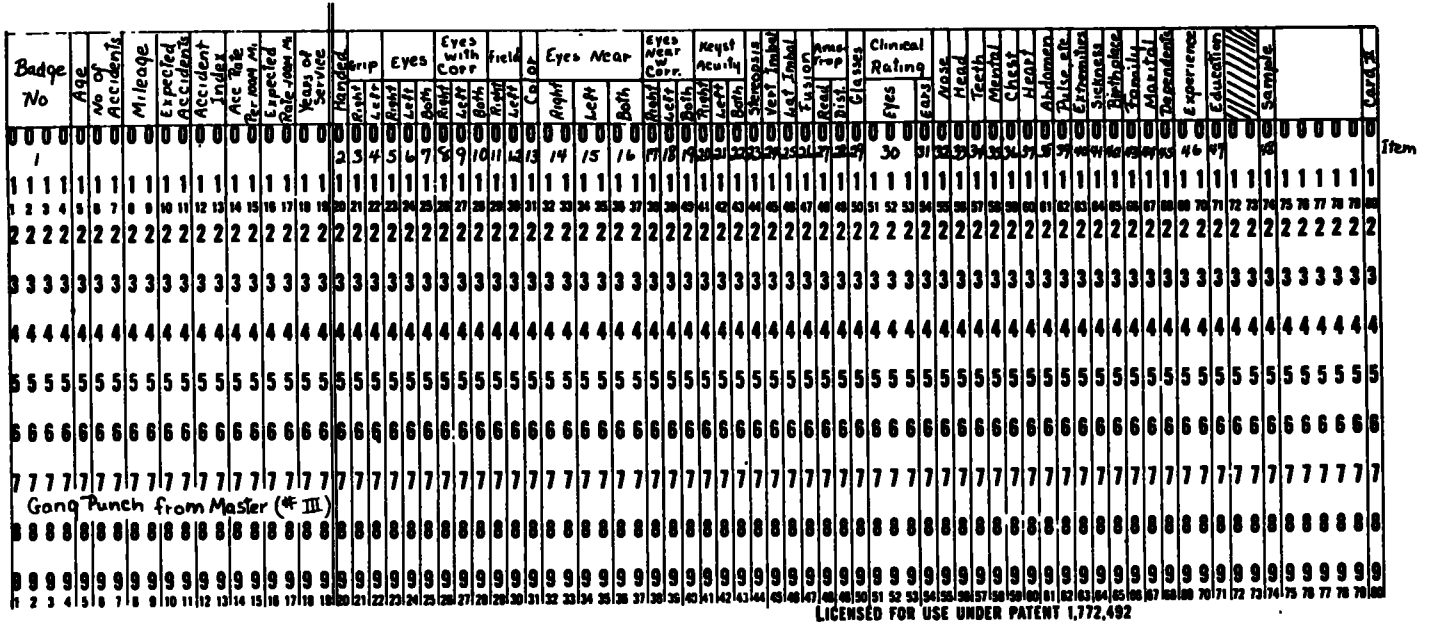
Although this study did produce findings of definite significance, and findings which will justify the project, it was quite disappointing to the extent that critical pass or fail points that could be used in initial selection procedures were not determined. Nevertheless, these results, together with experience from other studies, should encourage further investigations by either individual operating companies or national research agencies. Perhaps if further study is carried on, the accident expectancy technique described in this report may be supplemented by the elimination of accidents which could not be attributed to fault on the part of the operator. This of course assumes that routine procedures will permit a reasonable accurate determination of responsibility in all individual accident cases.

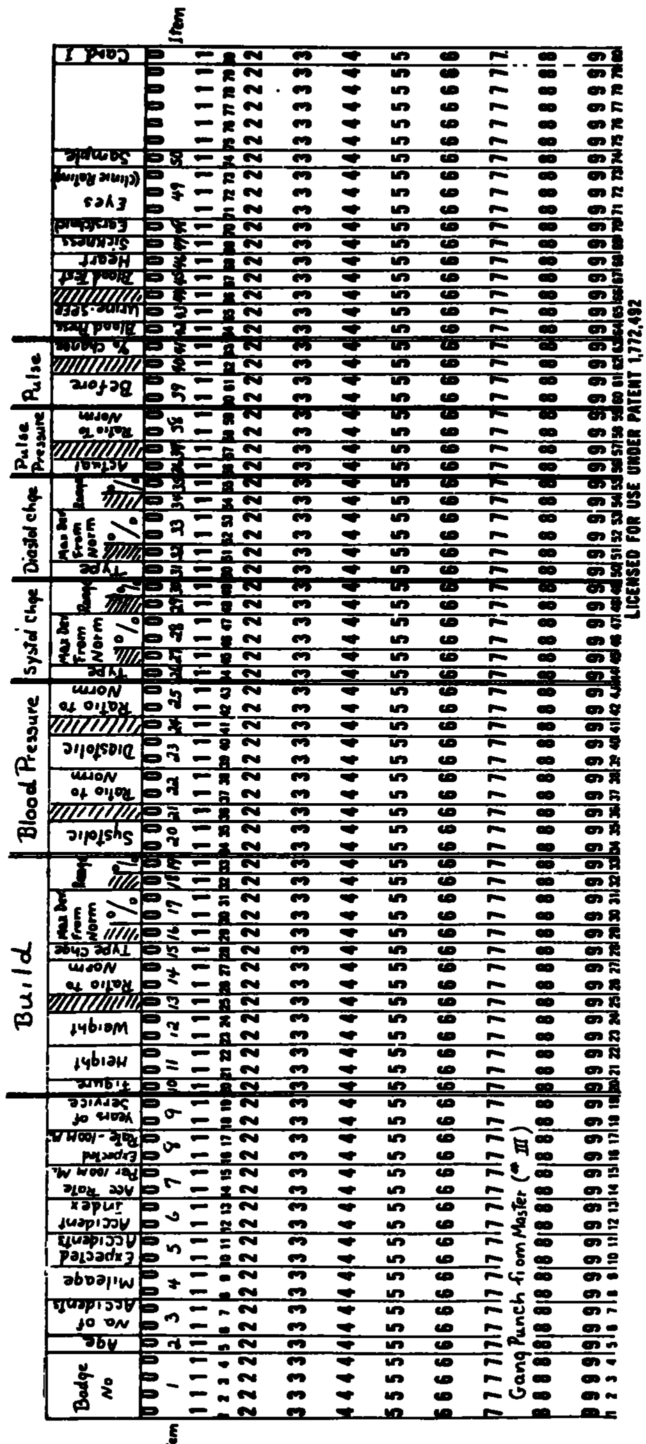
Likewise, on the basis of the distributions of individual accident expectancies, perhaps the concept of accident causation should be changed. Instead of assuming that certain characteristics are positive accident causes, it would be preferable to assume that operators are engaged in avoiding hazards by means of their skill. Accident causation then becomes a matter of the combined occurrence of certain physical hazards and some lapse of skill, care or attentiveness on the part of operators, with some of these lapses due to certain mental, physiological or other personal characteristics.

APPENDIX A

IBM TABULATING PUNCH CARDS

(Used in Analysis of Personal Characteristics of Transit Operators)




Badge No
Age
No. of Accidents
Mileage
Expected Accidents
Accident index
Acc Rate Per 100M M.
Expected Rate-100M M.
Years of Service
Figure
Height
Weight
Ratio to Norm
Type Chge
Max Dev From Norm
%
Range
Build
Systolic
Ratio to Norm
Diastolic
Ratio to Norm
Blood Pressure
Type
Systol Chge
Diastol Chge
Actual
Pulse Pressure
Before
Pulse
% Change
Blood Press
Urine-Spec
Blood Test
Heart
Sickness
Eyes (Clinic Rating)
Sample
Card I
Item
Gang Punch from Master (# III)
LICENSED FOR USE UNDER PATENT 1,772,492