a Portion of U. S. No. 30, Four-Lane Divided Pavement in Lake and Porter Counties," Unpublished Report No. 4 on Concrete Performance Survey, Project C-36-35, Joint Highway Research Project, Purdue University.

20. Belcher, D. J., Gregg, L. E., and Woods, K. B., "The Formation, Distribution, and Engineering Characteristics of Soils," Purdue University Engineering Experiment Station Bulletin No. 87, January, 1943.

DEPARTMENT OF TRAFFIC AND OPERATIONS

WILBUR S. SMITH, *Chairman*

THE USE OF THE AMERICAN TRANSIT MOTOR ABILITY TEST IN THE SELECTION OF BUS AND STREET CAR OPERATORS

BY J. V. WAITS,

Personnel Psychologist, Capital Transit Company, Washington, D. C.

SYNOPSIS

The American Transit Motor Ability Test was applied to 290 bus and street car operators during their first week in training and the test scores were later correlated with the accident responsibility rates of the men per 100,000 hours of operation and with ratings of the individuals based on their total desirabilities as employees.

The test attempts to sample such functions as ability to learn quickly, ability to react quickly and accurately, ability to follow directions, ability to execute movements and coordinate them with visual stimuli, and avoidance of emotional disturbance in difficult situations. The test equipment utilizes a steering wheel, gear shift lever and two foot pedals which are activated by the subject in response to light patterns produced by a signal board carrying a series of small green, amber and red lights and a regulation traffic signal with green, amber and red lights. The test was administered in accordance with detailed instructions which allow the examiner little discretion. The tests are in five consecutive sequences which increase in difficulty and complexity.

The scoring of the test is in terms of accuracy and speed of reaction. The subject must make the correct movement for the stimulus presented and in terms of two time intervals; the initial response time and the lapsed time to perform the movement.

The product-moment correlation between accident responsibility rate and test scores was found to be: street car operators, $r = 0.292$; bus operators, $r = 0.432$; combined, $r = 0.331$.

The correlation of the test scores with supervisory ratings was 0.089, while the correlation of accident responsibility rate with supervisory ratings was 0.482.

Although the correlations between accident responsibility rate and test scores are too low for clinical diagnosis of individuals they are significant for establishing usable employment ranges of test scores. As used by the Capital Transit Company these are:

Scores of 65 or more indicate the most suitable candidates.

Scores between 50 and 64 indicate candidates who should be employed if other factors are favorable.

Scores of 49 or less indicate those who should be rejected.

Prior to the first World War industry appeared to give little thought to the problem of improving selection methods in their employment of personnel. The transit industry was no exception. Most industries were aware that individual differences existed in the output and efficiency of various employees; possibly a few were aware of the fact that much of the difference was due to abilities which had been inherited or acquired. How-

ever, little was known about testing as a means of discovering which men were the best risks for employment until the work of U. S. Army scientists began to appear in print. Soon many industries began to experiment with the idea, but the depression came before the movement gained much headway. The vast manpower demands and shortages of the second World War again forced the armed services and industry to make tremendous efforts in the direction of scientific selection of personnel.

As a matter of fact, the transit industry found little need for any great amount of selection in its early existence. Up to the age of the automobile the job of operating a street car was at best a low-skilled occupation. The vehicles moved slowly and the objects which might get into position to be hit moved even more slowly. Quick thinking or fast reaction time were not vital elements in the situation. Today the operating problem is as different from that of former days as is the modern streamlined car from the street car at the turn of the century. The traffic conditions of a modern city demand that the operators of street cars and buses be highly skilled professional drivers who have been carefully selected and trained.

The Milwaukee Electric Railway and Transport Company was an early pioneer in the use of scientific method in the selection and training of street car operators. A motor ability test somewhat similar to the present apparatus was installed there in 1925. Cleveland Transit System adopted a variation of the test in 1930 along with other innovations in their personnel program.

The American Transit Motor Ability Test was designed under the supervision of Glen U. Cleeton for the American Transit Association. The forerunner of present apparatus, and its basic model, was installed by the Pittsburgh Railways Company in 1935, and valuable data have been obtained there. While the fundamental principles of the present test are the same as those of the Pittsburgh apparatus, many mechanical improvements have been made and various methods of scoring have been investigated. Thus it is believed that a more valid selection test has been developed.

The Capital Transit Company, Washington, D. C., started an ambitious program of personnel research, selection, and training in 1936.[1] Although progress has been slow, it has been continuous and steady since the inception of the program. The Company was selected in 1944 to undertake the initial validation of the present Motor Ability Test.

OBJECTIVES OF THE MOTOR ABILITY TEST

The motor ability test is a performance test. There is no intent to simulate actual operating conditions, so it is not a work sample. The responses of the subject are unlike those he would use in driving an automobile, bus, or street car. The stimuli resemble actual driving conditions only in the use of a traffic light during portions of the test. Even this similarity could be changed without altering the intent or results of the test.

The test is not, per se, a skill test, even though both skill and a considerable amount of motor coordination are involved. The functions tested are those which should be included in any statement of qualifications of street car or bus operators. That is, we attempt to sample such functions as the ability of the testee to learn quickly; his ability to react quickly and accurately; his ability to concentrate attention over an extended period of time; his ability to distribute his attention in a composite situation; his ability to understand and follow directions which become increasingly complex as the test progresses; his ability to execute given movements and to coordinate them with visual stimuli; and, in a minor way, his ability to avoid emotional disturbance when faced with a complex and difficult situation. No attempt is made to isolate these functions, to assess their relative weight in the situation, or to measure them separately. The test yields a single score which is supposed to measure the testee's ability to meet the situation as an integral whole.

[1] The continuous interest and support of E. D. Merrill, President, Capital Transit Company, has made this program possible. His decision to undertake the present experiment merely brings to light the progressive thinking he has brought to the transit industry.

The personnel program itself has been under the direction of Alexander Shapiro, Director of Personnel. His untiring determination to put our selection and training methods on a sound and scientific plane has been a constant source of inspiration to those who have worked with him.

We could hardly do less than use such a test as a whole. We are rather certain that all or nearly all of the functions enumerated are involved in the job of operating cars and buses. We do not know just when or to what extent each function is involved. We are moderately confident that the various functions given do not operate as constants from individual to individual, nor indeed, is the constellation constant for a given individual. At one moment emotional balance might be the dominant component in the operator's behaviour, whereas at still another moment the ability to react quickly and accurately represents the means of avoiding a serious accident. The test has thus been designed to involve all the functions outlined, but to leave the amount of their involvement to the "idiosyncrasy" of the individual being tested. It is our feeling that this is more probably an approximation of the job situation than any effort to isolate and weight various factors.

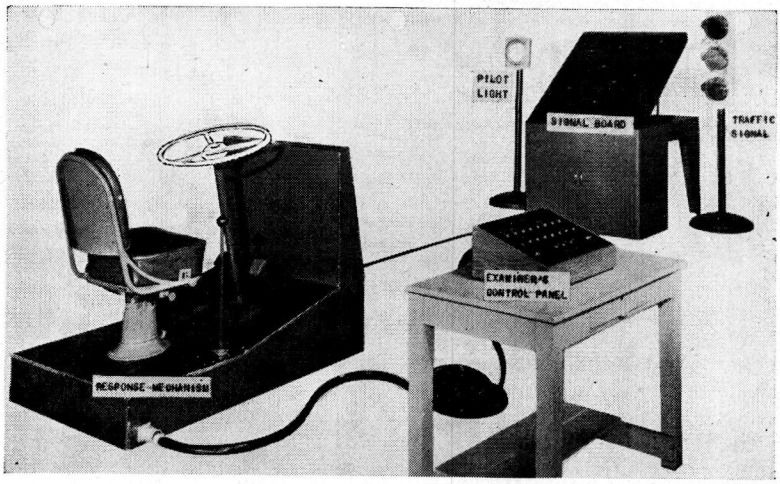

Figure 1. The American Transit Motor Ability Test Apparatus

THE TEST AND ITS OPERATION[2]

The American Transit Motor Ability Test equipment is made up of five main parts:

1. Response Mechanism: This utilizes a steering wheel, gear shift lever, and two foot pedals (See Fig. 1).

2. Examiner's Control Panel: This consists of a lighted panel carrying a number of switches which are used by the examiner in giving instructions and in releasing the automatic mechanism that operates in different parts of the test.

3. Signal Board: This is a board on which are mounted a series of small green, amber, and red lights as shown in Figures 1 and 3. Separately mounted so they may be placed on the left and right sides of the signal board respectively are a pilot light (which in reality serves as a distraction element) and a regulation traffic signal. The traffic signal has the regular green, amber, and red lights.

4. Automatic Signal Control: This part of the apparatus is a special program device which regulates time intervals in presenting stimuli (See Fig. 2).

5. Recording Apparatus: This part of the test mechanism is an Esterline-Angus Recorder which records responses on a moving tape.

The response mechanism and the signal board arrangement are placed 16 ft apart.

[2] The description of the test apparatus and of the test itself is taken from the manual of instructions for the American Transit Motor Ability Test issued by the American Transit Association. The use of quotation marks is omitted because the material contained herein has been changed slightly in some places. These changes were necessary since the original was designed to appear in the form of instructions and not as a part of a report.

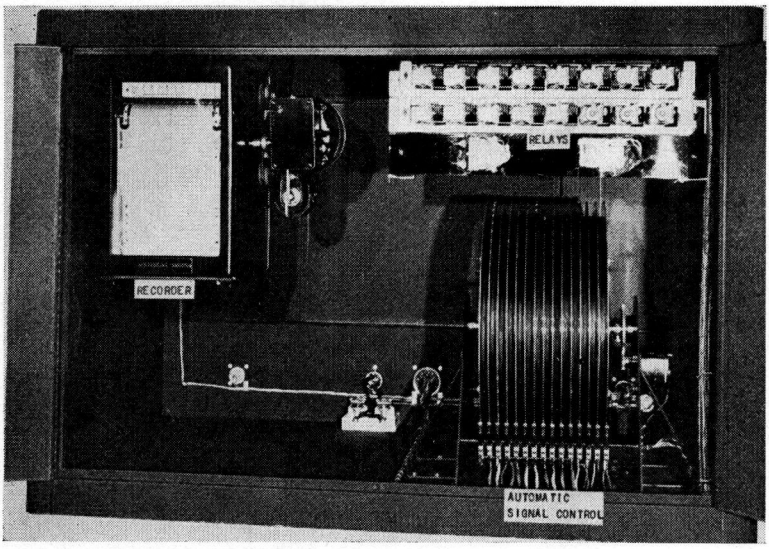

Figure 2. Automatic Signal Control and Recording Mechanism of the American Transit Motor Ability Test

The examiner's control board is placed in a specially constructed desk which also has compartments for the automatic signal control and the recorder. This desk is placed to the right of the applicant who is seated on the response platform.

During the conduct of the test the testee is required to make specific movements of the steering wheel, pedals, and gear shift lever in response to light patterns which appear on the signal board and traffic signal. The test provides for definite and fixed instruction or practice periods at various intervals during the test. During these practice periods the light patterns are operated manually by the examiner. In the test proper, the light patterns are presented at timed intervals through the operation of the automatic signal control. This insures that the presentation of stimuli will be constant. Both stimuli and responses are recorded on a moving paper tape by a bank of pens contained in the recording apparatus; thus, a complete record of accuracy and speed of responses is obtained.

The subject is seated in the response mechanism which faces the signal board directly across the room from him. As the light patterns appear on the signal board, the subject is required to make the appropriate move-

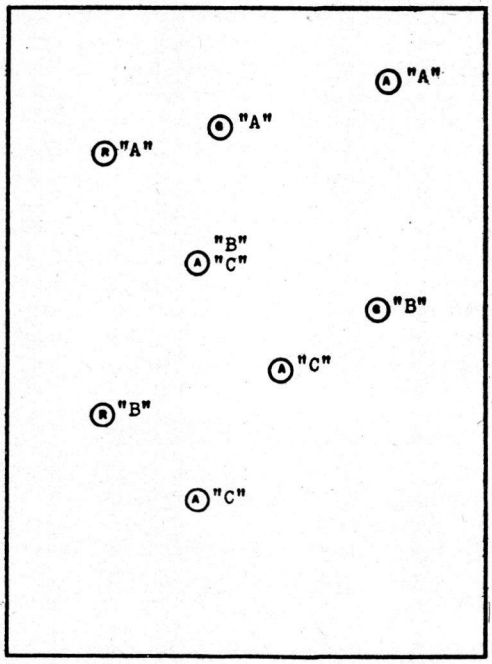

Figure 3. Scale Drawing of Signal Board. Letter in circle indicates the color of the light. Letter beside the circle indicates the stimulus pattern of which the light forms a part.

ments with the wheel, pedals, and gear shift lever. Electric contacts are attached to the steering wheel, pedals, and gear shift lever and these contacts are connected in series with the pens of the recording apparatus.

ADMINISTRATION OF THE TEST

The test was administered in accordance with detailed instructions. The examiner was allowed very little discretion, deviation consisting mostly of minor changes in wording. In addition to the author, the test was administered by two trained examiners. These men are supervising instructors of the Training Division of Capital Transit Company. Each of them had been carefully trained in administering the test.

The role of the examiner was two-fold. It was his job to put the subject at ease and obtain complete cooperation. In addition, the examiner had the duty of maintaining an active interest on the part of the subject. As a second role, the examiner served as an instructor in explaining to the testee the various movements and stimuli, and in administering the practice routines. Each part of the test is preceded by a practice of the sequences to be followed in that part of the test. Each of these is fixed in nature and amount by the written instructions for administering the test. Thus, each subject received exactly the same number of practice trials on each part of the test.

At no time during the course of the test was there any intimation to the subject that he might be doing poorly. At the end of each part of the test the examiner said to the subject "That is fine, you are doing very well" regardless of how well the subject was doing. No other comments were allowed, nor were comparisons with others permitted.

It is our feeling that the test administrations herein reported were as nearly constant as it is possible to obtain when more than one examiner is used.

Upon completion of the test, the examiner recorded the total testing time. Some subjects learn more quickly than others, resulting in time variations. The total time varied from 38 to 53 min. with a mean of about 45 min.

The examiner also recorded his subjective judgment of the subject including: learning ability, cooperativeness, attitude and approach, effort, interest, temperament, and an estimate of the man's capacity for bus and street car operation. These judgments have not been analyzed at this date, but offer possibilities for future study.

RESPONSES MADE BY SUBJECT

During the test, the subject was seated with both hands on the steering wheel, and both feet on the floor (called his "starting position"), and he resumed this position following each response. Three sets of responses were taught the subject. These are designated as movement 1, movement 2, and movement 3.

Movement 1 is a coordinated response requiring the use of both hands in moving the steering wheel and gear shift lever. The subject was instructed to make two quick movements of the wheel to the right (the wheel was so fixed that it would turn only to the right about 30 deg and was returned to original position by a spring) and then take the right hand and push the gear shift lever forward as far as it would go.

Movement 2 involved the use of the clutch pedal, two movements of the wheel, and the gear shift lever in that order. Exact sequence was demanded. Thus, the second movement is a coordinated response of both hands and the left foot. It is movement 1 preceded by a single depression of the clutch pedal.

Movement 3 involved the use of the brake pedal. This movement is movement 2 followed by a single depression of the brake pedal. It is a coordinated response which includes the use of both hands and both feet. Exact sequence was required.

TEST SEQUENCES

Part I.

The candidate is told to familiarize himself with the response mechanism by moving the steering wheel, gear shift lever, and pedals. He is told and shown how to make quick decisive movements. The examiner then demonstrates movement 1 and allows practice trials. Lights "A" are then switched on by the examiner while the subject makes ten repetitions of movement 1 as rapidly as possible.

Movement 2 is then demonstrated and the subject is given practice trials. Lights "B" are switched on while the subject makes ten

repetitions of movement 2 as rapidly as possible.

Movement 3 is demonstrated and the subject is permitted to practice it. Lights "C" are switched on while the subject makes ten repetitions of movement 3 as rapidly as possible.

This part of the test is essentially an abbreviated training period during which the subject is attempting to fix the movements in his mind and gain some facility in making them. Cumulatively, the results probably measure learning ability of the subject, as well as certain reaction factors.

Part II.

For the second sequence of the test, the subject is instructed to make a single response each time the lights on the signal board flash. The "A" lights flash at three second intervals and the subject responds with a No. 1 movement after each flash. There are ten repeated flashes of the "A" lights. Then the same procedure occurs with the "B" lights flashing and movement 2 as a response. Finally, there are ten repetitions of the "C" lights to which the subject responds with a No. 3 movement.

Part III.

Here the subject meets the first mixed series of lights. The "A", "B", and "C" lights flash in mixed sequence and with varying time intervals between the lights. The subject must identify the light, associate the proper movement, and then make the movement. The responses are the same as in Part II; "A" No. 1, "B" No. 2, and "C" No. 3. There are 20 light presentations in this mixed series.

Part IV.

In this part of the test, the traffic signal is presented for the first time. The subject is told that during the remainder of the test one of the traffic lights will flash together with the lights on the signal board. He is also told that these traffic lights will modify the responses he has previously made. The new response pattern is:

Movement No.	*Signal Board Lights*	*Traffic Light*
1	"A"	Green
2	"B"	Green or Amber
3	"C"	Green–Amber–Red
	"A" or "B"	Red

After an appropriate practice, the combination signal board and traffic signal lights are flashed in mixed sequence and with varying time intervals intervening. This series is composed of 25 stimuli.

Part V.

The subject is told that another mixed series, similar to the one just completed, will follow, but that the light flashes will be presented in more rapid sequence. The response pattern for Part V is the same as that for Part IV except that a new light combination is added, "A" with amber, for which the appropriate response is movement 2. This combination of lights did not appear in Part IV. A short practice period with this combination is given, but there is no practice of the combinations from Part IV. The time intervals between lights in this series average about one second less than those in Part IV. They are barely long enough to allow the subject to complete his response and return to his starting position. Any hesitation after a light appears is disastrous in this series. There are twenty stimuli in this series and they appear in a mixed sequence.

RECORDING AND SCORING THE TEST

Electrical circuits to the Esterline-Angus recorder are so fixed that a complete test record appears on the paper tape. The pens make a record of the inception and duration of the stimuli and a record of each movement of the steering wheel, gear shift lever, clutch, or brake (each of these response mechanisms registers on a separate pen). The paper tape moves through the time recorder at a constant speed of 1½ in. per sec.[3] As long as a pen

[3] The constancy of speed of the tape was determined experimentally despite the assurances of the manufacturers upon this point. Three hundred measurements of the speed were taken by starting and stopping the tape simultaneously with a stop watch. Time intervals varied from 5 to 30 sec. and measurements were made on 20 different days. Slight variations in speed were noted, but these were totally inconsequential. The mean error in speed was 0.005 in. per sec., with a standard deviation of 0.001. The maximum error noted in the 300 trials was 0.6 in. for an interval of 30 sec. The degree of this error can be noted when it is remembered that the tape moved 45 in. in this period.

circuit remains open, the pen makes a straight line on the chart. When the pen circuit is closed the pen is deflected ⅛ in. to the right of the straight line, and returns to normal position when the circuit is broken. The chart thus shows the movements called for and the responses which were made. This record permits determination of the accuracy of the response and the measurement of the time intervals pertaining to the responses.

The scoring of the test is in terms of accuracy and speed of response. The subject must make the correct movement for the stimulus presented, and in terms of two time intervals. These time intervals are (a) initial response time—that is, the time interval between the light flash and the start of the first movement in the response (wheel in No. 1 and clutch in No. 2 and No. 3) and (b) lapsed time—that is, the time interval between the start of the first movement in the response and the start of the last movement in the response. Reference to Figure 4 should clarify the measurement of these two time intervals.

The time interval is read from the tape by means of a graduated scale. This scale is graduated to tenths of a second and interpolation permits measurement with a maximum error of 0.03 sec.

The details of the scoring of each section of the test are to be found in subsequent discussion of the treatment of the data. The method was derived as a result of considerable experimentation. It was adopted because it gave maximum correlation (of those tried) with criteria, and is subject to further change if a method can be found that will increase this correlation. A study is now being made of some refinements in the scoring methods.

THE POPULATION[4]

The population comprised a group of 290 bus and street car operators who were employed by Capital Transit Company between July 1st, 1945 and December 31st, 1945. It includes all men employed during that period. About a dozen men were missed in the process of testing or had tests which could not be scored due to failure of the apparatus. The test was administered to each man during the first week in training, and, as far as possible, on the second day of his training period. The group was made up of 199 men who operated street cars only and 91 men who operated buses only during the criterion period.

THE CRITERIA

One of the most elusive factors involved in industrial testing is that of valid and reliable criteria. This is particularly true of objective criteria. It has long been known that the number of accidents each individual has can not be used to any advantage. Accident rates per unit of time or per unit of distance covered are also subject to many justifiable criticisms. Nevertheless some function of the accidents attributable to an individual is a highly desirable part of the measurement of his efficiency as an operator. With this in mind two criteria were developed:

1. The accident responsibility rate per 100,000 hours of operation for each individual in the population.
2. A rating of each individual based on his total desirability as an employee.

Accident Responsibility Rate

While the accident responsibility rate lacks some of the refinements introduced by Kraft and Forbes,[5] it includes one important element

[4] This test had previously been administered to a population of 300 employees who were employed during 1938, 1939, 1940, and 1941. The results were analyzed along with those obtained from several other tests given in an employment battery. The results were more or less what we might have expected from such a population. Factors of selection had operated for too long a period to make any differentiation possible. These factors were: (a) Promotion of the better men to jobs where they were not operating during the criterion period; (b) the worst men in the original group had been eliminated; (c) the selective service act had drawn off the best of the men not promoted; (d) the leavening effect of several years of training and experience tended to make the group even more homogenous. The testing of the population used in this study was in progress during the time used in statistical analysis of the first group. It is planned to make still another analysis of a group who were given the test previous to employment.

[5] Kraft and Forbes developed an "Accident Index" which eliminated non-personal accident hazard factors such as variations in mileage operated, differences in accident hazard of the various routes or lines, seasonal variation, day of the week, and hourly differences. Using

they could not obtain, a measure of the responsibility of the individual for the accident. On the whole, it represents a rather fair approximation of the individual's ability to avoid being involved in accidents.

For the purpose of this study, accidents included only collisions, that is, those accidents where the vehicle collided with another vehicle, a pedestrian, or a fixed object. The accidents for each individual were tabulated together with the degree of responsibility of the individual for the accident.

The responsibility of the individual for an accident is determined by persons specially trained for this task. Each accident is rated after a careful review of all available data, including witness statements, on a five category scale. This rating is entered on the accident card of the individual along with a brief description of the accident. These ratings range from "A" (no responsibility) through "B", "C", and "D" to "E" (operator totally responsible). Since this procedure is a part of the regular personnel program at Capital Transit Company, this work had already been done and was not a special rating for this study.

Several weighting schemes were tried. None seemed to give any better results than: "A"-1, "B"-2, "C"-3, "D"-4, and "E"-5. It can be seen that starting with "A"-0 would give the same comparative results. However, zero is a difficult concept to deal with statistically, and the author is opposed on philosophical considerations to rating any operator's responsibility for an accident as zero.[6]

The criterion period varied somewhat in length for the different individuals in the group. The period covered was from date of employment to April 1st, 1946. However, since we are dealing with the rate per 100,000 hours, this factor was comparatively minor.

The total accident responsibility of the individual was obtained by multiplying each accident by its appropriate weight for responsibility, and summing for all accidents. The number of hours of operation were obtained from payroll records. The accident responsibility rate per 100,000 hours was obtained by dividing the total accident responsibility by the number of hours of operation.

In any comparison of bus operators to street car operators it is necessary to take into consideration the differential accident rates of cars and buses. Results of analysis over an extended period of time indicate that cars have 2.15 times as many accidents as buses for the same mileage operated or for the same time operated. Thus, if we wish to combine bus operators and car operators into a single distribution, it is necessary to multiply the accident rate of the bus operators by 2.15.

Rating Method

The second criterion, a rating, was derived in a series of conferences which included: (a) the superintendent of transportation personnel; (b) the superintendent of operational training; (c) two of the supervising instructors. These men had available at the time of rating complete records of the men including training data and follow-up records. Rating was made after thorough discussion of all pertinent data in accordance with the following instructions.

"Suppose that you were told that you had to discharge 10 per cent of this group of men. You have full authority to pick the men with no other consideration except to get rid of the worst men in the group. Select the 29 you would let go first".

"Now suppose that you were told that you had to discharge all of the group except 10 per cent. The only consideration is to keep the best 10 per cent of the men. Select the 29 men you would keep."

The raters were told to repeat the process of selecting the worst and the best 29 men successively from each remaining population until all were arranged into 10 groups. These groups represented the order in which the men would be eliminated on the basis of total desirability as operators. The ratings were

---

factors they established an accident "expectancy" for each individual. The index was obtained by dividing the actual number of accidents by the expectancy. (Kraft, M. A. & Forbes, T. W., "Evaluating the Influences of Personal Characteristics on the Traffic Accident Experience of Transit Operators," *Proceedings*, Highway Research Board, Vol. 24, p. 278 (1944).)

[6] We can always ascribe at least the responsibility for taking the car or bus out on the street in the first place. Had he been absent that day the accident would not have happened to him.

made numerical by assigning numbers 1 to 10 to each ascending group. Each man in a group received the number of the group as a criterion score.

COLLECTION AND PRELIMINARY TREATMENT OF DATA

The first attempt at devising a method of scoring the tests was not successful. When the scores thus obtained were correlated with the accident criteria it was found that the correlation was not high enough to be significant. However, this first method is described as follows in some detail, because of the bearing of the study upon the development of the scoring method finally adopted.

The first step in scoring the tests consisted in tabulating for each subject the information for each part of the test shown below:

Part I. The total time consumed in making ten complete movements. Correctness of response was ignored in this part of the test. Three scores are obtained in this part of the test.

Parts II, III, IV, and V. In these parts of the test the subject had to get the response right to obtain any score. If the response was correct, then two time intervals were taken: (a) initial response time; (b) lapsed Time (see Fig. 4).

A sample score sheet for one subject is shown as Table 1. This individual had an average score on the test. As can be seen, this sheet contains about half of the test. The symbols used in the OK column are: the * indicates a correct response, the x an incorrect response, and the 0 no response at all. The time in each case is in hundredths of a second.

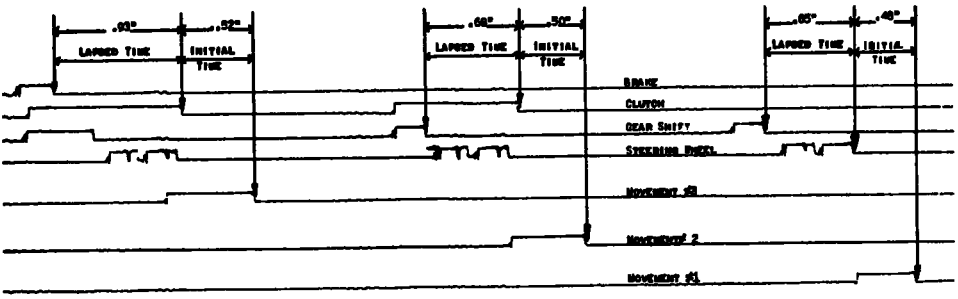

Figure 4. Portion of Paper Tape from the Recorder Showing the Scoring of a No. 1, No. 2, and No. 3 Movement. These are the first three stimuli of Part IV of the test

TABLE 1

SCORE SHEET FOR LISTING PRELIMINARY DATA FOR EACH INDIVIDUAL

	Part II			Part III				Part IV			Part V		
	OK	Init.	Lapsed	No.	OK	Init.	Lapsed	OK	Init.	Lapsed	OK	Init.	Lapsed
A—#1													
1	*	48	98	1	×			*	80	90	*	68	108
2	0			2	*	55	83	*	103	100	*	100	95
3	*	30	80	3	*	83	101	*	92	83	*	92	120
4	*	32	78	4	*	85	85	×			*	103	96
B—#2				5	0			*	93	136	*	102	120
1	*	60	93	6	*	78	118	*	90	140	0		
2	×			7	×			*	74	138	*	133	88
3	*	51	100	8	*	78	82	*	68	118	×		
4	*	46	92	9	*	77	138	0			×		
C—#3				10	*	90	127	*	109	61	*	125	120
1	×			11	*	70	92	*	108	108	*	85	75
2	*	88	135	12	×			*	93	84	*	71	84
3	*	60	128	13	*	84	100	×			*	68	75
4	*	57	125	14	*	62	94	×			*	88	110

Part I: Movement #1, 1375; Movement #2, 2312; Movement #3, 3038.

* Correct Response; × Incorrect Response; 0 No Response; Time is in hundredths of a second.

The first step in obtaining a score on the test involved the computation of the means and standard deviations of (a) the total time consumed for the ten repetitions of each movement in Part I; (b) the initial time and the lapsed time for Parts II, III, IV, and V. These are shown in Table 2.

TABLE 2

THE MEANS AND STANDARD DEVIATIONS FOR THE VARIOUS PARTS OF THE MOTOR ABILITY TEST (N-290)

Part I	Mean[a]		Standard Deviation	
Movement 1	12.23		2.37	
Movement 2	22.78		3.83	
Movement 3	28.04		4.96	
Part II	**Initial**	**Lapsed**	**Initial**	**Lapsed**
A—No. 1	.382	.865	.072	.145
B—No. 2	.540	1.000	.087	.166
C—No. 3	.627	1.310	.156	.218
Part III	.840	1.080	.129	.165
Part IV	.987	1.104	.167	.172
Part V	.834	.989	.150	.151

[a] All time is in terms of seconds.

It was now possible to set up a scoring scale based on the mean time taken for a response in each of the parts of the test. This was done by allowing ½ point for each correct initial response and ½ point for each correct lapsed response if completed within the following time limits:

Part	*Initial*	*Lapsed*
IIA—No. 1	.45	1.00
B—No. 2	.60	1.15
C—No. 3	.70	1.45
III	.95	1.20
IV	1.15	1.25
V	.95	1.10

Allow 2½ points for each series of repeated movements if completed within the following time limits:

Part I	
Movement 1	14.50
Movement 2	25.00
Movement 3	32.00

This method of scoring provided scores within a theoretical range of 0–102.5. As can be seen, the allowable time for obtaining points was roughly the mean plus one standard deviation in each case.

ANALYSIS OF RESULTS

All tests were scored using the scoring method outlined. It can be seen from the distribution of scores in Table 3 that the distribution is not normal. It is heavily weighted in the higher categories.

TABLE 3

DISTRIBUTION OF SCORES ON THE MOTOR ABILITY TEST (INITIAL SCORING METHOD)

Score	Frequency		Totals
	Car Operators	Bus Operators	
10–19	3	1	4
20–29	6	3	9
30–39	14	10	24
40–49	26	11	37
50–59	32	12	44
60–69	31	16	37
70–79	39	15	54
80–89	38	13	51
90–99	10	10	20
N	199	91	290
Mean	64.0	63.9	64.0
Median	66.1	65.6	65.7
S. D.	18.9	20.3	19.4

TABLE 4

DISTRIBUTION OF ACCIDENT RESPONSIBILITY RATES

Rate	Frequency		Totals
	Car Operators	Bus Operators	
0–9	101	60	161
10–19	58	21	79
20–29	20	6	26
30–39	14	2	16
40–49	4	2	6
50–59	2	0	2
N	199	91	290
Mean	13.3	10.2	12.3
Median	10.0	7.8	9.9
S. D.	11 0	8.8	10.5

The accident responsibility rate for each man was derived. These are shown in Table 4. This distribution is rather typical of accident distributions. It is heavily weighted with men in the lower accident rates. It might be well to point out that the men in the highest categories of this table have all been eliminated. Many of them were separated from company rolls before the time of tabulation.

The correlation of motor ability test score with accident responsibility was computed (a) for street car operators, (b) for bus operators, and (c) for the two groups combined (care being taken to weight the rates of the bus operators by 2.15). (See Table 5.)

The correlation of the motor ability scores with ratings by supervisors was 0.046. No separation was made between car operators and bus operators in the rating. The low correlation with supervisory ratings made it apparent that the test would not pick out men whom the supervisors consider the best operators, or at least the men whom the supervisors consider it most desirable to retain.

TABLE 5

PRODUCT-MOMENT CORRELATION OF MOTOR ABILITY TEST SCORES WITH ACCIDENT RESPONSIBILITY RATE

Population	r	N
Street Car Operators	−.139	199
Bus Operators	−.190	91
Combined Groups	−.141	290

As a matter of fact, it was apparent at this point that we did not have enough validity in the test to justify using it as a tool for the selection of new personnel. We were faced with one of two courses: to seek for revisions that would increase the validity, or to abandon the test entirely.

DEVELOPMENT OF NEW SCORING KEYS

Several revisions in scoring method were tried. Details of these methods would add considerable length to this report without adding anything to the worth thereof. Suffice it to say, three were tried and discarded because they did not increase the validity coefficients.

Study of the implications of the scoring method already described reveals the glaring weakness that both factors in the test, accuracy and speed, are operating largely as all or none elements. That is, the subject had to get the response right to get any credit. Moreover, a critical time limit was set and the response had to come within this time limit or no credit was given.

The following reasoning formed the basis of the new scoring method:

1. Accuracy must be retained as an all or none element.
2. If time is an element, then the shorter the time used by the subject, the more credit he should get.
3. Part I and Part II are largely practice periods and, as such, should be excluded from the test score. To include them would merely dilute the score and make it less sensitive.

Acting upon the reasoning outlined, a new set of scoring keys was derived. With these keys the subject could obtain from 0 to 4 credits for any initial response time or for any lapsed time where the response made was a correct one. Only Parts III, IV, and V were used in obtaining the score. The scales for the credits in the various parts of the test are shown in Table 6.

TABLE 6

TIME LIMITS FOR SCORING CREDITS FOR PARTS III, IV, AND V OF THE MOTOR ABILITY TEST

Test Sec.	Points Credit				
	0	1	2	3	4
Part III					
Initial Time	106 up	86–105	66–85	46–65	45 or less
Lapsed Time.	131 up	111–130	91–110	71–90	70 or less
Part IV					
Initial Time..	121 up	101–120	81–100	61–80	60 or less
Lapsed Time.	141 up	121–140	101–120	81–100	80 or less
Part V					
Initial Time..	106 up	86–105	61–85	46–65	45 or less
Lapsed Time.	136 up	116–135	96–115	76–95	75 or less

ANALYSIS OF RESULTS WITH REVISED SCORING

The tests were rescored using the new scoring method. It was apparent as we scored the tests that many of the men were not changed in their relative standings. However, many others were changed radically. The extremes of the distribution, either high or low, were not materially affected, but many in the middle ranges were shifted up or down past the mean. Most of these men had appeared out of position in the original correlation plots. The distribution of scores with the revised scoring is shown in Table 7.

This new distribution conforms more closely to what might be termed the usual test score distribution. It is possible that the greater range contributed somewhat to this change in shape of the curve, but it is our feeling that the probability of this being so is small. It is interesting to note that the means and the standard deviations show comparatively small change from the results of Table 3.

The product-moment correlation between accident responsibility rate and these revised motor ability test scores was computed and found to be:

Group	*r*
Street Car Operators... ...	−.292
Bus Operators.....	−.432
Combined Groups.....	−.331

These are comparative low correlations when regarded from the standpoint of mathematical certainty. They are far too low to use for any clinical diagnosis or for individual guidance.

TABLE 7
DISTRIBUTION OF MOTOR ABILITY TEST SCORES (REVISED SCORING)

Score	Frequency		Totals
	Car Operators	Bus Operators	
10–19	5	0	5
20–29	10	9	19
30–39	21	11	32
40–49	38	9	47
50–59	34	14	48
60–69	38	21	59
70–79	19	9	28
80–89	20	5	25
90–99	5	6	11
100–109	6	3	9
110–119	3	4	7
N	199	91	290
Mean	58.7	61.5	59.6
Median	57.7	61.4	58.6
S. D.	21.2	23.7	22.1

As validity coefficients for a single test in a battery of selection tests for industrial employment, they are high enough to be very significant.

The correlation of the revised motor ability test scores with supervisory ratings seemed little affected. The new correlation was 0.089 as compared to 0.046 under the original scoring. This was somewhat surprising. We offer no explanation for this apparent inconsistency. The correlation of accident responsibility rate with supervisor's rating is 0.482. It would appear from the facts at hand that the two criteria are measuring different functions. Furthermore, one of these functions cannot be predicted at all with the motor ability test scores.

USE OF THE MOTOR ABILITY TEST AS A SELECTION TOOL

A test is one source of information about an individual. It is a good source of information insofar as it is valid and reliable. It is not intended to supplant other normal sources of information, but to supplement them. The motor ability test would not be a perfect selection instrument even if it gave absolute mathematical certainty of prediction of the individual's accident record. Many other factors must be considered.

The results we have obtained are significant, not perfect. The effectiveness of the use of the test can be seen from some additional analyses we shall present.

Suppose we define a satisfactory accident record as any accident record which was better than the mean accident responsibility rate, and an unsatisfactory one as being worse than the mean. Using these definitions we can compute the bi-serial coefficient of correlation between accident responsibility rate and motor ability test scores. The point of dichotomy in the accident responsibility rate is the mean for the particular group with which we are dealing. These computations showed biserial correlations of:

Group	*r*
Street Car Operators .	−.48
Bus Operators	−.62
Combined groups..	−.54

Thus, if we desire to predict only whether the man will eventually be satisfactory or unsatisfactory, we can do so with much more accuracy than we can predict his exact location in the scale of accident responsibility. Out of the group of 290 men, 114 who scored above the mean of the motor ability test were better than average on accident responsibility rate; 92 who were below the mean of the motor ability test were worse than average on accident responsibility rate. These 206 men were correctly placed by the test if we are considering them on a satisfactory-unsatisfactory basis. This gives a correct prediction on approximately 71% of the individuals.

Another analysis might be noted from Table 8.

These figures tell the same story in a slightly different way. If we confine our selection for employment to those who make a score of 65 or more on the motor ability test, then the chances are about 4.5 to 1 that we will get a

man with a better than average accident record. In the range of scores 50 to 64, our chances are about even that the man will be above average or below average as an accident risk. When a man gets a score of 49 or less the chances are about 2 to 1 that he will have worse than an average accident record.

An additional fact might be pointed out here. Of all the operators who scored above 65 on the motor ability test, only one bus operator was as much as one standard deviation worse than the mean accident responsibility rate; and only five street car operators were as much as one standard deviation above the mean accident responsibility rate. None of these men were as much as two standard deviations above the mean accident responsibility rate. It is possible that by using the motor ability test we might avoid the very bad accident risks even though we still would get those with poor records.

TABLE 8
MOTOR ABILITY TEST SCORE

Accident Responsibility Rate	Car Operators			Bus Operators		
	0–49	50–64	65–119	0–49	50–64	65–119
Better than average	34	33	50	8	14	32
Worse than average	40	30	12	21	10	6

TABLE 9

	Car Operators		Bus Operators		Combined	
	Worst	Best	Worst	Best	Worst	Best
No Scoring 65 or more	3	19	1	8	4	27
No. Scoring 64 or less	17	1	8	1	25	2
No. Dismissed.	15	2	6	0	21	2
No. Resigned	5	7	2	4	7	11
Net after trial period . . .	0	11	1[a]	5	1	16

[a] This man was retrained and improved his record materially.

One other analysis which is frequently used for validation is the comparison of the test scores of the 10 per cent who had the worst accident records with the test scores of the 10 per cent who had the best accident records as given in Table 9.

Had we been using the motor ability test as a selection tool in our employment procedure, and had we set 65 as a minimum for aceptance, we would have eliminated 25 of the 29 men who had the worst accident records. We would have lost only 2 of the men who had the best accident records. Moreover, the net gain in men who scored 65 or more is 16 and in the men who scored 64 or less is 1, and that man had to be retrained before he was successful. We point out this net for the reason that it is the key figure in such an analysis. The cost of employing and training a bus or street car operator has been variously placed at from $300 to $500. When such an investment must be made in each man employed, it is vital that every means possible be utilized to train only those who will succeed and who will stay with the company. The investigation herein reported appears to indicate that the American Transit Motor Ability Test, while it does not guarantee results, does furnish significant information for use in isolating from the general population of applicants the group likely to furnish the best accident risks.

SUMMARY

We do not regard the results of this study as conclusive, but feel that sufficient evidence has been adduced to warrant an extensive trial use of the American Transit Motor Ability Test. We believe that such use will add new evidence of the validity of the test as a selective factor for the employment of bus and street car operators. The significant points of this study appear to be:

1. An accident criterion which is objective and usable was established. This criterion has validity based only on logical reasoning, but is an essential factor in any investigation of the efficiency of operators of transit vehicles. Its reliability has not been established.

2. A significant relationship between the accident criterion and scores on the American Transit Motor Ability Test was established for a population of 290 operators of street cars and buses.

3. No reliability coefficients were established for the test.

4. Rating methods were found to be of little use in this study. No relationship was found between the ratings and the test scores, and the ratings were not highly related to the objective criteria.

5. Usable employment ranges of test scores

were established. These are now in use at Capital Transit Company. For the sake of clarity these might be stated as:

(a) Men whose score is 65 or more furnish the most suitable candidates for employment.

(b) Men whose score is between 50 and 64 should be employed if other factors indicate that they will be suitable.

(c) Men whose score is 49 or less should be rejected unless there is strong evidence from other factors that they will be suitable.

6. Based on the evidence of this study, the use of the American Transit Motor Ability Test will materially aid in reducing the number of men who must be eliminated after a training and trial period.

Another evaluation of this test is planned. The population for that study will be drawn from the group which is being tested prior to employment. At that time we shall also investigate the relationship between test score and the ability of the candidate to complete training.

Acknowledgements

This report is based on an extensive validation study which has been in progress at the Capital Transit Company during the past three years. The author is greatly indebted to the following men: Alexander Shapiro, Director of Personnel, Capital Transit Company; Glen U. Cleeton, Consultant, American Transit Association; Merwyn A. Kraft, Accident Prevention Engineer, American Transit Association; George W. Cramer, Supt. of Transportation Personnel, Capital Transit Company. This experiment was designed and completed as a cooperative effort of the American Transit Association and the Capital Transit Company. Each step that was taken was carefully considered in extensive conferences by those listed. The author has served as the executor of these joint decisions and as the reporter of the findings.

TOLL BRIDGE INFLUENCE ON HIGHWAY TRAFFIC OPERATION[1]

By M. Earl Campbell

State Planning Engineer, State Road Commission of West Virginia[2]

SYNOPSIS

The diversity of opinions and policies with respect to the toll system is leading to serious inquiry as to the relative effects and values of free and toll bridges. A rational approach to the problem is attempted in this report.

This paper presents the development of a mathematical method for measuring objectively the restraint imposed upon highway traffic operation by toll bridges.

A formula is developed for measuring the monetary value placed upon time by the composite motorist. The application of the formula depends upon a measurement of sphere of influence of adjacent free and toll bridges, toll rate, and rates of vehicular speeds in the area studied.

Conversely, the formula may be used to determine the sphere of influence of the toll facility when the monetary value of time is given.

The method presented comprehends the analysis of time and delay studies, correlated to origin and destination surveys made before and after freeing toll facilities.

A number of specific cases were studied during 1946 by the Planning Division of The State Road Commission of West Virginia to develop a reservoir of experience. An interpretation of the analyses of cases studied (of which this paper presents but one case) indicates that:

1. Each toll facility has its own peculiar sphere of influence as determined by

[1] This paper is a brief of Parts I, IV, V, and VI, of a thesis bearing the same title submitted by the writer in partial fulfillment of requirements in Highway Traffic Engineering at the Bureau of Highway Traffic, Yale University, 1946.

[2] Mr. Campbell is now Engineer of Traffic and Operations, Highway Research Board.