HUMAN FACTORS in HIGHWAY-TRANSPORT SAFETY

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AS OUR environment has become more mechanized and our population more mobile, accidents have increased at an alarming rate. The loss of life and incapacity from this source is as great or greater than from any known disease entity and constitutes one of the major causes of death and injury in both civilian and military populations. Existing concepts of public health, therefore should be extended to include safety at home, in the factory and in transportation from one place to another.

The control of accidents falls within the province of preventive medicine and public health because of the important role played by human variables. It is not generally appreciated that injuries, as distinguished from disease, are also amenable to the epidemiological approach and that accidents follow some of the same biological laws as do disease process. In most instances, there is multiple causation and attempts at control should involve consideration of the interaction of agent, host, and environment. Although the host is of primary medical concern, the agent and the environment must also be considered.

The extensive movement of people, goods and materials from one place to another in some form of transport vehicle is one of the outstanding features of modern life. The number of passengers using buses far exceeds those using railways, steamships or air transportation. About nine billion revenue passengers use buses each year, while somewhat less than one billion revenue passengers use the railways. Thus it appears that practically everyone uses some form of highway transport each year in the United States, not only once but many times. The American Trucking Association estimates there are approximately six million truck drivers--one of the largest job classifications in the country. The volume of supplies these drivers move from one place to another is enormous. In 1949, it amounted to about 82 million tons for intercity service by common carriers. Approximately 40 percent of the nation's freight is transported over the highways.

In spite of the many loss prevention measures which have been developed and applied in the motor transport and other industries, there are still too many accidents. Outside the home, the largest proportion of accidents occurs in some form of transport vehicle. According to the National Safety Council, each year in the United States there are approximately 40,000 motor vehicle deaths, 100,000 permanent injuries and about 1,000,000 temporary total disabilities resulting from this source. The problem of vehicular accidents is even more serious in the federal government. For each 100 million miles driven by the 360,000 motor vehicles in government service, there are 15 fatal accidents, or twice as many as the national average of 7.4. Due to the increased mileage and exposure, the actual number of deaths and injuries has increased to such an extent that the National Safety Council estimates that 10 percent of the population of the United States may be expected to be killed or injured in highway accidents in a period of about 15 years.

INVESTIGATIONS IN ACCIDENT PREVENTION

A broad research program in accident prevention is currently being conducted at the Harvard School of Public Health in the Department of Industrial Hygiene. The program is sponsored by the American Trucking Associations, Inc., the National Association of Motor Bus Operators and the National Association of Automotive Mutual Insurance Companies. It is under the direction of Dr. Ross A. McFarland, and includes in its full-time staff Mr. Alfred L. Mosely (Experimental and Clinical Psychology), Mr. Jack W. Dunlap (Psychology and Engineering), and Mr. William A. Hall (Anthropology and Engineering). Additionally, the project involves a number of part-time workers from the fields of physiology, statistics, psychiatry, anthropology, engineering, psychology, and sociology.

It is not possible here to describe all the projects undertaken by this group, but investigations are being carried out in the following areas (1) analysis of activities and distribution of work loads of bus drivers, (2) selective placement of persons by objective tests and standardized interviews, (3) health maintenance examinations, (4) study of accident repeaters, (5) Human factors in the design of equipment, (6) environmental influences, (7) injuries from high decelerative forces, (8) personal adjustments and morale, (9) supervision and leadership, and (10) a study of near accidents and the critical components in driving.

DESIGNING TO SUIT THE OPERATOR

If significant progress is to be made in the future, mechanical design must be related more directly to the physiological and social habits of man. One of the first principles in accident prevention, therefore, is to design equipment to suit the operator instead of selecting an operator to fit the equipment or redesigning after the equipment is built.

All possible faults in equipment and in the working areas of vehicles should be subjected to an advance analysis in order to prevent accidents. If defects are present, it is only a matter of time before some operator "fails" and has an accident. An advance analysis involves several assumptions. The first is that an operational job analysis should include a survey of the nature of the task, the work surroundings, the locations of controls and instruments and the way an operator performs his duties. The second implies a functional concept of accidents; that is, it anticipates the errors that may occur while the operator is working at the machine. The repetition or recurrence of near or real accidents clearly indicates a need for redesign. A third consideration relates to human limitations. It should be assumed that no pilot or truck or bus driver is a perfect one. In fact, he may be far below the ability assumed by the designer. If his duties are too complex, the cumulative burden is great, and he reaches or exceeds his limits of attention and ability. Finally, a wide margin of safety should be provided to eliminate any possible situation that places the operator near his maximum ability with regard to aptitude or effort, especially when adverse factors enter the picture.

The compilation and use of anthropological measurements in relation to the design of equipment offer a very fruitful approach to the reduction of accidents. In order to improve the ease, efficiency and safety of equipment, consideration must be given to dynamic body measurements, an unobstructed view for all operations, the location of controls so that they can be worked at a bio-mechanical advantage, and restraining or protective devices in vehicles which will be decelerated rapidly. It is reasonable to demand that machines be designed from the man outward, with the instruments and controls considered as extensions of his nervous system and body appendages.

The use of "average" values to provide for the physical proportions of drivers may account for many defects. The average value cannot be employed directly, since, by definition, arrangements based upon an average would be unsuitable for 50 percent of the operators in a normally distributed group. Provision for 90 or 95 or any other predetermined percent of potential operators will require identifying the correct cut-off point. Where, for example, arm reach for the operation of manual controls is under consideration, the cut-off point should be well below the average reach; where strength of a structure intended to support one man or where body clearances are concerned, due consideration must be given to the 25 percent of the drivers whose dimensions exceed the average values as well as to the 25 percent whose measurements are below the average.

DEFECTS IN 1951 MODELS

Several examples may be given to illustrate defects in design of equipment which have direct implications for safety, comfort and efficiency:

1. Marked variations have been found to occur in the over-all working space provided for the drivers of trucks and tractors. In one instance,it was estimated only the drivers representing the smallest 40 percent of the group could be accommodated.

2. Many errors were observed in regard to human sizing. In several models, for example, only 5 percent of the drivers could comfortably reach and operate the hand brake. In others, only 60 percent could be accommodated for knee height between the pedals and the steering wheel. Some of the taller drivers are unable to adjust their sitting positions to obtain maximum visibility with regard to their instruments and the road ahead.

3. Failure to provide for adequate seat adjustments to allow for variations in human size was frequently noted.

4. There was no standardization of shift patterns in the various models studied. This predisposes the driver to error in the event that he is transferred from one model or type to another.

5. Adequate vision from the cab remains a serious problem in all models during operation in residential and busy areas. This contention is supported by an analysis of 57 light truck accidents, some 50 percent of which involved pedestrians. During bad weather, the range of forward vision is reduced approximately 50 percent, and visibility from the side is reduced even more because of no provision for cleaning or defogging.

6. Many errors have been observed in the location and design of electrical switches, especially with respect to headlamps, fog lamps and marker lights. In two instances, the dimmer switch was found to be located directly

beneath the foot pedals, behind the steering post. In these models, the driver may inadvertently operate the air horn or fog lamp while attempting to dim his headlamps. Even when he operates correctly, more complex motions and longer reaction times are required to avoid the pedals.

7. In studies of carbon monoxide concentration in trucks and tractors, the maximum safe levels were exceeded in almost every instance in which the sample was taken after the cab had been closed 15 min., with the engine idling. On repeated tests with one tractor, the level was high enough to be lethal in one hour. However, in no instance during normal cargo or passenger operations was an unsafe carbon monoxide level found. The maximum operational finding was 0.0025 percent, which is a safe level.

8. More attention should be given to the location of instruments in the panel with respect to ease of visibility. For example, in many cases the air gauge was placed directly behind the steering wheel and could not be seen by the driver without his twisting his body out of a good driving position. In another instance, the RPM indicator is placed on the extreme right of the dashboard, making it virtually impossible for the driver to read it accurately.

Design improvements alone cannot solve the accident prevention problem, and many studies point to the role of human variables in accident causation.

HUMAN FACTORS IN ACCIDENT CAUSATION

In an attempt to obtain additional information on the causes of accidents, a study was made of the records in insurance company files. The analysis included 305 cases in which a total of approximately two million dollars was paid in claims. The total number of serious accidents involved 82 drivers of fleet trucks, 63 of straight trucks, 34 of buses, and 126 long-haul drivers. The study revealed a number of significant findings. For instance, a large majority of the accidents occurred under the following conditions: at intersections or on country highways; on a dry level road surface made of concrete or macadam, having two lanes and with no reported structural defects; in daylight hours, when traffic was light. It should be noted that all of these conditions are favorable for safe operation. Human errors accounted for 90 percent of the accidents, and about 10 percent were attributable to mechanical failure. The causes which were traceable to the drivers were: (1) nonadjustment to the driving conditions, (2) inattention, (3) following too closely, (4) fatigue, (5) driving under the influence of liquor, (6) driving too fast for the range of vision and reaction time and (7) faulty meeting and passing.

PREVENTION OF ACCIDENTS BY SELECTIVE PLACEMENT OF PERSONNEL

There are several important considerations in the selection of drivers. One concerns psychological fitness, including mental ability, aptitude and temperament. Another relates to the possibility that certain employees may have repeated accidents. A third area deals with medical fitness, including such factors as vision, heart disease, susceptibility to fatigue, momentary lapses of attention or loss of consciousness, and age.

The first step in selective placement is to make an accurate job analysis. In so far as reducing accidents is concerned, this helps to identify the critical components of the job or to determine the way in which human errors may occur. An example will be drawn from the field of airline piloting. The information was obtained by "off-the-record" personal interviews as well as by direct observations. In one study it was found that 229 of 460 specific acts contributing to pilot error were due to confusion of two controls, and 83 to forgetting to operate a control. The results of these studies indicate not only that the design of equipment might be improved but also that great care must be given to the selection and training of pilots.

The next step is to develop and standardize suitable psychological tests to appraise the ability of the candidate. The tests should be given at the time of original selection to prevent labor difficulties later on. Critical scores should be determined experimentally for each job, for it is assumed that a candidate with low intelligence will be more subject to error if placed in a critical setting. It is equally important to determine cutoff points at the higher level, for it is obvious that the worker with superior ability may be bored and make errors while day-dreaming or thinking of other matters.

ANALYSIS OF THE CONCEPT OF ACCIDENT PRONENESS

The aspect of selection with which we are chiefly concerned relates to the detection of the so-called accident-prone individual. The word, "proneness" has been used to imply a series of personality traits which have not been precisely identified thus far. The term, "accident repeater" is preferable.

In any large group of workers it is often reported that a small percentage of the group give rise to most of the accident problems. In one large company, for example, it has been stated that "80 to 85 percent of the visits for injury or medical complaints are produced by 30 percent of the people. In this group there was a preponderance of neurotics and otherwise below par individuals with a high liability to hurt themselves and frequently involve others." Numerous studies from other companies including transport fields have also shown that some individuals tend to have a higher frequency of accidents than chance alone would indicate even when the exposure is controlled.

In order to demonstrate the existence of accident proneness, it is necessary to show that accidents do not distribute themselves by chance among the total group. Two lines of evidence show that this is so. In the first place, there are more people with no accidents at all and more people with multiple accidents than would be predicted by chance. Secondly, there is a tendency for those individuals who have multiple accidents in one period of time to continue to have multiple accidents in later periods of observation.

Before the importance of the purely personal factors in accident liability can be evaluated, it is first necessary to control such factors as amount of exposure in a given occupation. Furthermore, the criteria of what constitutes an accident must be controlled. If some individuals report even the slightest injuries as accidents, while others report only more serious injuries. there will be an apparent difference in liability due to this factor. Another reason which tends to make tests less successful than they might be is the multiplicity of personal factors involved. Thus, one person might have repeated accidents because of a slow reaction time, another because of a special eye defect and a third because of frequent quarrels with his wife, and so on for many other reasons.

A MAN 'DRIVES AS HE LIVES'

Our approach to the study of psychological fitness for driving relates to an exploration of the concept that a man drives as he lives. If a driver is maladjusted in his personal life, is unhappily married, is in debt, is drinking excessively and manifests other traits of personal and social maladjustments, his chances of becoming involved in an accident are much greater than if he were well adjusted. The fact that many serious trucking accidents occur toward the beginning of trips suggests that worry or apprehension carry over into the working periods, giving rise to distraction or lapses of attention. Furthermore, many drivers, who have become involved in serious accidents are known to be maladjusted in their personal lives.

In a preliminary study of high-accident as compared to low-accident taxi drivers, Dr. W. A. Tillman found that the former had a significantly high frequency of the following: divorced parents, excessive parental strictness and disharmony, excessive childhood phobias, excessive childhood aggression, truancy and disciplinary problems in school, frequent job changes, the history of being fired from employment, admitted hetero-sexual promiscuity, admitted bootlegging on the job, consciousness of physique and low interest in hobbies. Many of these items can be covered by the employment interview or identified in public records.

A study was then made of 300 passenger car operators from the general population. One hundred accident-free drivers and 100 accident repeaters were located through highway department records, and 100 additional accident-free drivers were located from insurance files. The records covered a 15-year period, and the drivers were matched for age but not for exposure. The following records were then checked: social service agency files and credit bureau, public health venereal disease records, and adult and juvenile court records. The accident repeater was known to one or more agencies in 66 percent of the cases, as compared to only 9 percent for the accident-free group.

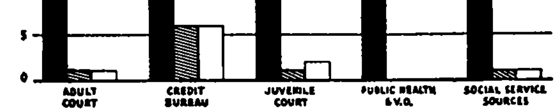

Figure 1. Social background of accident free and accident repeaters.

In our studies of truck drivers, additional refinements were made in regard to matching accident-free and accident-repeater drivers. The accident-free drivers were not involved in any accident at all, and the accident repeater had three or more chargeable accidents within a 12-month period. Exposure was controlled by matching the drivers on the following factors: (1) the traffic area in which they drive, (2) type of unit, (3) the length of the normal working day, (4) periods of operation with respect to peaks of traffic, (5) commercial driving experience, (6) marital status, (7) age, and (8) employment status. The checks made on a group of 102 drivers showed similar results to those mentioned above. The most important practical implication is that failure to check various records constitutes a serious omission in employment procedures.

PHYSICAL FITNESS

In regard to physical fitness, careful studies have shown little relationship between accidents and physical defects as revealed in the medical examinations. This may be related to the fact that the various tests are either (1) not related to the specific duties which the driver must perform, or (2) are not reliable. The physical examination for drivers should be revised on a functional basis. In other words, after the critical components of the driver's job are understood, it should then be possible to appraise those traits or functions and devise reliable tests.

One of the most important areas, which should concern the physican and safety director, relates to the basic causes of lapses of attention, distraction or temporary loss of consciousness. In many serious accidents on the highway, loss of attention may occur because of overeating, excessive fatigue or hypnotic effects of monotony. Loss of consciousness may also result from head injuries, epilepsy, advanced heart disease or diabetes. The basic causes cannot be revealed in a cursory physical examination.

If health maintenance examinations are carried out routinely and thoroughly, it is only very occasionally that a person is eliminated, and many are made safer and their useful lives prolonged if defects are detected early enough for correction.

As an illustration, consider the case of the Boston streetcar driver who was a patient of the late Dr. Soma Weiss, a specialist in the field of circulatory diseases and fainting attacks. The streetcar conductor had fainted at a particular corner on his run on several different occasions. Certain aspects of his behavior suggested that a psychological or emotional factor was involved. Dr. Weiss amazed his staff by asking to see the man's collar. He established the fact that when the conductor turned his head at the corner to look back for approaching traffic, his high collar stimulated the bundle of nerves (cartoid body) in his neck which controlled the blood supply to his brain. The man was put back to work with a low collar and had no further difficulty. This is what is meant by corrective action based on insight into the physical condition of the operator.

OPERATIONAL ASPECTS OF FATIGUE

In recent years, we have devoted a great deal of attention to the problem of fatigue in pilots, drivers and others engaged in the operation of machines. One of the most interesting findings relates to the deterioration of skills or habits which usually operate unconsciously. Studies have shown that the early signs of skill fatigue are as follows: (1) a tendency to require a stronger stimulus before action takes place, (2) a reduction in the ability to anticipate what may take place, (3) inaccurate timing of control movements, and (4) increased sensitivity, with more aggressive action both towards people and towards the machine being operated. The fringe skills or subtler reactions, which usually operate unwittingly, are lost and more effort and attention are required to carry out the tasks successfully. Finally, there seems to be a loss of insight into the extent of one's own deterioration. Such behavior naturally forms the basis for errors or accidents.

AGING AND ACCIDENTS

Not many months ago a bill was introduced into the Massachusetts State Legislature to limit the licensing of aircraft pilots to those who are 50 years of age and younger, following a fatal accident to a private pilot who was over 60 years of age. At present there is insufficient evidence to set an arbitrary retirement age for pilots or drivers. The ability to perform duties, i.e., functional age, is far more important than chronological age. Furthermore, there is a great deal of evidence to suggest that the older pilots and drivers are as safe as, or possibly safer than, younger ones. It might be possible to utilize the older worker safely if more facts were known about the functional changes which occur with age. He could then be taught how to compensate for his deficiencies. No better illustration can be given than the results which we have obtained from studies of the ability to see under low illumination in relation to age. Older people are markedly handicapped in regard to this function, and drivers over 60 or 65 years of age might be confined to day rather than night runs in order to utilize their abilities without hazard to others.

CONCLUSIONS

Our studies emphasize the fact that many variables contribute to motor transport accidents rather than any one single causative factor. Improvements can be brought about only through increased vigilance and research with regard to the design of equipment, the selection and training of personnel and safe operating practices. The prevention of accidents requires the teamwork of (1) research specialists, (2) operators who are concerned with routine scheduling and maintenance of equipment, and (3) the management groups interested in making an operating profit. It is only through coordinated efforts that any real and permanent improvement can be accomplished.