System Standards for Drivers, Vehicles and Highways

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NATIONAL TRANSPORTATION SAFETY BOARD

The National Transportation Safety Board was established by Congress in the Department of Transportation Act of 1966. The safety board's basic functions include the investigation of major transportation accidents in all modes of transportation and the execution of special studies of safety problems which influence casualties in transportation. The safety board is made up of a chairman and four members, appointed by the President and confirmed by the Senate. The chairman of the safety board is John H. Reed, former governor of the state of Maine. The safety board develops recommendations in transportation safety which are directed to the administrations of the Department of Transportation and other nationally important institutions which influence transportation safety.

SAFETY BOARD ADOPTS STUDY—COMPATIBILITY OF STANDARDS FOR DRIVERS, VEHICLES AND HIGHWAYS

Mutually Compatible Definitions of Performance Largely Absent for Systems Analysis

In 1969 the safety board adopted what we believe to be a very significant study titled, "Compatibility of Standards for Drivers, Vehicles, and Highways." This study described the wide range of standards which, assembled, constitute the functional definition of the highway and the vehicle operating system. It has been appreciated for some time that the safety performance of drivers, roads, and highways was only poorly defined, if compared with the degree of definition and specification found in other well-developed systems, such as aerospace systems. The problem was strongly emphasized, however, when an effort was made to employ system analysis and system design in connection with the New York State Safety Car

Project of 1966. This project was a precursor of the present Experimental Safety Vehicle Authority of the Department of Transportation. That early effort highlighted a major problem of the highway transportation system. The study report of that project said:

> ". . . The vehicle's performance cannot be defined except in relation to (poorly defined safety performance parameters of the driver and road). . . . It is only in terms of mutually compatible definitions of performance that the different elements of a traffic system can be assembled and seen as an operational system."

This statement is, of course, completely true for any type of system subject to the systems approach. The safety board's study showed in detail that the mutually compatible definitions of performance were largely absent. The study described the nature of the incompatibility in considerable detail and discussed the problems of organization which would have to be solved if compatible standards were ever to be produced.

Systems Approach and Defining and Interrelating Compatible Functions—Standards

Under the systems approach, the construction of a functional system depends upon defining and interrelating the necessary functions. If the methods of defining these functions (let's call them standards for the time being) are technically incompatible, or if the standards merely describe the structure of the system rather than its function, then it will be almost impossible to employ the standards to describe an integrated operating system. We cannot assess the mode of operation which was intended by the designers, nor can we analyze the operation actually produced, without introducing novel methods of analysis of a nonstandard nature. The result of this difficulty is that we are led to consider the operation of the system mostly in terms of the effectiveness of its isolated parts. Inevitably, we must make our decisions of highway and vehicle design, and driver selection on a narrow basis. This leads to hazardous and inefficient operations.

EXAMPLES OF DIFFICULTIES PRODUCED BY INCOMPATIBLE STANDARDS

Standards Defined

Now, that is a theoretical statement of the difficulty produced by incompatible standards. A few examples will serve to show what we are talking about in practical engineering terms.

First, we are considering under the word "standard" any form of specification, standard, definition, or description which serves to describe the combined operation of the driver, the vehicle and the highway, whether voluntary or regulatory. We include, for example, the Snellen eye chart used to test the visual acuity of drivers. We include the functional description of instrumented anthropometric dummies which represent the human body in crash injury tests. We include crash-test objects which represent objects along the highway which may be struck by vehicles. We include highway design policies. There appear to be hundreds of such standards. We are *not* concerned with those elements of description which are internal to one part of the system, such as the compressive strength of concrete, the voltage used for vehicle light, the driver's eyeglass prescription, or the specification of his hearing aid.

Incompatibility of Standards of Rear View Mirror Visibility and Standards for Geometric Design

The first example describes a problem which is on the way toward solution in the case of passenger cars. I refer to the incompatibility between standards of rear view mirror visibility and standards for the geometric design of highways. Acceptable highway designs include many illustrations of merging or weaving situations in which a vehicle can potentially be overtaken by traffic approaching from the left or right rear. Half a dozen are shown in the blue book of AASHO. Tangential entries are allowable on the interstate system, and indeed, are the normal method of entry to high speed lanes. Notice, however, that such standards are not numerical descriptions of a functional requirement, but simply layouts of acceptable design. There is no statement in these layouts of any assumed or intended rear vision characteristics of vehicles which will use the roads.

On the vehicle side, we have "Federal Motor Vehicle Safety Standard 111" which specifies, "Requirements for rear view mirrors to provide the driver with a clear and reasonably unobstructed view to the rear." This standard is numerical in nature, producing with an *inside* rear view mirror a view to the rear of at least 20 degrees horizontal angle. However, since this view may be totally obscured by interior loading which is not disapproved under the standard, an outside rear view mirror on the driver's side is also required. The performance standard for the outside rear view mirror is stated in terms of points and distances from the driver's eyes which must be visible in the rear view mirror.

It can be shown by calculation that within the standard layouts of AASHO, one vehicle can approach another vehicle from the rear in such a way that the rear vehicle cannot reliably be detected by the forward driver using his rear view mirror. Thus, the forward driver, if he perceives this difficulty, ceases to employ the rear view mirror and will turn to the rear, looking through the left side windows of the vehicle (or the right side where merging into the left lane is permitted). We all know the hazard which this produces. One cannot look to the rear and forward at the same time. Of course, there are also no windshield wiping or defrosing standards for the vehicle side windows which must be used in this situation. Most important, the existence of these standards has not served to show that a hazard existed, and thus the standard is of little use in creating a safe system.

This difficulty may be greatly alleviated by the current DOT proposal to alter the rear visibility standard so that it will, in effect, require periscopic rear view mirrors for passenger cars. The rear vision angle may increase by 1976 from about 20 degrees to about 80 degrees. We do not know whether this proposal was assisted by the safety board's study, but we would like to think that it was.

Incompatibility of Standards of Driver Vision and Traffic Sign Legibility

Consider the need for technical coordination of standards which describe driver vision capability and traffic signing legibility. Systematic control of the interaction between drivers and signs requires at least consideration of four matters: driver visual acuity, traffic sign letter-sizes, placement of signs relative to highway features, and allowable speed. The lack of compatible definitions makes it unnecessarily difficult to analyze these factors at any given highway location.

The 1967 vision requirements for motor vehicle operators show a variety of visual acuity ranging from 20/40 to 20/70. The requirements for visual acuity are such that several states now license some drivers who are unable to detect words on signs until they are much closer to the sign than other drivers licensed in the same states. It also appears that some states having very high speed limits also employ the lower standard for visual acuity, while other states having low speed limits employ the higher standard of visual acuity.

This driver vision standard, employing the Snellen eye chart, is based upon the tested ability of persons to read letters similar to those of highway signs. A person having 20/20 vision is able to read at 20 feet, letters of a height that a person having normal (youthful) vision can also see at 20 feet. A person having 20/70 vision can read at 20 feet, letters readable by a normal person at 70 feet. Thus the standard is, on the surface, merely a relative standard.

At the other end of the vision circuit, the legibility of traffic signs is defined simply by the height of the letters and the size of the sign which must be used in certain areas. This is the method employed in the *Manual for Signing and Pavement Marking of the National System of Interstate and Defense Highways.* There is no standard way to relate the visual acuity standard to the legibility standard.

Difficulties are thus created. It can be shown by calculation, for example, that a motorist having 20/20 vision is able to read signs specifying exit speed from the interstate system at a distance of 920 feet from the sign; whereas, the driver having 20/70 vision cannot read the sign until he is only 263 feet from the sign. This driver, if moving at legally allowed speed of 60 miles per hour at such a location, has three seconds for perception, reaction, and braking which will reduce the speed of his vehicle from 60 miles per hour to the posted ramp speed of 20 miles per hour. This does not mean that the operation at these exits is unsafe at all times, because drivers can, in daylight, see other indications of the need for lower speed. The problem does mean, however, that the placement of a sign does not provide assurance that it is adequate under the full range of existing drivers and speed combinations.

The correction for this difficulty seems rather simple. By going to the original definition of visiual acuity according to the Snellen eye chart, we find that 20/20 vision also means that letters of a certain included angle can be seen at a 20-foot distance. Thus, calculations can be employed to develop charts which would interrelate the factors of driver visual acuity, speed, and letter size required in signs. The charts could then provide a more systematic basis for sign placement. It is a simple task, but no one has done it yet on an authoritative level.

Incompatibility of Standards of Windshield Visibility Versus Standards of Sign Placement

There are many other problems of this type. It can be shown that the standards of windshield visibility in Federal Motor Vehicle Safety Standards 103 and 104 are stated in different technical terms than standards for placement of signs appearing in the *Manual on Uniform Traffic Control Devices for Streets and Highways.* The methods of definition of the vision capability are stated in angular terms in the one standard and in terms of linear dimensions in the other standard. Thus, rather difficult calculations are required in order to make an analytical placement of a stop line or of the faces of a traffic signal.

Barrier Characteristics Definition Vs. Definition of Crash Test Objects

We are seeing a great deal of effort to produce improved barrier systems which will prevent vehicles from striking heavy obstacles along the highway. At present, however, the definitions of barrier characteristics are not related to the definition of crash test objects employed in Federal Motor Vehicle Safety Standards. One result is that vehicles are not actually required to be tested by impacts against any of the guardrails or median barriers described in the relevant documents of the Highway Research Board. This is not yet a problem of inadequate communication, but a state-of-the-art problem. This field is relatively young and growing rapidly. For example, we still do not have a systematic test of the results of crashing trucks into highway guardrails. It is easy to see that there should be an objective of merging these standards as they are developed so that a true description of interrelated system performance would be created.

NONSYSTEMATIC OR INCONSISTENT STANDARDS IN ELEMENTS OF HIGHWAY SYSTEM

These examples describe problems with the interrelationship among vehicle, highway, and drivers. However, there are many examples of nonsystematic or inconsistent standards or specifications occurring entirely within the province of standards agencies in each of the three main elements in the highway system. For example, we have highways in which the stopping sight distance over a hill is below the distance at which a stop can be made at the established speed limit. In the vehicle standards field, we find that for typical night speed limits the headlights of vehicles do not provide sufficient forward illumination to permit a driver to perceive an object, react, and stop before the object is reached. There is a clear inconsistency between necessity to dim headlights for vehicles in an opposing lane and the need to employ one's own headlights to see objects in one's own lane. In the field of driver definitions, we know that vehicle seating and control arrangements are determined for a given range of drivers' size, but we do not account either in the licensing arrangements or in the qualifications of vehicles for those drivers who are outside the range.

WHAT PROBLEMS OF SYSTEM DEFINITION MEAN

Uncertainty of System Operating Within Known Safety Margins

What do such problems of system definition mean in practical terms? First, where standards are incompatible, the great difficulty in analyzing the interrelationships means that we are not certain that the system will actually operate within known safety margins. The margins of operation in which hazards can develop are literally unknown.

Advanced Development of Highway System Retarded

Second, the advanced development of a highway transportation system will be retarded. This consideration is more important than it seems because so many of the problems of incompatibility of standards influence the *efficiency of operation* as well as the safety of operation. For example, when a driver suffers from delayed reading of traffic signs, he may miss his turnoff on the interstate system and be legally required to drive many miles in order to return.

Dependence on Allowing Occurrence of Accidents to Show Improvement Needs

Third, incompatibility of standards means that we are dependent upon allowing the occurrence of accidents and analysis of the results of the accidents to show the need for improvements in existing roads and for changes in advanced highway design standards. We are now placing great emphasis upon the maintenance of traffic records and analysis to determine high hazard locations and to point out inadequacies of design. Yet, it appears that many of the problems revealed by this long-term analysis could have been revealed without waiting for accidents to occur by means of engineering analysis based upon standards.

NO COMPATIBLE SYSTEM STANDARDS—NO SYSTEMS ANALYSIS

The example of the Apollo Project provides perspective. Would anyone believe that it would have been possible to design any of the major systems or subsystems in the Apollo Project by relying upon accident data to prove that a hazard existed? In actual fact there has been only one significant accident in the Apollo Project which has not been compensated for by system design. Thus, in a very real sense, the absence of compatible system standards for highway transportation prohibits us from employing one of the major modern techniques, that of systems analysis.

Inadequate Standards and the Problem of Teaching Highway Transportation

This problem of inadequate standards even reaches into the *teaching* of highway transportation, highway engineering, and automotive engineering. In most modern technological systems, the systems approach is a basic method of organization. Yet, the systems approach is not now taught as a practical approach in highway engineering, traffic engineering, or automotive engineering. Elaborate data systems and business systems are being installed for highway transportation elements which are not a system. Systems engineering can be used only for subsystems in highway transportation.

Major Implications for the Future

The 1969 safety board study of incompatibility of standards pointed out the major implications for the future from the continued process of development of regulatory standards which are not joined by system concepts. *Almost every new standard which describes the functional operation of a major element in the highway transportation system will have to be changed or reinterpreted eventually* if we are ever to enjoy the benefits of integrated operation in a true highway transportation system. We are constantly producing new standards which describe system performance and which are not compatibly related. The task of correction is becoming more difficult with every new standard which is not analyzed for system compatibility.

Use of Interim Transitional Definitions

The 1969 study of the safety board also included methods for dealing with this problem, both in the long and short term. In the short term, the safety board proposed the use of what it called, "Interim transitional definitions." An interim transitional definition might consist of the development of charts which would relate Snellen eye test results to traffic sign letter heights. It is believed that these interim transitional definitions would cover a portion of the problem, but not all of it.

Organization of Standard Producing Institutions

A more significant problem is that of the organization of standard-producing institutions which could attack the problem of new compatible standards. The safety board identified about one dozen institutions or organizations which substantially affect the development of standards and definitions which apply to highway transportation and its elements. The board also noted that the Department of Transportation has significant capability to encourage compatibility in these standards through adoption or nonadoption of the standards in rules, regulations, or as a prerequisite for funding. Accordingly, one of the safety board's recommendations to the federal highway administrator (at that time responsible for all federal use of these standards) was that he undertake the task of leading improved organization of these standards through the efforts of the many organizations. The board recommended specifically a detailed review of the problems of communication and fields of responsibility among the agencies.

An Ad Hoc Committee on Highway System Standards

The Federal Highway Administration has, in accordance with these recommendations, a continuing function in one of its offices in the form of an ad hoc committee on highway system standards. The staff person in charge is Charles Prisk, one of the most experienced task force organizers in the Federal Highway Administration.

A DETERRENT TO THE SYSTEMS APPROACH

I should not close without pointing out also one of the major disadvantages in applying the systems approach to present and future highway operations. That disadvantage is, strange to say, the very strong drive now being made in all government agencies to ensure that government efforts are most economically applied. Every agency involved with highway safety is seeking to show that the benefits of its efforts in accident loss reduction are worth the cost of the effort. Cost/benefit and cost-effectiveness analysis are disciplines sought to be applied in the whole process of allocation of funds and efforts. It appears however, that this strong drive for efficiency may in some cases tend to oppose the application of a full systems approach. The reason is that it is far easier to prove that accidents and accident fatalities and losses will be reduced by studying the existing accidents, than by studying the larger scale disorganization of the system. When high accident locations are detectable, for example, it is readily apparent that concentrated effort to repair the situation at that location will save lives and prevent accidents efficiently. The analytical method of proving how attention to system organization will prevent lives from being lost more efficiently is much more difficult. We can, however, show by historical example that intense system organization can produce almost a perfect safety record. The near-perfect record of the Atomic Energy Commission and the excellent record of the Apollo Project are examples. The very low fatality record in commercial aviation and in rail rapid transit are other examples. We also know intuitively that a highway transportation system which is shaped by the repeated application of corrective and repair measures will probably not reach the highly efficient status that will be needed. Perhaps the discussion period can help to develop some new ideas in meeting this particular problem.