SAFETY INSPECTION OF THE HIGHWAY AND THE VEHICLE

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•THERE can be no single solution to highway safety for accidents may be caused by any one or combination of five factors: society, highway user, highway facility, highway environment, and vehicle. The degree to which each factor reacts either alone or with other factors is not fully understood and bears continuing study if a desired level of safety on highways is to be achieved. In June 1967, the National Highway Safety Bureau (NHSB) issued the initial standards relating to 13 areas associated with highway safety; in November 1968, 3 additional standards were issued. These 16 standards identify and describe basic performance goals in the major problem areas of highway safety. Two additional standards—school bus safety and accident investigation—are currently being developed. There are several program areas to be considered in managing a state program directed to providing the safest possible highway system. Although some problem areas can be studied in independent efforts, they should be studied in interdisciplinary efforts to obtain the best possible results. For example, driver education programs will be more effective if the program material keeps pace with changes in highway design as well as changes in safety features of the automobile. The areas that are the subject of this paper, highway and vehicle inspection, are vital to the development and management of an effective anti-skid program.

SAFETY INSPECTION OF THE HIGHWAY

The states, through the Federal-Aid Highway Safety "Spot" Improvement Program, have completed the programming of approximately 21,600 improvements at high-accident locations on the federal-aid system. Although the exact description of these improvements were not reported, it is known that many involved corrective measures for improving pavement surface skid resistance. Where skid-resistance measurements are involved, the states have worked in many instances through the Federal Highway Administration in the development of skid trailers for measuring the level of skid resistance. The skid trailer has become the most widely used equipment for ascertaining the level of skid resistance of pavements.

The Department of Transportation's Instructional Memorandum of April 28, 1968, provided a major "push" to make highways skid safe. This memorandum stated the following:

> . . . the skid resistance qualities of questioned pavement surfaces shall be tested by operating thereon at a speed of 40 miles per hour with a two-wheel skid resistant trailer or equivalent device following the procedures outlined in ASTM E-274-65T, Tentative Method of Test for Skid Resistance of Highway Pavements Using aTwo-Wheel Trailer and the ASTM Technical Publication No. 366 - Measuring Road Surface Slipperiness . . . .
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> It also provides that the Bureau of Public Roads (FHWA) will participate in the resurfacing costs of maintaining state highway surface skid resistance at a skid number level of 0.35. Hence, the desire for the states to inspect and inventory their pavement surface is predicated to a degree by the willingness of FHWA to participate in the cost of corrective measures.

There are several methods for measuring pavement skid resistance. They may be grouped conveniently in four general classes, three of which involve a moving vehicle: (a) portable devices, (b) automobile stopping distance, (c) automobile deceleration, and

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(d) towed trailers. Over the years, the greatest improvements have occurred in the development of towed-trailer techniques. Only modest improvements have been achieved in the stopping-distance automobile method.

Briefly, the most widely known portable methods used in this country are the National Crushed Stone Association's (NCSA) bicycle wheel, the British portable tester, and the Penn State drag tester. The NCSA wheel is now being used to a lesser degree than the two testers.

The NCSA method (1) consists essentially of determining the degrees of rotation of a bicycle-sized wheel with the tire sliding against the pavement surface after being started by an initital constant rotational force. The greater is the angular rotation of the wheel, the more slippery is the surface.

The British portable tester was used widely for field measurements in the early 1960s, but it is now being used cautiously because of a better understanding of its limitations. It is a dynamic, pendulum-impact type of tester and essentially consists of a rubber slider fixed to a shoe that is attached to an arm that rotates about a fixed point. When the arm and attached shoe are raised to a fixed level and then released, the pendulum swings unrestrained except when in contact with the surface under test. The height (indicating energy loss) that the shoe travels after sliding over the surface is an indication of the surface frictional resistance. This method is standardized as ASTM Designation E 303.

The Penn State drag tester is a small test unit that uses a test shoe of the type used with the British portable tester. The tester is pushed by the operator over the test surface at a normal walking speed of 2 to 3 mph. An indication of the surface resistance is obtained by reading the dial that measures the "drag force" caused by the test shoe when the tester is pushed at a constant rate across the surface.

In each of the three portable methods, it is necessary to block traffic while the test is being conducted. Also, if other than dry tests are desired, it is necessary to wet the surface prior to each test. There have been efforts to correlate these test methods with one another as well as with other methods. Although the results have not been completely successful, they are reported in the referenced literature.

The automobile stopping distance method (2) is one of the three moving-vehicle methods. It consists essentially of driving a test car at the desired test speed over the surface to be tested, locking the brakes, and allowing the car to slide to rest. The sliding distance is measured, and the coefficient of friction is calculated. This test method approximates real-world situations and is most frequently used by state highway patrolmen to spot-check accident locations. The method is currently being reviewed and readied for acceptance as an ASTM standard.

The second moving-vehicle method involves the measurement of momentary deceleration of a test car. This method (3) is usually conducted with a decelerometer mounted on the floor of the test vehicle. The vehicle is brought to slightly above the desired test speed, and the brakes are momentarily applied hard enough to cause a short, quick skid. The deceleration of the test vehicle during the short skid is a measure of skid resistance. This method, like the stopping-distance method, is not so convenient to conduct because it requires the close control of traffic and a watering truck for wetting the pavement area to be tested. Both methods, however, have been used in statewide inventory work.

The most widely used method for measuring pavement skid resistance involves a moving vehicle with a trailer in tow. This method is used in 29 states. There are four states in which the task of building a trailer or purchasing one from one of the several commercial sources is being considered. The development of the towed-trailer method has been evolving since about 1920, and the two-wheel trailer is now an ASTM standard method (ASTM Designation E 274). In this method either a one- or two-wheeled trailer may be used. The test is conducted by towing the trailer at a predetermined test speed over the section of pavement to be tested, locking the wheel(s), and measuring the force required to "drag" the trailer at a constant speed. The surface skid resistance (or skid number) is calculated from the known or measured forces acting on the trailer during the test. The advantage of this test method is that the test can be conducted in moving traffic because of the trailer's self-contained watering system.

In summary, the inspection of a particular highway facility in regard to an anti-skid program involves all features of the facility, but emphasis should be placed on the roadway pavement characteristics (level of friction). Characteristics related to the ability of the motorist to perform necessary maneuvers are of paramount importance (e.g., the level of pavement friction needed by a driver to negotiate a turning maneuver or an emergency stop).

Also, in such a program, minimum levels of skid resistance will need to be established and will of necessity be influenced by the type of facility and its anticipated use. In addition to these facets of the program, enforcement techniques such as "wet-weather" speed limits and safety inspection of automobiles will need to be considered.

SAFETY INSPECTION OF THE VEHICLE

In addition to providing a continuing inventory and inspection of facilities, an anti-skid management program can be effective in identifying and seeking corrective measures for motor vehicles. This can be most effectively accomplished by working with and through periodic motor vehicle inspection systems.

The first subject of the initial 13 standards issued by the National Highway Safety Bureau is periodic motor vehicle inspection. The introduction to this standard states the following:

> Until recently there was very little firm evidence to support the reasonable supposition that state inspection systems contribute to highway safety. This deficiency has now been overcome, at least, in part. Recent research demonstrates significant differences in state motor vehicle accident death rates associated with inspection programs. Although much more specific information is needed, especially with respect to the extent to which various kinds of inspection contribute to the overall results, it is clear that the inspection of motor vehicles by the states has an important place in highway safety.

The purpose of this standard is "... to increase, through periodic vehicle inspection, the likelihood that every vehicle operated on the public highways is properly equipped and is being maintained in reasonably safe working order...."

Motor vehicle inspection in the United States began with a voluntary program in Massachusetts in 1926 (4). Although two other states participated in voluntary programs, Massachusetts, Maryland, and Pennsylvania enacted legislation in 1929 requiring inspection of all motor vehicles. At present, 31 states, the District of Columbia, and Puerto Rico require inspection of nearly all vehicles. These programs vary in manner of operation, as well as details of inspection, and have exhibited varying degrees of success. For example, 2 states and the District of Columbia operate under entirely state-owned and -operated systems, 27 use the state-appointed and -supervised system, and 2 (Florida and South Carolina) have combination systems. Of the 19 states that do not have an inspection law for all vehicles, 8 have spot-check programs that are administered on the highways by specially trained officers on a random basis, 6 have programs directed to certain vehicles or authorize inspections to be conducted on a local level, and 5 have not adopted any form of inspection. In Tennessee, where local option is in effect, five cities have an inspection requirement. Three of these are large metropolitan areas; two, Chattanooga and Memphis, have very fine municipally owned and operated inspection lanes.

Not only does the manner of system operation differ among states, but there is also a difference of opinion as to what should be inspected. In general, however, all systems require the inspection of brakes and lights. The extent to which other items, such as steering mechanisms, suspension, and exhaust systems, are inspected varies considerably.

The greatest deterrent to the states complying with standard 1 of the 1966 Safety Act lies in the belief that there is insufficient research data to show that periodic motor vehicle inspection significantly reduces traffic fatalities. The lack of information regarding accident causation as related to vehicle condition may be attributed in part to inadequate accident records. This inadequacy was recognized at the time the initial highway safety standards were promulgated, as they included standard 10 on traffic records. Thirty-two states, including Tennessee, are now studying, improving, and developing their records-keeping system and are including a uniform reporting form. Along with the development of adequate records systems, there is an urgent need to acquire on-site information concerning the influence of vehicle condition on accident causation. Data being collected in programs that are training accident investigation teams of the type under way at Georgia Institute of Technology will be useful in identifying this relationship. In this regard, McCutcheon and Sherman concluded in their study that "...it was found that the mechanical condition of a vehicle population is substantially improved as the frequency of inspections increases and that the number of defects per rejected vehicle decreases as the frequency of inspection decreases" (5).

Another indication of vehicle condition is inferred from the safety defect recall campaigns that are required by the 1966 Safety Act. For example, during a 3-month period (January 1, 1970, to March 31, 1970) manufacturers reported that 223,234 foreign and domestic vehicles were recalled for reasons varying from wheels with improper welds to incorrect steering shafts that could become disconnected and cause loss of steering (6). Another example of defected vehicles on highways is illustrated in the work of the Bureau of Motor Carrier Safety. In 1969, the Bureau inspected "... 397 buses operated by 107 different interstate motor carriers of passengers. Forty-seven (11.8 percent) of these were ordered out of service until corrections essential for safe operation have been effected" (7). There is evidence that periodic motor vehicle inspection will help ensure that better maintained automobiles will operate on the streets and highways.

There are two general approaches to the development of an inspection system: the voluntary and the compulsory. The voluntary system is one in which there is no formal legislation or, at the most, only limited legislation. The compulsory system, on the other hand, requires legislation. There are 19 states that do not have a law requiring periodic inspection of all registered vehicles on a statewide basis. Of these 19, 14 either require that only certain vehicles be inspected, such as school buses, or may have a "voluntary" inspection program. A study of the literature did not reveal data for a comparison of citizens' attitudes toward voluntary and compulsory systems. I believe, however, that voluntary systems can be made effective by appropriate controls. Generally, voluntary systems are thought of in relation to diagnostic centers or one's own garage mechanic. The basic types of compulsory systems are either state owned and operated or state appointed and privately operated. The nature of the inspection procedure and the type of facility can range from inspections provided by the owner-operator to those at well-equipped, state-owned and -operated inspection lanes. Each type of system seems to have its unique advantages. The most frequently discussed systems are given in Table 1.

Diagnostic clinics (or an individual's private garage) represent the ultimate in the truly voluntary type of system. They have been popular in Europe for several years, having been made available mostly through automobile clubs. They have become generally available in this country during the last 10 years. About the time of the approval of the Highway Safety Act, clinics were enjoying rapid development. More recently,

TABLE 1

TYPES OF INSPECTION SYSTEMS

Type	Ownership and Operation	Facility
Compulsory	Owned and operated by state or city	Permanently located inspection lanes Portable facilities Fixed facility and roving inspectors
	Appointed by state and operated privately	Garages and service stations
	Operated privately under state contract	Permanently located inspection lanes
Voluntary		Diagnostic clinics Random spot-check Trial substitute

however, they have not enjoyed such prosperity because of their high equipment cost and general lack of public interest in their service. The centers are designed to test many items, including those that are not necessarily safety related. Although several nationwide organizations, such as Sears Roebuck, Montgomery Ward, J.C. Penney, and major oil companies, have diagnostic centers, the most comprehensive one seems to be the rather modern clinic that is operated by the St. Louis Automobile Club. It has equipment to test a great number of items, and many of these tests can be made with the vehicle operating at speeds under load to simulate actual driving conditions. Diagnostic clinics have the potential of providing a greater amount of information, accurately obtained, than do smaller facilities, but the cost of services related only to safety inspection may be too high for widespread acceptance.

Although established by legislation, the random spot-check system is somewhat voluntary in that the motorist does not have to report to a specific location for the inspection. This system consists of roadside checks usually performed by the state's highway patrol. It is conducted at various times and at random locations throughout the state. It is reported (8) that in California about 15 percent of all vehicles are checked annually and about 62 percent of those fail. In the California system, those vehicles that pass inspection receive a sticker. The owners of those vehicles that fail must have the defect corrected and the vehicle reinspected. During the inspection, the officer checks windshield and side-window views, spray-on window tints, muffler condition, lights, tires, and other items that have been judged as safety related. At present, eight states (California, Michigan, Minnesota, North Dakota, Ohio, Oregon, and Washington) use this system with slight variation. The effectiveness of the spot-check approach is closely related to the level of enforcement and the penalty imposed.

The trial substitute system is also a partially voluntary system, but it does require limited legislation. This system (9) is unique and relatively untried; it authorizes the owner to inspect the vehicle himself or to have someone do it for him. The inspection is required at regular intervals, after all reportable traffic mishaps, and at the time of the purchase of a new or used vehicle. Each vehicle owner is provided inspection guidelines and two types of vehicle inspection certification forms. One provides for a minimum level of inspection, whereas the other encourages the owner to conduct a more extensive check. The monitoring of the system is accomplished by regular enforcement channels in addition to spot-checking. The advantages of this system are reported to be that the motorist will be better informed of the operating condition of his vehicle; he will not be subject to the potentially unscrupulous actions of service station attendants or garage attendants or garage mechanics; his cost is less than it would be with most systems; and his repairs may be done as needed. The immediately apparent disadvantage is that the great majority of owners who inspect their own vehicles are not skilled and may believe that a vehicle component is safe when it is not.

Although voluntary systems are intriguing to the individual motorist, these systems are not generally satisfactory from the viewpoint of uniformity of inspection and ensured compliance. This is not to say, however, that such systems cannot be made effective.

Compulsory systems are the most desirable type for ensuring uniformity and compliance. Although there are several approaches to such systems, the state-appointed and privately operated system is in most widespread use. This type of system is currently operating in 29 states, two of which (Florida and South Carolina) have combination systems. In this system, the state defines the program and then licenses private garages, service stations, and other groups, such as automobile dealers and fleet operators to perform the inspection. In general, inspection facilities are not elaborate, but, usually, an area is reserved for the performance of the work. The equipment cost depends on the items to be inspected. The state charges an authorization fee—usually \$25—to discourage casual and "fly-by-night" operators from obtaining a license. The inspection fee of the vehicle owner is set by the state and frequently ranges between \$2 and \$5. The state's portion of the fee is generally about 50 cents.

The principal advantage of the state-appointed and privately operated system is the low initial cost to the state. The vehicle owner has the advantage of usually having an inspection station nearby; frequently, his regular service station will be an authorized inspection station. A major disadvantage lies in the difficulty in providing uniformity in inspection. For example, because the inspectors are not generally trained by the state and because the equipment will not be equally maintained, there will be a different level of inspection among and between inspection stations. There is also a major disadvantage to the inspection station operator because he does not receive adequate compensation for services performed. Also, if new items, such as exhaust emission, are to be checked, the equipment cost to small operators may be prohibitive.

State-owned and -operated systems currently exist only in Delaware, New Jersey, and the District of Columbia. Florida and South Carolina, as earlier reported, have dual systems whereby they combine the state operated with the privately operated. The state-owned and -operated system is quite similar to the municipally operated systems in Chattanooga and Memphis, Tennessee. Although not well documented, cost may be the reason for so few state-owned systems. Once the system is in operation, however, inspection fees can be established at a level sufficiently adequate to support the program. New Jersey has about 40 stations that serve approximately 3,000,000 registered vehicles, whereas Delaware has only four inspection facilities. The Delaware stations are located such that there is at least one station within 35 miles of a vehicle owner. The distribution and location of inspection facilities may be governed by vehicle density and population movement. For example, in heavily populated areas it may be wise to locate the facility near a major shopping center so that the inspection can be made while drivers are on a shopping or work trip. In any case, adequate planning is needed to ensure public acceptance. Also, in this type of system, it may be desirable to have permanent locations in remote areas that would be staffed only on a periodic basis. For example, research sponsored by the National Highway Safety Bureau has resulted in the development of a portable, truck-mounted facility that serves the remote areas of a state, not unlike the early American "rolling store" idea.

The advantages of the state-owned and -operated system are that it separates inspection from repair, provides uniformity in inspection because of uniform equipment and personnel training, is easy to monitor and update, is convenient for training personnel, and will probably provide the revenue for supervision and enforcement. The greatest disadvantage lies in its initial cost. This is particularly true if it is not instituted on an incremental basis.

The state-contracted system is another method of providing the attributes of a state-owned and -operated system by contracting with a private company to design and operate the system. Basically, a private firm would negotiate a contract with a state to finance, design, erect, equip, operate, and maintain the necessary facilities required to provide the state with a comprehensive vehicle inspection program. The private firm would assist the state in preparing public-relation materials to secure acceptance and response to the system. The state, in turn, would have to pass the appropriate enabling legislation to authorize the program and to ensure a degree of continuity for a period of about 10 years, which is roughly considered to be the amortization period for the land and building.

Several of the reported advantages of such a system are that it offers an inspection program established by an independent contractor who has no vested interest; it offers the motoring public a program of greatest value received per dollar spent; and it offers the engineering expertise and experience of private firms. The greatest disadvantage seems to be in the difficulty in ensuring support by the state and its citizens for a minimum period of 10 years. If public acceptance is not ensured, the system could become a major liability.

In the design of a vehicle inspection system, the most critical factor with regard to the relationship of vehicle condition and accident rate is the vehicle features to be inspected. Because there are insufficient data to indicate this relationship, considerable judgment must be exercised in the determination of items to be inspected. For example, there is considerable difference of opinion as to the influence of front-end alignment. In view of the lack of firm data, it is appropriate to classify inspection items into those that the driver must correct (i.e., the vehicle is rejected during inspection) and those that he is advised to correct. It is desirable to reevaluate periodically the items in these classifications on the basis of records and experience and to make appropriate changes. An indication of the frequency that particular items cause rejection was reported by Coverdale and Colpitts (10) on the basis of information reported by the New Jersey Division of Motor Vehicles for a 2-month period in 1963 (Tables 2 and 3). Headlights were rejected most frequently in vehicles less than 10 years old. Brakes and all other lights were the next most frequently rejected items. These data also were supported by those given in Table 4 from the voluntary national vehicle safety check that was reported in 1963 (11). In addition, the rejection frequency was born out in a study of the Memphis system but was not supported by data from the Knoxville system. The Knoxville data show that wheel-alignment defects had the highest rate of rejection followed by lighting systems. The results of a mechanical factor investigation of 409 fatal single-vehicle traffic accidents in California revealed that the braking system was the most commonly observed mechanical defect. Steering system defects, which accounted for 26 percent of all defects, were next (12).

TABLE 2

VEHICLES INSPECTED DURING 1963 VEHICLE INSPECTION IN NEW JERSEY

Vehicle Age (year)	Inspected	Approved	Rejected	
			Number	Percent
Under 1	76,368	57,616	18,752	24.6
1 to 5	214,876	129,561	85,315	39.7
6 to 10	145,801	74,218	75,583	50.5
Over 10	484,817	281,791	203,026	41.9

TABLE 3

ITEMS REJECTED DURING 1963 VEHICLE INSPECTION IN NEW JERSEY

Item	Vehicles by Age Having Deficient Items (percent)				
	Under 1 Year	1 to 5 Years	6 to 10 Years	Over 10 Years	Total
Headlights	16.9	19.6	20.10	20.6	19.4
All other lights	4.9	12.8	2.12	23.7	15.1
Brakes	2.7	10.0	17.00	23.5	12.1
Steering operation	.4	3.3	7.70	11.5	5.0
Steering alignment	2.4	4.1	6.70	6.8	4.9
Directional signals	1.1	2.9	4.80	4.3	3.3
Windshield wipers	0.2	1.4	4.50	6.0	2.6

TABLE 4

ITEMS REJECTED DURING 1963 NATIONAL VEHICLE SAFETY CHECK

Item	Items Rejected on Cars		Items Rejected on Trucks		Items Rejected on Cars and Trucks	
	Number	Percent	Number	Percent	Number	Percent
Rear lights	90,960	18.8	12,892	17.7	103,852	18.7
Front lights	69,120	14.3	8,931	12.3	78,051	14.0
Brakes	49,366	10.2	7,016	9.6	56,382	10.1
Rear turn signals	43,929	9.1	6,138	8.4	50,067	9.0
Front turn signals	42,182	8.7	6,047	8.3	48,229	8.7
Stop lights	35,112	7.3	9,834	13.5	44,946	8.1
Exhaust system	36,562	7.6	3,627	5.0	40,189	7.2
Tires	33,715	7.0	5,140	7.1	38,855	7.0
Windshield wipers	19,197	4.1	3,128	4.3	23,045	4.2
Steering	18,276	3.8	1,893	2.6	20,169	3.6
Glass	15,499	3.2	3,224	4.4	18,723	3.4
Horn	13,974	2.9	2,822	3.9	16,796	3.0
Windshield washers	9,091	1.9	622	.9	9,713	1.8
Rearview mirrors	5,051	1.1	1,479	2.0	6,530	1.2
Total	482,754	100.0	72,793	100.0	555,547	100.0

Note: Total vehicles checked--3,448,976.

The broad categories of items that should be inspected for any total system are lighting and electrical systems; steering alignment and suspension; tires, wheels, and rims; body glazing and sheet metal; exhaust and fuel systems; and brakes (13). For a defined set of conditions, the malfunctioning of one or more vehicle components within any one of the broad categories listed could cause an accident. For an anti-skid management program, however, the most significant category is vehicle tires because of their contribution to the skidding phenomenon. The motor vehicle inspection system should include tires among items to be inspected. Data obtained in a midwestern state indicated that about one-third of the cars involved in 631 accidents had defective tires based on a minimum tread depth of $^2/_{32}$ in. Of this group, 22 percent had tread depths less than the established minimum. In some few instances, states that have a vehicle inspection system are beginning to inspect tires. Initially, inspectors are advising the owner of defects and inadequate tread depth and are rejecting his car in extreme cases only. Retreaded tires and off-the-road tires are coming under greater scrutiny by the National Highway Traffic Safety Administration. Recently, an advisory circular was sent to all states calling attention to the undesirable use of off-the-road tires on freeways. Because the sidewalls of such tires are now marked, the tires can be spotted during the regular inspection cycle. The NHTSA held a public meeting in January 1971 to discuss a proposed amendment to standard 109 requiring tire manufacturers to label passenger car tires with information on the number of times they can be retreaded. Tires make an important contribution to the skidding phenomenon; therefore, a successful anti-skid program will need to be closely coordinated with a vehicle inspection system to ensure adequate inspection and corrective measures.

SUMMARY

Although accident causation is not clearly delineated, it is believed that the number of skidding accidents is significantly great to warrant continued study. In this regard, the inspection of highway characteristics, as well as an inventory of pavements as to their level of skid resistance, must be undertaken by each state. Also, it is of great importance that the periodic motor vehicle inspection program be reviewed in context with the objectives of the anti-skid programs to achieve and maintain an appropriate relationship between the two efforts. An anti-skid program is needed in each state because it can be an effective adjunct to a state's total effort in making highways safe for motorists.

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